University of Southern Queensland

Faculty of Engineering and Surveying

A Study and Evaluation on Seri Wawasan Bridge in Putrajaya, Malaysia.

A dissertation submitted by

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Abstract

Bridges are essential part of communication, affording the most direct route where practicable. Wit national progress and technological advancement, a relative new bridge type is approached in Malaysia, known as Cable-Stayed bridge. The Seri Wawasan Bridge which is chosen for this research project is one of the most beautiful cable-stayed bridges in Malaysia. Seri Wawasan Bridge is an asymmetric cable-stayed bridge with a 75º forward-inclined pylon, which is located in Putrajaya Main Island Area.

This research project is brought out to study the construction method and design of cable-stayed bridge. To accomplish this research project, a lot study materials are needed. The literature review involves a comprehensive study on the types of bridge currently used, the development of cable-stayed bridge, the concept of cable-stayed bridge and the bridge construction methods currently used. Site visits and interview are made to collect more information regarding the Seri Wawasan Bridge and the problem that mostly encounter during bridge construction. Finally, evaluate the suitability of the Seri Wawasan Bridge base on the compiled information.

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Limitations of Use

Certification

I certify that the ideas, design and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Signature

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Date

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CHAPTER 1: INTRODUCTION

1.0 Rationale for This Research

Bridges are an essential form of communications, connecting two areas separated by an obstacle. Bridge can be defined as a structure built to span a gorge, valley, road, railroad track, river or other body of water, or any other physical obstacle. It is used to carry the loads of pedestrians, vehicles or trains. Before a bridge can be build, it is necessary for the designers to determine the design loads required for the selection of suitable member sizes.

Generally there are five types of bridge used nowadays and they are Girder, Arch, Rigid Frame, Suspension, and Cable-Stayed bridges. All these bridges are different in their design, structure, and function. All of these bridges have since evolved according to particular requirements, local conditions, state of knowledge and the materials available.

Most of the bridges in Malaysia are Girder Bridge, made of concrete. The usage of reinforced slab or the pre-stressed beam and slab to form deck structures is popular because of their relatively lower construction cost, ease of construction and also of the technology available locally that is familiarity of use.

Typically, cable-stayed bridge is a continuous girder with one or more towers supported by the bridge foundation. The Seri Wawasan Bridge which is chosen for this research project is one of the most beautiful cable-stayed bridges in Malaysia. Seri Wawasan Bridge is an asymmetric cable-stayed box girder bridge with a 75º forward-inclined pylon. This cable-stayed bridge has a main span of 165 m connecting Precinct 8 and the mixed development at Precinct 2 located at the Putrajaya Main Island Area. The design and construction technologies which were adopted for this bridge had set a good example and standard in forwarding the technologies of bridges in Malaysia, for robustness and aesthetic value.

Source: Putrajaya Bridge Construction Team, 2005

Figure 1: Seri Wawasan Bridge, Malaysia

This type of bridge is considered new and rarely applied in Malaysia. Therefore, this research is carried out to study the applications of stay cable in bridge design and to determine the various methods available to construct the cable-stayed bridge. Besides that, the research is also intended to identify the various possible problems arise during the construction of this bridge and to suggest some possible solution to the problems encountered.

This research is helpful to me as a civil engineering student interested in bridge designs and constructions. It will make me more appreciate, aware, understand and learn how to adopt the latest innovation in designing bridges.

1.1 Background

The Seri Wawasan Bridge, which is located in Putrajaya Main Island Area, is one of the cable-stayed bridges available in Malaysia. This single span cable-stayed bridge with single tower was built to span a 168.5m wide man-made lake in Malaysia's new administrative capital, Putrajaya. This bridge is connecting Precinct 8 and the mixed development at Precinct 2. Due to its highly visible location, the Seri Wawasan Bridge is categorized under the aesthetic bridge category in Putrajaya planning classifications. The design and construction technologies adopted in this bridge set a good example and standard in forwarding the design and construction of bridges in Malaysia, for both robustness and aesthetic values.

1.2 Nature of the Problem

It has been reported during the last few decades that the construction of the bridge in Malaysia is mainly dominated by girder bridges where mostly use of pre-stressed I-girder beam and reinforced concrete slab supported on beams. So, can this "new" bridge design i.e. "Cable-Stayed Bridge", with lower construction cost and higher speed in construction for longer span, made its presence felt locally. Therefore, this project dissertation is aimed to carry out a study on the use of stay cables in bridge design and bridge construction.

1.3 Research Goals

1.3.1 Aim

The main aim for this project is to research the construction method and concept of cable-stayed bridge.

1.3.2 Objectives

a. The objectives of this research are: -
b. Research the history and potential of cable-stayed bridge.
c. To study the concept of cable-stayed bridge.
d. To determine the construction method being used.
e. To determine the problems being encounter during construction process.
f. Investigate the suitability of the bridge.

It is hope that the possible outcome from this research may give some contributions to the bridge contractor about the construction of the "new" type of bridge in this region i.e. the cable-stayed bridge. Through this research, the bridge contractors know that there is a new innovation of bridge, which is essential for them to understand and learn how to apply this latest cost savings, timely and efficient innovations.

It is also important to help the bridge contractor to understand the basic concept of cable-stayed and the various construction methods available in the bridge constructions. This research study is valuable because bridge design in Malaysia is still new and there are a lot of rooms for improvement in future.

1.3.3 Hypothesis

The use of cable-stayed bridge construction is new and rare to be used in Malaysia. Due to its lower construction cost and speed of construction, it has created my interest in doing a research on the construction of this cable-stayed bridge “Seri Wawasan Bridge”.

1.4 Research Methodology

First of all we must know the due date of each assignment and final report of this research project. Then plan for conducting literature, collecting information and site visits. Before starting any report or assignment, try to understand the requirements and then try to fulfill all the requirements. Since the selected research project is more to theoretical, therefore a lot study materials are needed to complete it. The collection information can be done through internet searching and site visit.

The stages which will be go through to complete this research project:

Stage 1 – Literature Review

First, obtain the relevant reading materials to find the required information. Conducting related reading materials will be the first choice to start the research project. These reading materials can be obtain from library or search through internet.

<u>Stage 2 – Data Collection</u>

To obtain more related information, interview and companies visit can be made. Before the visit, a formal letter will be sent to the companies and agents to ask for permission and appointment for interview. Questionnaires for the interview will be prepared before the visits.

<u>Stage 3 – Data Analysis</u>

The compiled information is arranged systematically to ease data analysis. This will also allow the readers to pursue the research project easily. All the data will be organized according to the sub-topic; this will smoothen the flow of information and to ensure that the information is not out of topic or not related to the research project's objectives.

<u>Stage 4 – Discussion</u>

Discussion will be made based on those analyzed information. Conclusion or further recommendation can later be made from the discussion ties to achieve the objectives of the research project.

1.5 Scope and Limitations of Study

This research is limited to the study of the construction of the superstructure i.e. the development, concept of the cable –stayed bridge, and construction method of the cable-stayed bridge, the designing method will be omitted in this research.

1.6 Conclusion

Overall in this research study, introduction of cable-stayed bridge in Malaysia is considered a new innovation in technology. As we know, usually bridges are build using concrete or steel as their main structure. Cable-stayed can be considered as alternative bridge design, which is good in items of aesthetic value and the most important; it is strong and durable.

Hopefully with the methodology have been set can allow me to achieve all the stated aims. This research project is limited study of the construction of cable-stayed bridges' superstructures.

CHAPTER 2: LITERATURE REVIEW

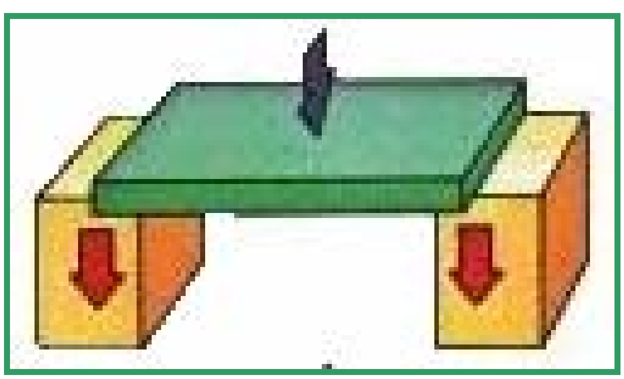
2.1 Definition of Bridge.

A simple definition given by Little Oxford Dictionary: Bridge is a structure which providing way over road, railway, river, etc. For more technically, bridge can be defined as a structure built to span a gorge, valley, road, railroad track, river or other body of water, or any other physical obstacle, whilst used to carry loads. The bridge should cater dead load (self weight of bridge), live loads (pass by vehicles and pedestrians), wind loads, natural disaster and etc.

2.2 The General Bridge Types Available For Use.

Basically there are five bridge types in common use now days. They are Girder Bridge, Arch Bridge, Rigid Frame Bridge, Suspension Bridge and Cable-Stayed Bridge. In order to clarify the differences and function of each type of bridge, a brief description of each type of bridge is presented as following.

2.2.1 Girder Bridge



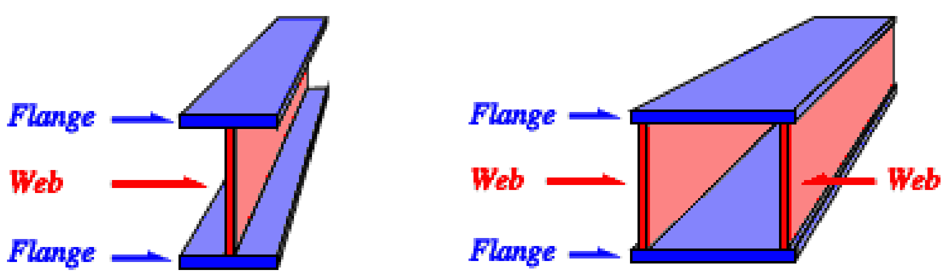
Source: MacDonnell, J (nd)

Figure 2: Simple Example of Girder Bridge

Girder Bridge also name as Beam Bridge. This is the simplest and most economical kind of bridge; therefore this bridge type is perhaps the most common uses. In its most basic form, a girder bridge consist a horizontal beam which is supported at each end by piers. The loads carry by the girder will push straight down to the piers. When the loads are pushing down on the girder, the top edge of the girder will be compressed (compression), while the bottom edge will be stretched (tension). Therefore the girder itself must be strong enough and not bending under its self weight and the added weight of crossing traffic. (pbs.org, 2000)

The horizontal girder can be made of concrete or made of steel. The most common uses of steel girder types in now days are I-Beam girder and Box girder. I-beam girder was given named as its cross section is likely the capital letter 'I' (Figure3). The top and bottom plates are known as flanges while the vertical element which joints those two flanges is known as web.

Box girder is quite similar to I beam girder; they have the same structure members (flange and web). Except the obviously different of their shape, box girder takes the shape of box. Typically box girder has two webs and two flanges, in some cases it can more than two webs become a multiple chamber box girder (Figure 3).



Source: **Matsuo-Bridge co. ltd. (1999)**

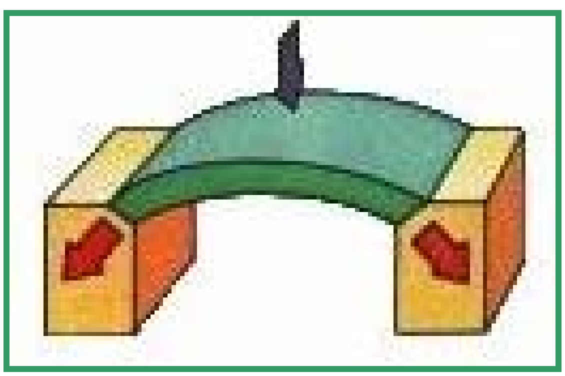
Figure 3: I-Beam Girder (left); Box Girder (right)

By adding the second web in box girder it may improve the stability and increase the resistance to twisting force. And this make box girder become an ideal girder especially for those bridges with any significant curve in them. The stability also allow box girder to span greater distance, that's why it often used for longer spans.

Source: Putrajaya Bridge Construction Team (2005)

Figure 4: Sei Perdana Bridge (Twin-cell Box Girder), Malaysia

2.2.2 Arch Bridge



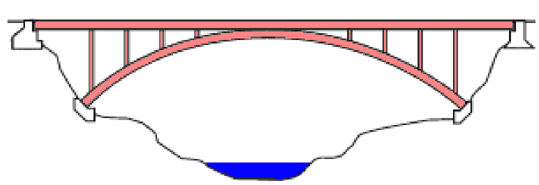
Source: MacDonnell, J. (nd)

Figure 5: Simple Example of Arch Bridge

Arch bridge is one of the oldest types of bridge with a classic structure and has a great natural strength. It is a very good choice for crossing a valley or river, since it does not obtain any piers in between. Its typical span length is between 40m to 150m. Arch bridge is very easy to notifying its type, where it obtains a curved structure which provides a high resistance to bending force. Both of its ends are fixed in the horizontal direction and no horizontal movement is allowed. Therefore instead of pursuing the horizontal force, all the loads will carry outward along the curve to the support at each end. The supports called abutments, its push back on the arch to prevent the arch ends spreading apart. (pbs.org, 2000)

Since the horizontal forces are unique to the arch bridge, it indirectly limits the uses of arch bridge. Arch can be only used where the ground or foundation is solid and stable. Basically there are four type of arch bridge:

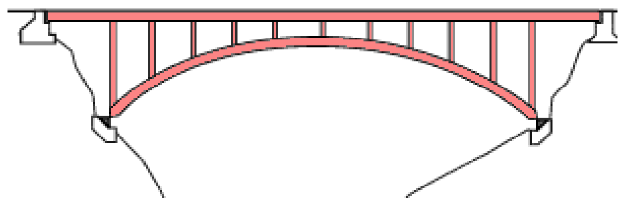
- Hinge-less Arch – Not using any hinges and no rotation is allows at the foundations (Figure 6). As a result, significant horizontal, vertical, and bending forces are generated at the foundations. Therefore it only can be constructs where the ground or foundation is solid and stable. This type of arch bridge is a very stiff structure and experiences less deflection than other arches. (Matsuo-Bridge co. ltd., 1999)



Source: Matsuo-Bridge co. ltd. (1999)

Figure 6: Hinge-less Arch Bridge

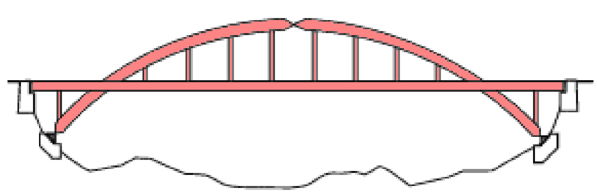
- Two-Hinged Arch – This is the most common type of arch bridge because of its economical design. It uses hinged bearings which allow rotation at the both end of the arch (Figure 7). The horizontal and vertical forces are the only forces generated at the bearings. (Matsuo-Bridge co. ltd., 1999)



Source: Matsuo-Bridge co. ltd. (1999)

Figure 7: Two-Hinged Arch Bridge

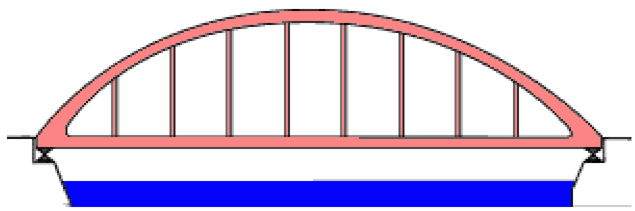
- Three-Hinged Arch – This is an ideal choice to deal with the earth movement because three-hinged arch will suffers very less if there is earthquake or earth sinking. The additional hinge is added on the top of the arch (Figure 8). This design is rarely used in now days because it experienced more deflection and the hinges are very complicated and hard to fabricate. (Matsuo-Bridge co. ltd, 1999)



Source: Matsuo-Bridge co. ltd. (1999)

Figure 8: Three-Hinged Arch Bridge

- Tied Arch – The only design of arch bridges that allows to constructs even the ground is not solid enough. Instead to resist the horizontal forces, the girder itself "ties" both ends of the arch together rather than relying on the foundation to restraint the horizontal force. (Matsuo-Bridge .co .ltd, 1999)



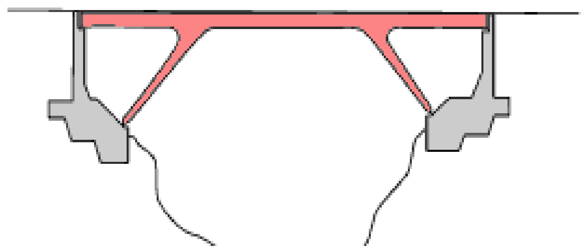
Source: Matsuo-Bridge co. ltd. (1999)

Figure 9: Tied Arch Bridge

2.2.3 Rigid Frame Bridge

Rigid frame bridge also known as Rahmen Bridge. (Matsuo-Bridge co. ltd, 1999) In a rigid frame bridge, the piers and girder form one solid structure not like the standard girder bridge where the piers and girder are separate structure. Usually the cross sections of the beams in a rigid frame are I shaped or box shapes. The design calculation of a rigid frame bridge is more complicated compare to those standard girder bridges. The junction of the piers and the girders can be difficult to fabricate and requires accuracy and attention to detail. Although there are many potential shapes, but the common styles are the batter post frame, the shaped frame and the pi-shaped frame.

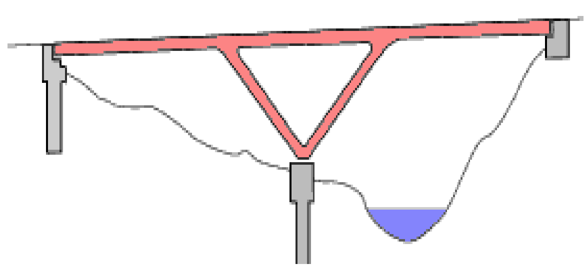
- Batter Post Frame – It is a very good choice for crossing a valley or river, since the piers tilted at an angle can straddle the crossing more effectively and no foundation constructions are required (Figure 10).



Source: Matsuo-Bridge co. ltd. (1999)

Figure 10: Batter Post Frame

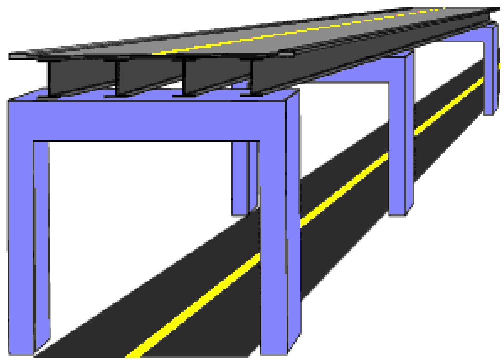
- V-Shaped Frame – This type frame effectively use of the foundations, where each V-shaped pier provides two supports to the girder. With such supporting method, the number of foundations can be reduces and creating less cluttered profiles (Figure 11).



Source: Matsuo-Bridge co. ltd. (1999)

Figure 11: V Shaped Frame

• Pi Shaped Frame – This type of structure is used frequently for inner city highway to rise up the highway, whilst provide additional route for traffics run directly underneath.

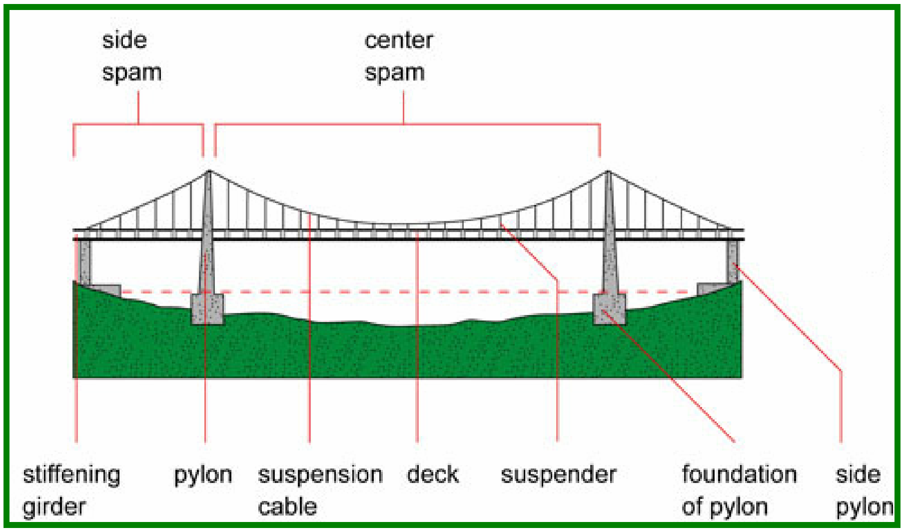


Source: Matsuo-Bridge co. ltd. (1999)

Figure 12: Pi Shaped Frame

2.2.4 Suspension Bridge

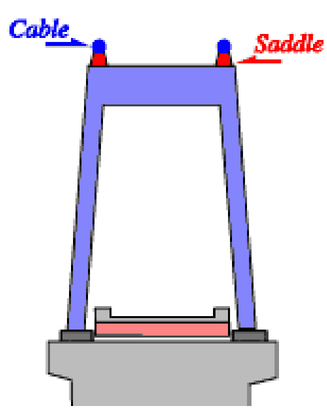
Typically, suspension bridge (Figure13) is a continuous girder with one or more towers erected above piers in the middle of the spans. Although in the middle of the span, the girder usually is a box girder or a truss. Large anchors or counter weight are place at the both end of the bridge to hold the ends of the cables. The cables which are stretched over the top of the towers and attached at the both end's anchor known as main cables. Then the smaller cables hung down from the main cables and attached to the girder are called hanger cables or hanger ropes.



Source: Déry, B. (2005)

Figure 13: Typical Suspension Bridge

Actually at the top of the towers the main cables are passing over a special structure known as a saddle (Figure14). This saddle will allow the main cables to slide and transfer the loads smoothly from the cables to the tower. For those suspension bridges which are not using anchors, the main cables are attached to the girder and these types of bridges are known as self anchoring suspension bridge. They only rely on the weight of the end span to balance the center span and anchor the cables.



Source: Matsuo-Bridge co. ltd. (1999)

Figure 14: Typical Tower

Therefore, suspension bridge is unlike the normal bridge which rest on piers and abutments. Actually the girder is hanging suspended from the main cables. The majority of the load of the bridge and the traffics are suspended from the cables, and then transfer to the towers. As a result the towers must be able to carry an incredible amount of weight. (Matsuo-Bridge co. ltd, 1999)

Between all types of bridge, suspension bridge allows for the longest spans. Its typical span lengths are around 70 m to 1,000 m+. At the moment, the world's longest suspension bridge is Akashi Kaikyo Bridge in Japan (Figure15), where the total length is 3,911 m and the center span is 1,991 m. (Matsuo-Bridge co. ltd, 1999)

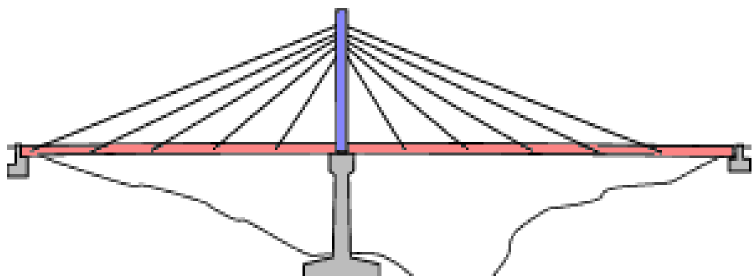
Source: en.wikipedia.org (2005)

Figure 15: Akashi Kaikyo Bridge, Japan

2.2.3 Cable-Stayed Bridge

At the first glance, the cable-stayed and suspension may look similar – both have the girders or the roadway that supported by cables, but in facts is quite different in principle and in the construction method.

A typical cable stayed bridge (Figure16) is a continuous girder with one or more towers erected in between of the span. Cables are stretch diagonally from the towers to attach to the girder (usually both sides). The typical span lengths of cable-stayed bridges are around 110 m to 480 m. At the moment, Tatara Ohashi Bridge in Japan (Figure17) is the world's longest cable-stayed bridge. The total length of this bridge is 1,480 m and the center span is 890 m.



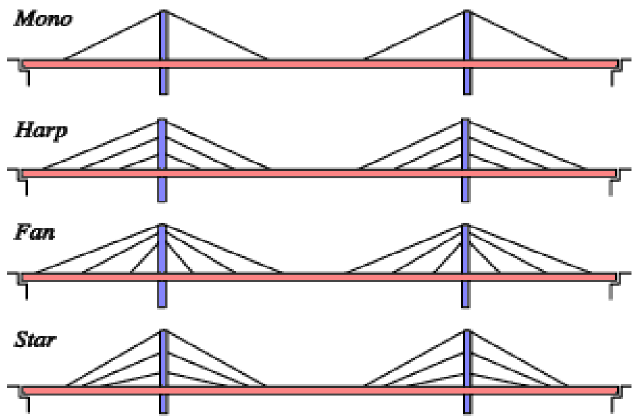
Source: Matsuo-Bridge co. ltd. (1999)

Figure 16: Typical Cable-Stayed Bridge

Source: en.wikipedia.org, (2005)

Figure 17: Tatara Ohashi Bridge, Japan

There are various ways to distinguish a cable-stayed bridge. It can be distinguished by the number of spans, number of towers, girder type, number of cables, etc. The arrangement of the stay cables could be divided into four basic system; typical varieties are mono, fan, harp and star arrangement (Figure18).



Source: Matsuo-Bridge co. ltd. (1999)

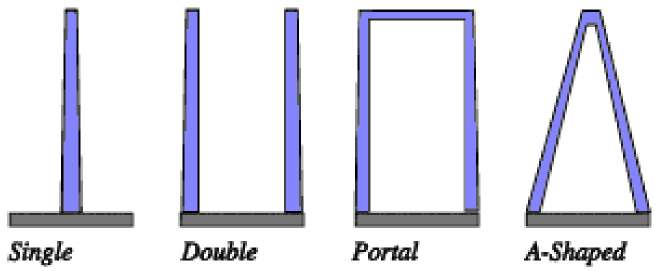
Figure 18: The Typical Arrangement of Stay Cables

The properties of the steel cables are extremely strong, flexible and economical. As using a slender and lightweight structure supported by steel cables, it is still able to span longer distance. The disadvantage of steel cables is weak against to the wind force. To develop a longer span, the designer must carefully study and analyze to ensure the cables and the bridge is stable in the wind.

There is an advantage for steel cable during an earthquake due to its flexibility and lightweight of it. Thus, the foundations must be well designed and effectively planned to oppose the movement of earth. In designing the cable stayed bridge, there are some considerations to be taken into account. There are:

- The properties of cables.
- For longer span resistance thru wind and temperature.
- The design calculations have to be done using computer software rather than manual.
- Fabrication of the bridge structure members.

There are varies type of towers that can be used in cable bridge design, those typical towers are single, double, portal, or even A-shaped towers (Figure19).

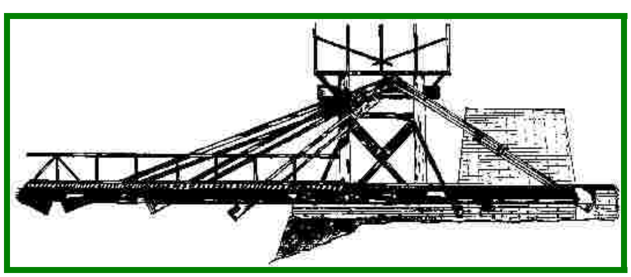


Source: Matsuo-Bridge co. ltd. (1999)

Figure 19: The Typical Towers Used in Cable-Stayed Bridge

2.3 Development of Cable-Stayed Bridge.

The idea of supporting a beam by inclined rope or chains hanging from a mast or tower in ancient time had evolved into the development of the modern cable stayed bridge. The first bridge using such idea was constructed in 1600's, when Verantius, a noted Venetian carpenter built a timber bridge with several stays. In 1784, C.J. Löcsher a noted carpenter constructs a 32 m span bridge made wholly of timber even the stays (Figure 20). (Walther, R. and Houriet, B. 1999)



Source: Clubi.ie (2001)

Figure 20: The First Trukky Cable-Stayed Bridge, Designrd by C.J. Löcsher

Since the tension members were made of low strength materials such as timber, round bars, or chains, the early cable-stayed bridge had suffered from excessive girder deflections; full resistance was not developed until significant deformations occurred. This caused the abandonment of the cable-stayed bridge.The cable-stayed bridge revive after 1950, when the first two cable-stayed bridges of modern design had proven to be very stiff under traffic load, aesthetically appealing, economical and relatively simple to erect. (Troisky, M.S. 1988)Besides that, these two bridges also proved that cable-stayed bridges were more economical than the suspension or the self-anchored suspension bridges.

In 1952, Leonhardt designed the cable-stayed bridge across the Rhine River in Düsseldorf, but the bridge was not build until 1958. In the same period, the German firm Demag, in collaboration with Franz Dischinger, designed the Strömsund Bridge in Sweden, which erected in 1955, may be considered as the first modern cable-stayed bridge.

(Troisky, M.S. 1988)

Source Clubi.ie, 2001

Figure 21: Strömsund Bridge in Sweden

There are more than 50 bridges that have been built since 1955. Where the system of cable-stayed bridge were contemplated and incorporating. About one-third of those bridges have been built in Germany and others are located through out the world. Due to its simplicity of the deck structure and pylon and ease of construction, I believe that more cable-stayed bridge will be built in future.

2.3 The Basic Concept of Cable-Stayed Bridge.

The growth of inclined cable application gave a new stimulus to the construction of large bridge. The concept of cable-stayed bridge has been around for a long time, since discover the rigid structure could be formed by joining triangle together. But it only becomes more prevalent in the last 50years. (Troisky, M.S. 1988)

Although most of the earlier designs were based on sound principles and assumption, because of some misfortunes happened to those early implementations resulted this system was abandoned. Actually, the system itself was not at all unsuitable. The main factor is the solution of the problem had been attempted wrongly. Beside that, the equilibrium of these highly intermediate systems had not been clearly appreciated and controlled. Whilst the tension members were using low strength materials like timber, round bars or chain. These resulted in excessive deflections in the girders, as full resistance was not developed until significant deflections occurred. With the improvement of structure analysis methods, construction techniques and material technologies, the cable-stayed bridge has experienced a modern renaissance. (Troisky, M.S. 1988)

After the modernization, cable-stayed bridge presented a three dimension system. This system is consisted of stiffening girders, transverse and longitudinal bracing, orthotropic-type deck and supporting parts such as towers in compression and inclined cables in tension. The main function of this system is involved all the transverse construction in the work of the main longitudinal structure. With able to provides stiffer structure and less deflection, lighter and more slender deck is allowed.

2.4 Conclusion

A bridge may be defined as a structure build to span over road, rail road track, river or any other body of water, or any other physical obstacle. There are five basic types of bridge which are used in now days. They are Girder Bridge, Arch Bridge, Rigid Frame Bridge, Suspension Bridge and Cable-stayed Bridge.

The cable stayed bridge concept was evolved from the idea of supporting a beam by inclined rope or chains hanging from a mast or tower. The first bridge using such idea was built in 1600's where the bridge were wholly made of timber. Because of some failure in structure members due to use low strength material, this type of bridge design was abandoned. The cable stayed bridge revive after 1950, when the first two cable-stayed bridges had proven the idea of supporting a continuous girder by inclined cables is reliable, safe to be used, economical and simple to erect.

CHAPTER 3: THE CONCEPT OF CABLE-STAYED BRIDGE

3.0 Introduction

Bridge can be defined as a structure built to span a gorge, valley, road, railroad track, river or other body of water, or any other physical obstacle, whilst used to carry loads. The loads which cater by the bridge can be defined as the weight of vehicles and pedestrians. At the first glance, the cable-stayed and suspension may look similar – both have the girders or the roadway that supported by cables, but in facts is quite different in principle and in the construction method.

3.1 The Concept of Cable-Stayed Bridge.

Typically, cable stayed bridge is a continuous girder with one or more towers erected in between of the span. Cables are stretch diagonally from the towers to attach to the girder (usually both sides).The concept of cable-stayed bridge presented a three dimension system. This system is consisted of stiffening girders, transverse and longitudinal bracing, orthotropic type deck and supporting parts such as towers in compression and inclined cables in tension. From the structural behavior of each structure member, cable-stayed systems in the vein of the combination of girder bridge system and suspension bridge system.

In the cable-stayed system, the pre-stressing cables will pass through or attached to the tower before they are anchored to the stiffening girders. This is how the integral action occurs in the cables and girders and it is considered as one of the important structural characteristics of cable-stayed bridge system.

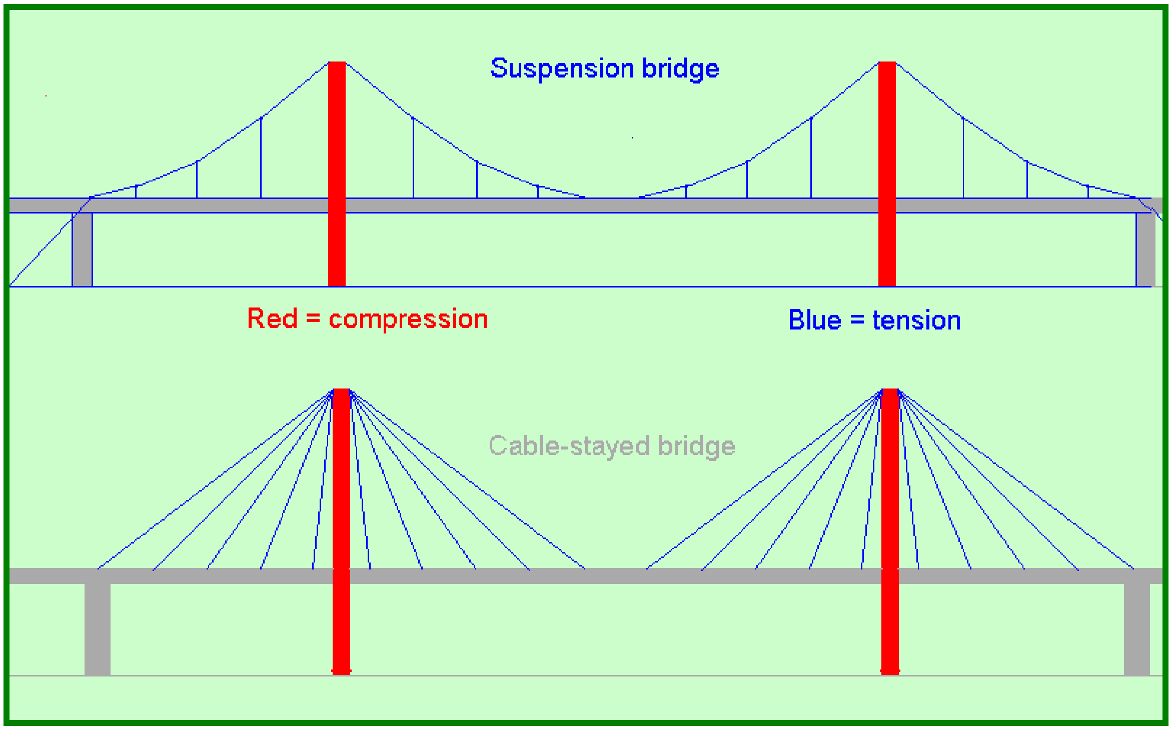
Since the stiffening girders take the horizontal compressive force from the cables action, no massive anchorages are required. Therefore the cost of this sub-structure could be economical. (Troisky, M.S. 1988)

In olden concept, the superstructures like slab, floor beams, stringers and girders were considered as independent members where they act independently. Such concept was not used in cable-stayed bridges. With the introduction of orthotropic system, some new superstructures were created. For example, an orthotropic deck designed with a large cross section. Besides acting as main girders and transverse beams, it also acts as the horizontal plate girder. It gives more lateral stiffness to the modern bridge compare to the wind bracing which is used in the old bridge system. The members of the roadway and the secondary parts of the bridge superstructure are parts of the main bridge system. Therefore, the depth of the girder and the amount of steel used in the bridge construction can be minimized. (Troisky, M.S. 1988)

Since all the cables are in tension stage, the geometrics of the bridge remain unchanged under any load position on the bridge. Therefore, light flexible elements like cables can be used in construction of this type of bridge. (Troisky, M.S. 1988) The arrangement of the cables has an effect on the stiffness of a bridge and its sensitivity to vibration. Therefore, the wind effect on the cable-stayed bridges is controllable.

3.2 Comparison of Cable-Stayed and Suspension Bridge.

Suspension bridge and cable-stayed may look similar where both of them are using cables as part of the structures of the bridge, but they are very different in principles, and the method of construction.



Source: Brantacan (2005)

Figure 22: Structural Behavior of Suspension Vs Cable-Stayed Bridge

In suspension bridge, a huge main cable is hung from one end to another between two pillars and the end of this cable will be anchored into the ground or anchored to an anchorage. This main cable is under tension by it self weight before the deck is installed. There will have some smaller suspender cables or rods suspended on the main cables, and then the deck will be attached to those smaller suspended cables. When this is done, the tensions in the cables not only increase by obtain the dead load of the structure members, but the imposed load as well. Imposed load could be varied from time to time depend on the capacity of traffics of the bridge. Then, the tension in the cables will be transfer to the anchorages which are usually buried. Therefore, the soil conditions will be very important for constructing suspension bridge.

(Absoluteastronomy nd)

In cable-stayed bridge the deck is directly supported by the cables which are attached to the tower, but it only for the further areas of deck. Those decks near to the tower are approach cantilever principle. The disadvantage of approach cable-stayed system is the deck itself must be strong enough to resist the cables force. The advantage is no massive anchorages are required to resist a horizontal pull as in the suspension bridge.

(Absoluteastronomy nd)

Cable-stayed bridges have an optimal range of lengths within which they will outperform suspension bridges. For a three-span configuration of moderate length, a cable-stayed bridge will have lower midspan deflections than a suspension bridge. However, if the span length is exceeds a limiting value (which may depend on specific proportions), the midspan deflection of the cable-stayed bridge may exceed that of the suspension bridge.

(Troisky, M.S. 1988)

Beside the comparisons above, suspension bridge and the cable-stayed bridge also can be compared based on the cost and quantities steel required for each bridge. According to the analysis from Gimsing, N.J. (1997), an investigation had been done on few cable supported bridges and come out with a ratio of pylon height and length of main span. From this investigation, they found that cable-stayed bridge with the fan shape arrangement of the cables is the most economic. This result also showing that the suspension bridge is 24% higher. The following table is showing the comparison of quantities of steel between cable-stayed bridge with fan system and suspension bridge for 1000m and 2000m span. The load caring by these two types of bridge is considered equal.

Table 3.1: Quantities of steel (Adapted from Gimsing, N.J. 1997)

Bridge system	Span (m)	Cable steel (tons)	Structural steel (tons)
Suspension	1000	7500	23000
Cable-stayed		3900	25000
Suspension	2000	3600	55000
Cable-stayed		1900	94000

From the above data, it is shown the quantities of structural steel used in these two types of bridge are increasing according to the increase of the span length. The increasing of the structural steels' tonnages is more significant; the increment of the quantities is almost four times of the quantities used in 1000m span bridge. Meanwhile, the quantities of cable steel are not increasing although the span is longer. The quantities of cable steel used in 2000m is reduce more than half of the quantities used in 1000m for both type of bridge. As conclusion from this table, suspension bridge is using less steel than cable-stayed bridge especially for longer span.

3.3 Layout of Cable Stays.

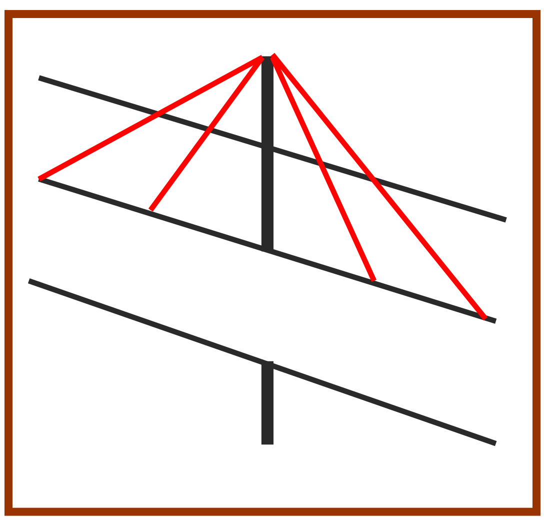
Layout of cable stays is a basic item in designing a cable stayed bridge but it consists of the number of planes, arrangement of the cables and the spacing of the stays. Therefore decisions making during this section not only will influence the structure performance but also the erection method. Indirectly, the economical of the structure also relates to the layout of cable stays.

(Walther, R. and Houriet, B. 1999)

3.3.1 Number of Planes

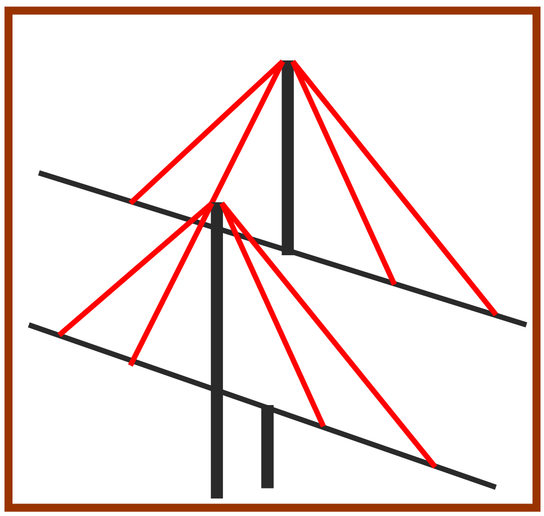
The main function of the number of plane used in a cable-stayed bridge is to reduce the cross section force of the deck. Most of the existing cable-stayed bridges are consist of two planes of cables where cables are attached to the side of the plane. Only recently has the single-center-plane system been successfully built. If the deck of the bridge is too wide, using of more planes of cables is a better way to against cross section force. The following are the common plane system or number of planes used in now days:

a. <u>Single plane system</u>



There is only one vertical plane of stay along the super structure. Either the cables anchored to the center of the deck or the deck side. Anchored area should always leave empty; not being used. If the plane of cables is located in the middle of the deck, this system will naturally separate the lane. In order to overcome the cross section deformation when due to eccentric live load within allowable limit, a hollow box main girder is needed in this suspension system (Walther, R. and Houriet, B. 1999). The disadvantage of using this system is the width of the bridge is limited and not encourage for further enlargement. (Gimsing, N.J. 1997) This system is more suitable for intermediate span (Walther, R. and Houriet, B. 1999). It is not only economical but also providing high aesthetic value.

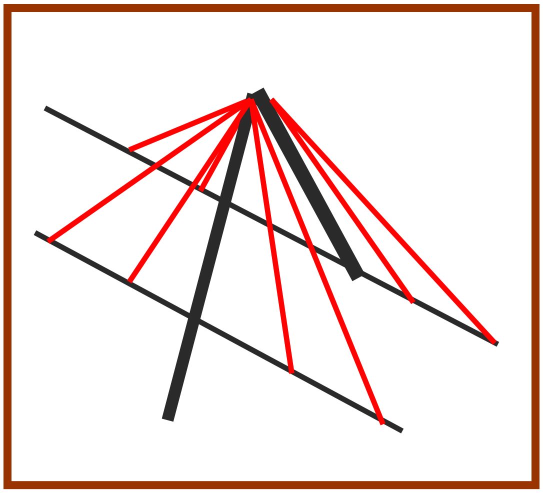
b. <u>Two vertical plane system</u>



The most common suspension system used in cable-stayed bridge is two planes system. In this suspension system the planes could be formed in vertically or in incline. The stays in vertical plane which are in tension state are required to ensure the connection between deck and pylons are rigid. The deformation of deck is due to the deformation of pylon and variation of stresses in cable stays.

The width of the deck depends on the minimum distance between the pylon arms which are located out of the deck. Upper bracing is used to balance the transverse bending of the pylon caused by the deviation of cables. The erection of the pylon with vertical arms is more simple and economical compare to incline plane system.

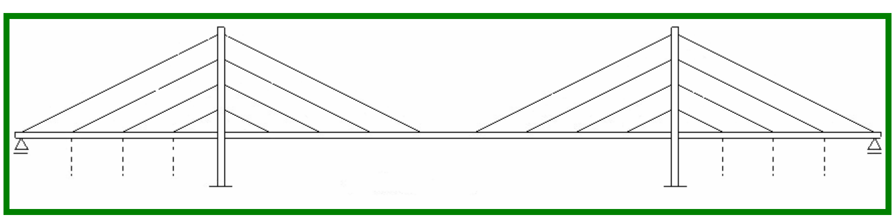
c. Two inclined plane system



Severin Bridge in Cologne, Germany is the first bridge using the inclined plane system. (Walther, R and Houriet, B. 1999) The inclined plane system is also known as A-frame pylon. The arms of the pylon which are connected at the top of the bridge can improve the stiffness and stability of the structure. The deck and the plane behave like a rigid close section in bending to reduce the possible rotation of the deck surface. (Walther, R and Houriet, B. 1999) The A-frame pylon is recommended for bridges with large span. However, the erection of A-frame pylon is more complicated.

3.3.2 Arrangement of the Stay Cables.

a. Harp Pattern (Parallel system)

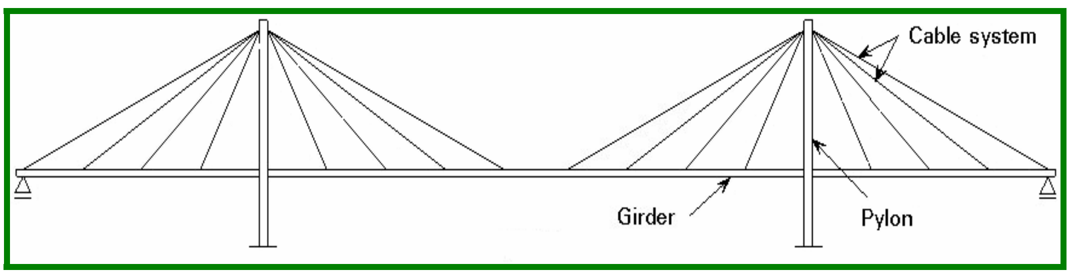


Source: Kuleun (2005)

Figure 23: Harp Pattern Arrangement

In harp system, the cables are connected to the tower at different heights and parallel to one and another. Between all of the stay patterns, harp pattern always considered as the most aesthetical arrangement but not offers a sufficient structural. The cable connected may cause bending moment in the tower. Therefore it is necessary to study whether the support of the lower cable can be fixed at the tower leg or must be made movable in horizontal direction. The harp pattern cables arrangement provide an excellent stiffness for the main span when it is anchored to the ground. The erection of the harp-shaped cables required more steel. A higher tower is chosen to increase the system resistance against deflection. (Gimsing, N.J. 1997)

b. <u>Fan Pattern (Intermediate system)</u>

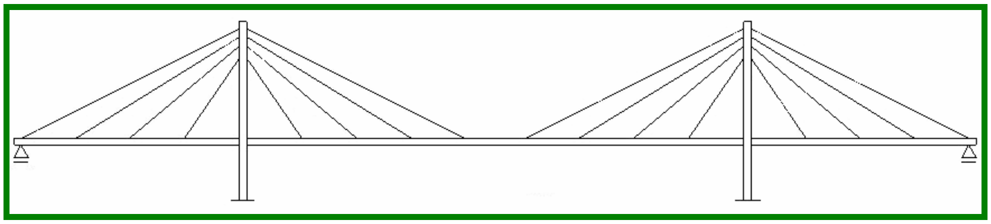


Source: Kuleun (2005)

Figure 24: Fan Pattern Arrangement

This system represents a modification of the harp system.(Gimsing, N.J. 1997) Compare to harp pattern, the smaller cables and less material are used in fan pattern because the axial force of the horizontal components are smaller. Since all cables are connect to the top of the pylon, the design and construction of the pylon become more complicate and become the biggest disadvantage of fan pattern.

c. Radial Pattern (Converging system)

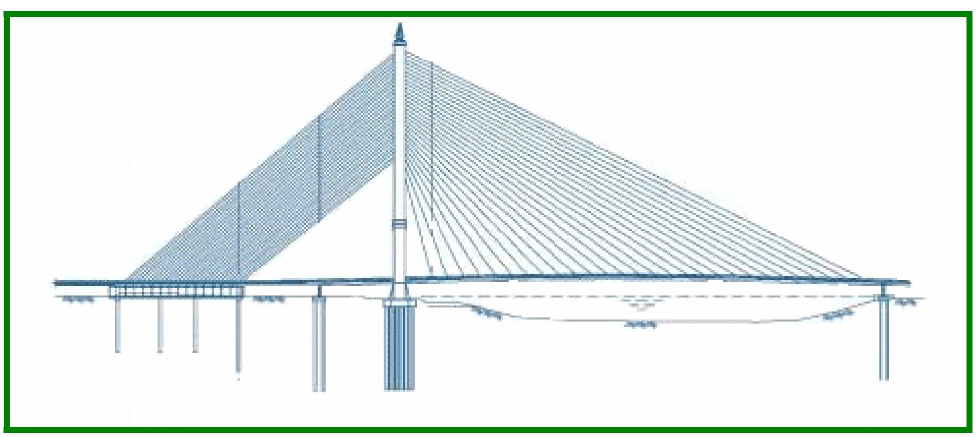


Source: Kuleun (2005)

Figure 25: Radial Pattern Arrangement

In this system maximum inclination to the horizontal is achieved and lesser amount of steel is required since all the cables are leading to the top of the pylon. The cables will carry the dead and live load, and the axial load at the deck is minimums. However, the detailing of radial pattern may be complex because congestion of cables may occur at the top of the pylon and a considerable vertical force has to be transfer to the support.
(Gimsing, N.J. 1997)

d. Asymmetric pattern



Source: Heidengren, C.R. (2003)

Figure 26: Asymmetric Pattern Arrangement

The asymmetric pattern can be considered as modification of radial pattern. The attachment of the front stays and back stays to the deck are not symmetric. Beside the aesthetical value, this pattern also increases the constructability of the bridge and reduces the amount of cables. The points of attachment of the cables are distributed along the main girder. (Gimsing, N.J. 1997) The tower always plays the most important roll in carrying almost the entire load of the main span. Therefore, it is doable to support the span from one side.

3.3.3 Number and Spacing of the Cables.

Some of the cable-stayed bridge may have more cables and some may be less. This only can be compared when the bridge's span is considered large, where the span at least 240m. (Troisky, M.S. 1988) Using less cables and wider spacing will leads to large cables force whilst complicated cable anchorages are required. Indirectly the larger cross section of the deck will be used. 30m to 73m spacing which used in first modern cable-stayed bridge is no longer applicable, especially for those large structure bridges. In fact more material are needed and cost more. The maximum spacing of the cables depends on the width and the shape of the deck. Spacing of 15m to 25m is used when the deck is made of steel or composite steel-concrete. The maximum spacing of the cables depends on the width and the shape of the deck. Spacing of 15m to 25m is used when the deck is made of steel or composite steel-concrete.

Using smaller spacing not only can reduce the cables force but also encourage using shallower main girder and simple anchorages. Actually, the depth of main girder is not helping much to decrease the deflection of the deck. Shallow girders also help the aerodynamic stability. The cable spacing should be varying so that the cable forces are similar. According to analysis of M.S. Troisky, 1988, there must be a strong cable from the top of the tower to the abutment at the end of the side span or to the intermediate piers in order to restrict the horizontal movement of the tower. The following are the advantages of using 6.2m to 9.2m spacing in construction cable-stayed bridge:

- The bending strength of the stiffening girder is increased and it may support heavier load.
- Concentrated forces at anchorages are reduced.
- Bending moments between points of suspension are decreased.
- Deck erection by cantilevering method is simplified.
- The replacement of stay cables in the case of deterioration may be achieved more easily.

3.4 Data for Beginning of Bridge Design.

The important data in beginning of design work for a bridge:

- Condition and structure of the proposed location. Site plan is the best data to showing the existing condition and type of the obstacles which will be bridged.
- Topography to show the environment whether it is a mountainous or open flat area, urban or rural area, etc.
- Requirement due to the purpose of the bridge, i.e. width of the bridge, number of lanes, pedestrian walkways, safety measures etc.
- Soil mechanic data which provide information regarding soil condition. This will influence the choice of foundation to be used in the design.
- Type of existing feasibility for the particular area. Feasibility could be the available of electricity supply, water supply, transportation, etc. This will influence the choice of construction technology and materials that can be used.

- Weather report, rainfall data and wind data are used to determine the suitable structure to be used.
- Aesthetic requirement from the client and relating authority.

3.5 The preliminary list of loads considered during bridge design.

Normally we define loads as the weights of vehicle and pedestrian. This type of load also known as Primary loads, where it is expresses the purpose of the bridge. Beside define into this term; loads also can be qualified into few terms such as, service loads, design loads and legal loads. It is necessary for a designer to consider and decide the loads that will be carrying by the bridge him / her design. The loads used in design will directly affect the selection of structure members' sizes. The following is the list of loads which needed to consider in every bridge design.

- The pedestrians and vehicle weights.
- Self-weight of the structures.
- The horizontal vehicles loads, which occur when vehicles suddenly stop down or turn.
- Dynamic vertical loads, which occur when vehicles bounce due to the roughness of the road surface.
- Force of the water current against bridge supports.
- Wind load.
- Earthquake load.
- Thermal effects

3.6 Conclusion

At the first glance, the cable-stayed and suspension may look similar, but in facts is quite different in principle and in the construction method. A typical cable stayed bridge is a continuous girder with one or more towers erected in between of the span. Cables are stretch diagonally from the towers to attach to centre of the girder or both sides. One of the important structural characteristics of cable-stayed bridge system is the cables are pre-stressed, and then attached to the tower before they are anchored to the stiffening girders. This is how the integral action occurs in the cables and girders. Layout of cable stays is a basic item in designing a cable stayed bridge, where it consists of the number of planes, arrangement of the cables and the spacing of the stays. The decisions made in this stage will influence the structural performance, erection method and costing of the structure.

CHAPTER 4: PROJECT DESCRIPTION

4.1 Organization of the Project.

Client: Putrajaya Holdings Sdn. Bhd.

Consultant: Perunding Jurutera Satu (INT.) Sdn. Bhd. (a.k.a. PJSI)

Designer: Michael Yomout (PJSI)

Contractor: Muhibah Engineering Sdn. Bhd

Main Supplier (stay cables and prestressing): Freyssinet International

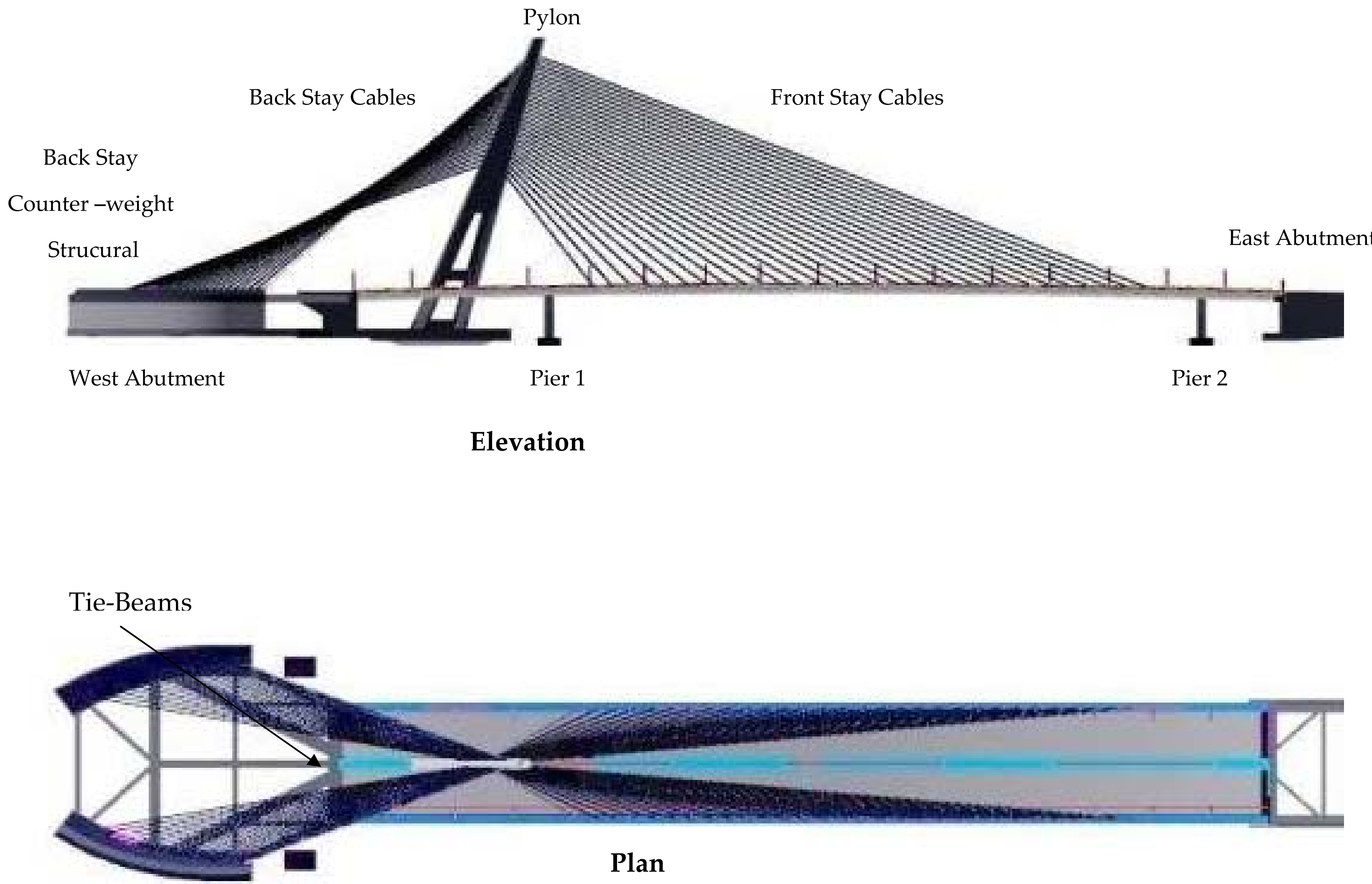
4.2 Design Concept

To span over a 168.5m wide man-made lake, a single span cable stayed bridge with a 75° forward-inclined pylon was a competitive solution from the economical and aesthetical standpoint. The concept of design was inspired from a sailing boat (Refer to figure 27). It is more emphasizes on the aesthetic of the structure and its relationship with the morphology of its surroundings. Actually the pylon can be designed inclined in opposite direction, because it still carries out the same function. The main feature of this single inclined pylon is providing the suspension point for cable stays to support the cantilever span. Almost entire loads of the main span are carried by the pylon.

The inclined pylon was designed into inverted 'Y' shape is mainly for distributing the bridge loads and for aesthetical purpose. Pylon shape such as the A-frame pylon is used to increase the stability and stiffness of the structure. Besides, the structural ability, the cost of maintainability, the build-ability of the structure and the comfortable riding quality on the bridge deck were the utmost concerns of the designer as well as client.

Figure 27: Overall View of Seri Wawasan Bridge

Source: Putrajaya Bridge Construction Team (2005)



4.3 Geometry

Seri Wawasan Bridge is an asymmetric cable-stayed box girder bridge with an inclined concrete pylon 96m height. The overall length of the bridge between two abutments is 240m. The length of the main span is 165m and supported by stay cables anchored at one side of the inclined pylon. The network of cable backstays balances those front stays. The inclined concrete pylon and the backstays are anchored into bore piled foundation.

The total width of the bridge deck is 37.2m including, it provides dual three lane carriageways 11.5m each; a 4.0m wide median, and two cycle track cum pedestrian walkways 4.95m wide. The bridge deck has a parabolic profile with level varies from reduce level RL 32.0m (at abutment) to RL 34.5m (at the bridge center).

4.4 Geometric Design Data

4.4.1 Cross Section

The road cross section is design to match the connecting roads on East and West.

No. of lanes	: Dual – 3 lanes
Lane width	: 3 x 3.5m
Marginal strip	: 0.50m
Walkway/Cycle track	: 4.95m
Median	: 4.00m
Total width	:37.2m

(Note: The total width is including the traffic barriers and balustrades)

4.4.2 Horizontal Alignment

a. Bridge: Straight

b. Approaches:

- East Approach: curve (500 Radiant)
- West Approach: straight

4.4.3 Vertical Alignment

a. Bridge:

- Centre of the bridge : RL34.50m
- Both abutments : RL32.00m

(Notes: the vertical alignment is on vertical parabolic curve with finished deck levels)

b. Approach gradients :

- Parabolic vertical curve joining the approach road levels.

4.4.4 Navigation Clearances

a. Vertical clearance over the highest tied level : 9.0m (min)

b. Horizontal clearance between shore lines : 165.0m

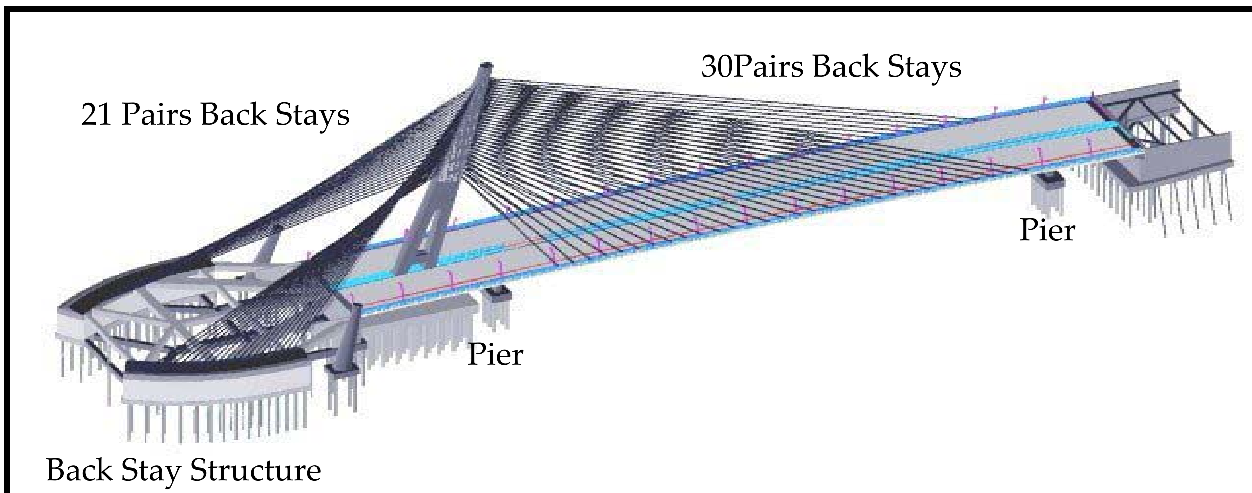
(The data above are refer from site interview and construction drawings attached in Appendix-B)

4.5 Structural Detail of Seri Wawasan Bridge

The 240m long cable-stayed bridge has a single inverted 'Y' shape pylon inclined at 15° vertical, sloping towards the main span. The cast in-situ bridge deck is made up of a 3.5m deep longitudinal post-tensioned spine box spine beam connected to two solid edge beams by post-tensioned transverse rib beams spaced at 4.0m.

The cable system is formed by thirty pairs of stay cables which support the main span, and countered balanced by twenty one pairs of retaining cables with crisscross pattern when viewed from side elevation. This unique arrangement of stays has provided an aesthetic enhancement to the bridge without cost implications. Furthermore, the world's latest cable-stayed technology and specifications have been implemented in the bridge design and construction.

In the absence of the compensating side spans, all retaining cables are anchored into two counterweight boxes which located on the east approached road. The counterweight structure is curved in plan, and made up of multi-cells reinforced concrete boxes in-filled with compacted sandy. The use of high strength pre-stressing loop tendons in the wall has efficiently transferred the stays' uplifting forces to its foundation. The uplift component of retaining cables is counterbalanced by the static weight of the back stay boxes, while the horizontal component is balanced by the closed polygon of underground beams, which are rigidly connected between the bridge deck and the counterweight structures (Refer to Appendix B2 – B3).



Source: Putrajaya Bridge Construction Team (2005)

Figure 28: Isometric View of Seri Wawasan Bridge

4.5.1 Foundation

The bored pile system was chosen due to its reliability in resisting the horizontal forces. In bore piling, all piles are cast in situ. The ground will be bored and keep as hollow by assist of steel casing. The steel casings are screwed together in section. Boring process will be continuing until a necessary depth where the required bearing capacity can be developed by the pile. Then reinforcement steel will be paced centrally in the section before the hollow section is filled with high workability concrete. All piles were about 30m to 40m deep from pile cut-off level, and each pile has been properly designed and supervised to socket into sound rock level to achieve the required design capacities. The arrangement and all piles details are shown in Appendix B4 – B6.

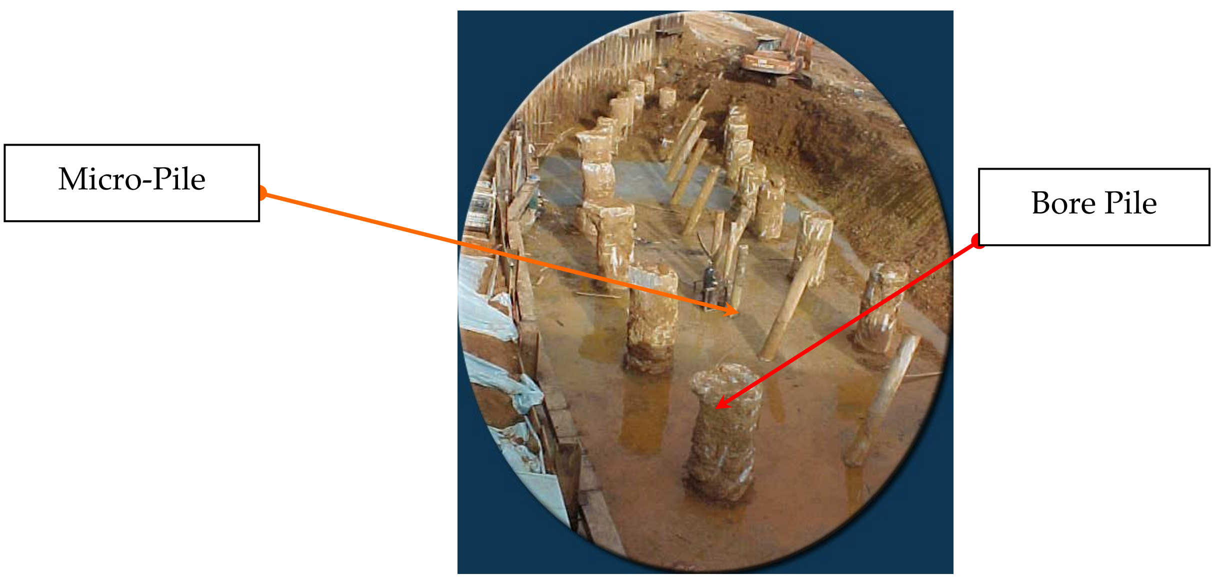
Source: Putrajaya Bridge Construction Team (2005)

Figure 29: Piling Machine Used BG30

A pile load test of 2500 tons was performed in this project to study and evaluate the design parameters of pile. It held the record of the largest test load for pile testing in Putrajaya. Beside bore piles, micro piles also used in this project. Micro piles only used at the back stay boxes as additional support for the foundation, in order to increase the stability of the structure whilst the bed rock at this project area is shallow. The main usage of micro pile is to withstand tension and/ or compression loads as a friction pile. It is usually 300mm to 350mm diameter, where the steel reinforcing consists of single or multiple piles are place at the center. The pile is usually drilled and grouted by concrete.

Source: Putrajaya Bridge Construction Team (2005)

Figure 30: Types of Reinforcing Material (Micro-Piles)



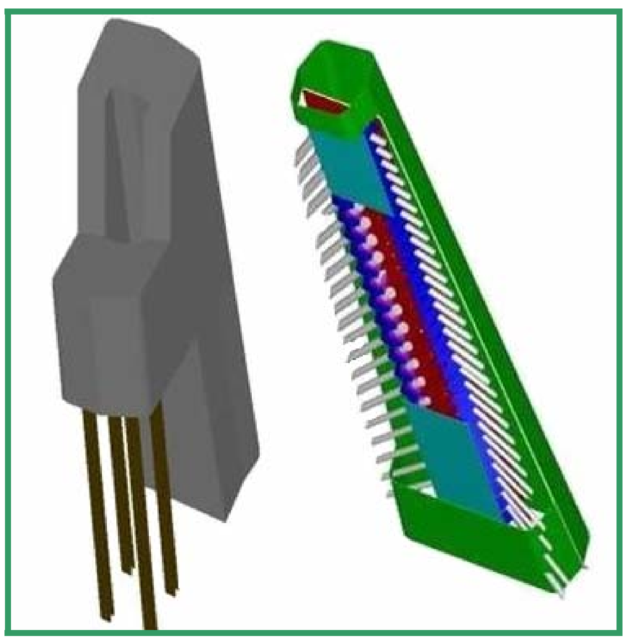
Source: Putrajaya Bridge Construction Team, 2005

Figure 31: 900ϕ Bored Piles and 350 ϕ Micropiles at Back Stay Boxes

4.5.2 Pylon

The inverted 'Y' shape pylon has an overall height of 96.6m from top of the pile-cap level; 83.7m from the deck level. The foundation of the pylon is 4.0m ~ 4.5m thick reinforced concrete pile-cap supported by 76 nos. of 1.35m diameter bored piles. The 3600 cubic meter concrete pile-cap was cast continuously for 36 hours, it was reported the largest mass pour in Putrajaya projects. The selection of inverted 'Y' has limited the second order-effects of forces. Whilst, increase the structural capacities at the lower part which is subjected to high axial loads and moments.

The lower part of the pylon is constructed by reinforced concrete and post reinforced (by steel rolled UC sections to act as composite section) to resist the imposed moments and axial loads. High performance concrete G60 with silica fumes additives was used to achieve higher material strength and enhances the structural durability.



Source: Putrajaya Bridge Construction Team (2005)

Figure 32: R.C Section and Steel Composite for Pylon Head

The top section of the pylon in the region of stays is a hollow core structure formed by high strength G50B steel plates and in-filled in concrete (Refer Appendix B7 – B8). The adoption of this unique is combined steel/concrete design technology for the top section, is adopted to provide direct transfer mechanism of stay forces from front to back stays and provide high accuracy for positioning the stay guide pipes and anchorages. The central void in the pylon head provides access for future maintenance inspection of stays anchorages in the pylon head. Each pair of front and back stays were anchored and locked on inclined steel transfer box which was welded to longitudinal steel plates along the internal pylon shaft corresponding to the longitudinal direction of the bridge (Refer Appendix B9).

The splitting effect due to horizontal component of front and back stay forces is resisted by these vertical plates, and the vertical component of stay force is transferred to the surrounded concrete by shear connectors and fin plates welded on the longitudinal plates. The top steel section is 46.67m high and was factory built by eleven segments. Each segment was crane launched and fixed in position by welding. The length of each segment was governed by the logistics such as transportation length and lifting capacities of the available cranes; the heaviest segment was about 27.2 tons. As the pylon was inclined, extensive construction engineering checking and site survey monitoring were utilized to ensure the intended design position was achieved.

4.5.3 Deck

The bridge deck is a twin-cell cast in-situ pre-stressed reinforced concrete box girder with two transverse rib wings spaced at every 5m, and two 1.5m deep edge beams to accommodate the cable stay anchorages. The designer used the state of art finite element tools to carry out the structural analysis to understand the actual distribution of loads and the behavior of the bridge. Criteria for designing the deck was based more on cost and constructability factors rather than aesthetics. The deck possesses a streamlined profile with sharp edges that help it to dampen forced oscillations caused by vortex shedding. Post-tensioning tendons are placed within hollow sections in the spine beam, forming a self-supporting structure after stress is applied. Heavy-duty pipe sleeves for the electrical supply cables are also placed in the spine beam.

Source: Putrajaya Bridge Construction Team 2(005)

Figure 33: Typical Deck Cross-Section

4.5.4 Stay Cables

There are thirty pairs of front stays and twenty one pairs of back stays. All of the front stays supporting the main span are arranged in a fan shape (Refer Appendix B11). Each of the front stay cables consists of 15.7mm-nominal-diameter strands ranging from 13 to 68 numbers (Refer Appendix B12). All of the front stays have anchored within the hollow pylon and were stressed from the lower adjustable anchors which located in the concrete beams at the bridge deck.

The arrangement of the twenty one pairs back stays has a crisscross pattern, where the stay anchored at the highest point of the pylon is anchored at the backstay anchorage point nearest to the pylon creating a cross-over effect from side elevation view. Each of the back stay cables consists of 15.7mmnorminal-diameter strands ranging from 45 to 125 numbers (Refer to Appendix-B10).

The stay cables are a bundle of parallel, individually was composed of seven galvanized wires. Each strand is galvanized with extruded PE coating and wax filled in between the wire voids. Then, the whole bundle of strand is inserted into a 6 to 10mm thick HDPE pipe which serves as sheathing for strands (Refer Appendix B12). Specially designed helical fins welded to outer surface on HDPE pipe is used to reduce the possible wind-rain vibration of stays. The Seri Wawasan Bridge is the first bridge in Malaysia to implement the world's latest stayed-cable technology. Two full scale fatigue test were carried on the stay system, where the stay cable was subjected to two million cycles of fatigue loading ascertain the high quality of the system. The arrangement of stays at the pylon head has improved the efficiency in reducing the torsional deformations of the pylon under unbalanced loads such as traffic and wind loads.

Source: Putrajaya Bridge Construction Team (2005)

Figure 34: Threading of the Cable Stay Strands inside the HDPE Tubes.

4.5 Conclusion

Seri Wawasan Bridge is an asymmetric cable-stayed box girder bridge with an inclined concrete pylon 96m height. The overall length of the bridge between two abutments is 240m. The design of this bridge is more emphasizes on the aesthetic of the structure and its relationship with the morphology of its surroundings.

The main span of this bridge is supported by thirty pairs of front stays, and then balanced by twenty one pairs of back stays. The cable stays are arranged in an asymmetric design where the back stays are arranged in criss-cross pattern. The stays anchored at the highest point of the pylon are anchored at the backstay anchorage point nearest to the pylon creating a cross-over effect from side elevation view.

The inverted 'Y' shape pylon was designed to limit the second order-effects of forces and increase the structural capacities at the lower part to overcome the axial loads and moments. The top section of the pylon is a hollow core structure formed by high strength G50B steel plates and in-filled in concrete. The combination of steel/concrete design technology is adopted to provide direct transfer mechanism of stay forces from front to back adequately. The central void in the pylon head provides access for future maintenance inspection of stay anchorage in the pylon head.

CHAPTER 5: CONSTRUCTION METHOD

5.0 Introduction

Cable-stayed bridge is considered as big turning point in bridge construction industry, because of the simplicity in the bridge erection. There is a wide range of erection techniques available to construct the cable-stayed bridge. The conventional method (construction on temporary support or scaffoldings) is used to erecting the Seri Wawasan Bridge in Putrajaya. There are some other methods which are considerable and applicable to construct this bridge are discussed in section 5.3.

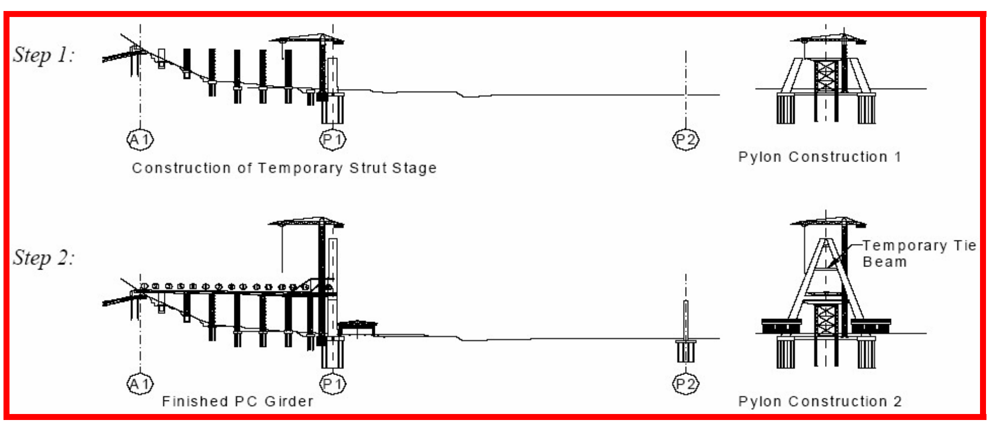
5.1 Construction on Temporary Support Method

Construction on temporary support method is very rarely used in now days. This is the most traditional method is extremely simple; either in term of erection or structural analyzing where no geometry drawback are present. Nevertheless this method is not the preferable method to be used in cable-stayed bridge construction. The main reason is the cost of the temporary supports such as the scaffoldings and falseworks that are used as the temporary prop, and then the location for the supports must be clear and stable. Anyway this is the method used in constructing Seri Wawasan Bridge. All of the concrete segments are cast in situ and not pre-fabricated in plants.

Since Seri Wawasan Bridge is build to span over a man-made lake where the bridge was erected before the lake even existed. There is no obstruction during the construction process as the bridge is approximately 10m from the ground during construction. Therefore, temporary support method is the most suitable and economic construction method. The temporary tower can be easily assemble and dismantled. Beside that, the scaffoldings also can be used in other construction works. Whilst, cast in situ offer less tensile strength during construction; the deck is very flexible as it is more frequently used in construction.

In temporary support method, the superstructure can be cast-in-situ concrete or prefabricated elements. As its name implies, the superstructure is erect by section on the temporary supports. Usually, temporary supports are placed between piers and abutments. Before the temporary supports removed, the particular deck will be anchored with cable stays. The temporary support will be shifted and used for the following segments until the final segment reach opposite abutment as shown in Figure 35. The construction process for Seri Wawasan Bridge project will be discussed in following chapter.

One of the disadvantages of this construction method is the time period taken to assemble the temporary support. The temporary supports have to be erected on the temporary foundation manually; therefore the manpower needed in this project will be higher. This method involves a lot falseworks that will obstruct the traffic flow if the bridge is to be constructed over an existing road. The disadvantage of cast in situ is the progress of the construction can be affected by the weather, where casting work cannot be done during rainy season.



Source: Hong, S.M (2000)

Figure 35: Construction on Temporary Support Method Diagram.

5.2 Construction Processes of Seri Wawasan Bridge.

Stage 1:

- Construct pylon's piles and pilecap, and temporary foundation for tower crane. Then, proceed to install tower crane and jump form for pylon casting.
- Proceed piling and pilecap for backstay box, abutments, piers, retaining wall and `T' beams.
- Start fabrication of steel pylon head off-site.

Stage 2:

- Proceed casting of concrete pylon legs by using Jump Form method. Three layers of temporary steel braces were installed between pylon's legs at every 15m height.
- Install temporary foundation (oiling) for shoring or falsework for casting in-situ deck.

Stage 3:

- Proceed casting of concrete pylon and install temporary back stay cables at approximately RL = 50.00m and 65.00m (2nos of 24 x Φ 15.7mm strands on each level).
- Erect falsework for casting of deck between piers and abutments by conventional construction method.
- Install temporary steel falsework and modulus deck formwork for cable stay span.

Stage 4:

- Fixing steel pylon head and place in-fill concrete.
- Cast cable stay deck; carry out transverse rib pre-stressing before removal of formwork and then move forward to the next segment casting.
- Progressively install back stay and front stay cables.
- Proceed longitudinal pre-stressing of deck.
- Carry out stressing work for stay cables as required to engineer approval.
- Remove temporary tower after stressing of stay cables. Adjust cable tensions as required to achieve correct deck alignment.

Stage 5:

- Repeat `Stage 4' to complete the construction of deck structure.
- Final adjustment of cable tension as required achieving correct deck alignment.

Stage 6:

- Construct walkways; erect traffic barriers, placing of wearing surface, cat ladder steel platforms and others to complete the works.
- Final adjustment of cable tensions as required achieving the correct deck alignment.
- Install deck expansion joint at east alignment.

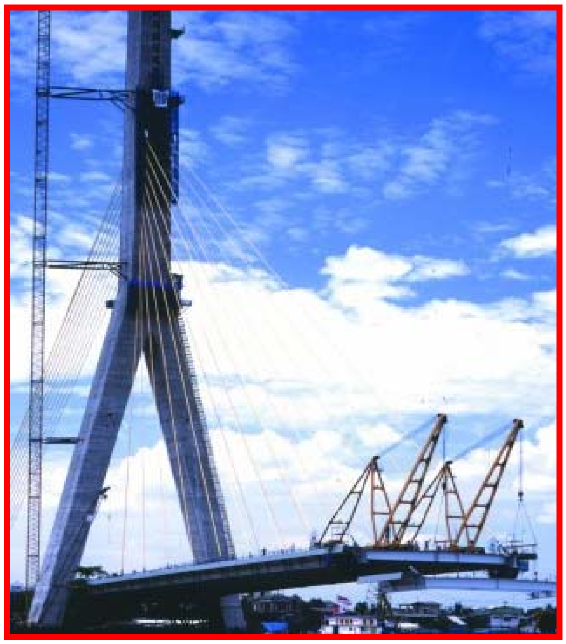
5.3 Optional Construction Method

5.3.1 Progressive Placement Method

Progressive placement method is one of the basic cantilevering methods. Another cantilevering method is balance cantilevering method; this method also known as free cantilevering. Pre-cast segments or cast in situ segment can be used in cantilevering method. In the cantilevering process the segments are arranged in a row and the pre-stressing work will proceed after the arrangement of the pre-cast is done. The pre-stressed cables are anchored to the upper most of the segment in order the withstand the self-weight and also live load during the construction The concrete segments will developed the strength as the ageing of concrete and the curing process takes place. The segments will transfer the loads to each other until the construction of all the segments are in place as a closure to the bridge span. According to Vrlogeux, M. (1991), the important criterions of the cantilever method in bridge construction are:

- The influence of the static configuration
- The reduction of the bending moment during the erection of the concrete bridge
- The construction of composite and steel decks
- The deformation of the cable tension and the geometric control

Balanced cantilever method is not suggested as optional method because this method is unsuitable for Seri Wawasan Bridge. Seri Wawasan Bridge is a single supported bridge, where the inclined pylon is located at one side of the abutment; balanced cantilevering method is a two-direction process method. In this method, the superstructures are erected symmetrically from both side of the tower and advanced to the mid span or to an abutment. Progressive placement method can be carried out either by pre-cast or cast-in-situ. Compare to balanced cantilevering, this method is more suitable for constructing a single support cable-stayed bridge like Seri Wawasan Bridge. This progressive method is one-directional process, where the segments are subsequently erected from a pier to another pier or to opposite abutment. Every new segment is erect at the pit of a successive cantilever for the whole bridge. Since the length of cantilever (single span) related to the construction depth, a moveable temporary stay arrangement is used during construction to reduce the cantilever stress. Usually the cable stays are anchored at a temporary tower to support those complete segments. This support mechanism will be advanced against the extension of the cantilever. Rama VIII Bridge in Thailand is a good example for constructing cable-stayed bridges by using progressive cantilevering method (Figure 36).



Source: Heidengren, C.R. (2003)

Figure 36: Rama VIII Bridge, Thailand

As one of the basic cantilevering methods, the most important and biggest contribution of this method is no falseworks are required to advance the superstructure. Falseworks may be only used to construct the segments near to the abutment, abutments or pier. Since this method is one-directional process, it is easier to control compare to balanced cantilevering method. The progress of erection does not have to switch side and the erection method is not complicated as balanced cantilevering. With the good placement location offered by this progressive method, horizontal curves can be carried out easily. (Mathivat, J.

1983) If compare this progressive placement method with incremental launching and balanced cantilever method, no horizontal force and unbalanced bending moment is catered by the piers. There are only simple flow of force exist between the superstructure and piers, this is the reason why permanent bearing can be immediately installed. (Mathivat, J. 1983)

The disadvantage of progressive placement method is the design of this method is complicated and only can carry out by specialized consultant. Although the erection method of progressive placement method is more simplified than balanced cantilevering method, but any how the construction process of this method is slower. Therefore, this progressive method will be uneconomical for medium span cable-stayed bridge. The erection of the first span always be the hardest part and time consuming, therefore this method may be replace by other method during this starting stage.

5.3.2 Incremental Launching

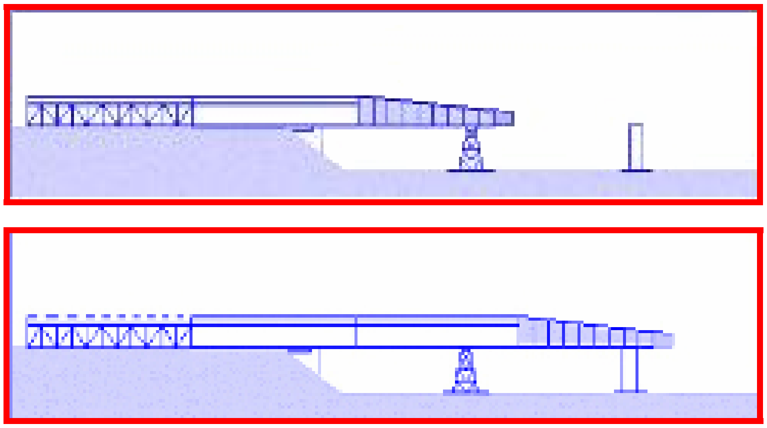
The incremental launching method is one of the most suitable methods for constructing multi-span bridge, especially in situations where temporary supports are infeasible. The method is considered a highly mechanized one. Bridge superstructure is advanced section by section, with each segment being cast at one of the abutments and then launched. Each new section is pushed forward by hydraulic jacks along the bridge axis. A typical section may have spans between 15m to 30m (Liebenberg, A.C 1992), and can be completed in roughly 7 days. Sections are cast continuously, one after the other, and tied together with post-tensioning cables. A finished section is pushed over temporary bearings placed on the piers. The constant of the section is very particular in this construction method. The hydraulic jack devices located at the abutment are able to act horizontally and vertically. With this device, to erect a bridge curve in both horizontally and vertically is possible for this launching method. With a condition where the superstructure must has a spatial curve of constant radius through out the length.

In this launching method, bridge sections are subject to moment reversals from casting to launching to placement in their final positions. The maximum negative moment occurs when a suspended section is pushed to a position immediately before it reaches the next pier support. In order to reduce the cantilevering bending moment of the superstructure, a lightweight launching nose is applied during the launching process. Launching nose is a light weight metal and it is attached at the front of the first segment. It will be dismantled, once the superstructure has reached the opposite abutment. According to Tse, J.K. (2004), the length of the launching nose is about 65% of the bridge span. Besides using launching nose, there is another method can be used to control the bending moment of the launching superstructure. This optional method is involves a system of stay cables and tower. The temporary towers are mounted between the bridge piers and abutments to support the launching superstructure and reduce the negative moment (Figure 37). To easier the advancing process, a temporary sliding bearings are installed at the abutment, top of the piers and temporary tower as well. Before the temporary tower is dismantled, those temporary sliding bearings will be replaced with the permanent bearing. The temporary stay cables used in this supporting system are post-tensioning tendons. Usually these temporary tendons are designed to be placed at the centric of the bridge cross section. The temporary tendons provide compression along the top and bottom fibers of the section.

Since the superstructure's sections are fabricated at one of the abutments, it means incremental launching method combines the advantages of pre-cast and cast-in-situ. The transportation distance is very short, no worry about late delivery of the segments; the contractor can control the casting; the progress is independent of the weather. If launching nose is applied in incremental launching, this method will offer the advantage like any cantilevering methods where it is independent from the problems of using falseworks. The bridge can be erected with leave the site underneath clear without any obstruction. With widely use of mechanization, this method offer high rate progress can be attained. Additionally, the different operations can go on simultaneously and independently in a cyclical fashion, so that high quality work and output rates are achieved.

There is no perfect method in this world; every construction method has their strong point and weak point. The disadvantages of incremental launching are:

- Sufficient area is needed at the abutment for fabricating segments and storage purposes.
- Big investment for the mechanization such as hydraulic jack, launching nose, etc.
- The construction method is complicated in respect of shuttering and support, and not suitable for twin-cell box girder.
- The sections undergo stress reversal.



Source: Tse, J.K. (2004)

Figure 37: Incremental Launching Diagram

5.4 Methods of Pre-stressing

Concrete has been widely used in now days, because it is greatly strong, economic, and the most important is it can be mold into any shape. Its major disadvantage is that it is weak in tension, possessing a tensile strength which is roughly one tenth of its compressive strength. As a solution for this weakness, steel reinforcement is added to resist tensile forces. Generally, there are three methods to introduce steel into concrete – reinforcing, pre-tensioning and post-tensioning. Only pre-tensioning and post-tensioning will be discussed in the following chapter. The biggest different between these two methods are whether pre-stress tendons are tensioned before or after the concrete is hardening.

5.4.1 Pre-Tensioning

In pre-tensioning, the tendons are stressed against external reactions before the concrete is poured. In the most common cases, high strength strands are stretched between two abutments and jacked to 70 to 80% of their ultimate strength (Gerwick, B.C. 1993), and then the concrete is poured within forms around the tendons. That particular concrete segment will be left for hardening; the tendons will be release when the concrete is set and gain a substantial portion of its ultimate strength. Usually, the cure of the concrete is accelerated by low pressure steam curing. Once the strands are cut, the stress will transfer into the concrete by bond (Chudley, R. 1987).The high stretched wires shorten slightly, pre-compressing and shortening the concrete.

Pre-tensioning is widely used in now days, this method is very commonly applied for fabricate pre-cast concrete elements in factories or casting yard. Typical products produced are roof slab, floor slabs, wall panels, piles, railroad ties and box girder. Pre-tensioning is rarely applied for cast-in-situ concrete segments, except the segments are huge and cannot be traveled by transportation.

During the fabrication, the pre-tensioned concrete segments will not shortening immediately once the tendons are released. Longitudinal shortening of the segments may be prevented by the concrete frictional weight or restrained by formworks. The segments will only shortening when they are lifted. Not shortening means the segments are not yet resist by the pre-stress. During this period, some defects may occur to the segments such as shrinkage, thermal cracking, etc. There are two ways of pre-tensioning: long line method and individual mould method. Long line method means the tendons are stretched between abutments and anchored at the abutment, and then followed by mould erection and concreting. According to Ir. Chin Mee Poon (2000), the managing director of Prestasi Concrete Sdn. Bhd., the range of the segment length is around 100 to 150 meters. In the individual mould method, the tendons are tensioned and anchored at the ends of each mould, which must be sufficiently stiff to sustain the pre-stressing force and which can be handled separately in each stage of manufacture.

For most cases of pre-tensioned concrete, a relatively long transfer length is desirable. Short transfer lengths cause high transverse tensile stresses in the end block and may cause cracking between strand groups (e.g., at the end of a girder). Increasing the transfer length reduces the magnitude of these internal stresses. To achieve this, the ends of tendons may be sheathed in plastic or coated with grease. Exceptions where short transfer lengths are desirable also exist, such as when high moments must be resisted a short distance from the end (e.g., cantilevered beams, railroad ties and columns at rigid connections).

5.4.2 Post-Tensioning

In pre-tensioning, the pre-stressing tendons are stressed and anchored against hardener concrete. This type of reinforcing method requires specialized knowledge and expertise in fabrication, assemble and installation. For most cases of post-tensioning structural, thin-walled steel sheaths are used to form ducts in the concrete body. The ducts accommodate the post-tensioned tendons and provide an annular space for grout. The tendons will be inserted and stressed in the duct by jacking, when the concrete is set and gain a substantial portion of its ultimate strength. Wedges, small conically shaped steel components, are placed to grip the strands so that loads are transferred from the jack to the anchorages. The duct is then filled with cement grout or other substance designed to prevent corrosion of the tendons and also bonding the tendons to the duct. (Post Tensioning Institute, 2000)

It is possible to insert the tendons into the ducts before casting, and it is normally used in certain cases. Accidental leakage of grout into the duct is one of the hazards which would delay the later tensioning, and in some cases it also increases the exposure to corrosion. Tendons that are post-tensioned, will be preencased in plastic sheaths together with the lubricant, and installed before concreting. The tendons are stressed after the concrete is hardened.

Post Tensioning is an optional method that are used when the members that are produce is huge and lengthy. Transporting these types of structures to the construction site is usually the main problems that will be considered when using post-tensioning methods. In this method it is normally more expensive than pre-tensioning as the products manufactured in the plant are usually better quality. Therefore post-tensioning is normally used joint the pre-cast segments. This is the common methods that are used to hold the pre-cast and post-tensioning members to form a self supporting superstructure. In this case accuracy and precision is mainly the main criterion that will be focused during the installation and concrete casting.

In post-tensioning method there are two common methods that are used such as bonded and unbonded. In bonded system that is normally two or more strands that are inserted into the metal or plastic duct the will be embedded in concrete. In unbonded system, the pre-stressed steel is actually not in contact with concrete except for the anchorage only (Post Tensioning Institute, 2000). The main advantage of the unbonded system is the easy accessibility for maintenance purposes but one the other hand the tendons are exposed to corrosion due to weathering after some time. Therefore in Seri Wawasan Bridge construction the bonded system is used as corrosion is one of the main problems that will affect the bridge integrity as Malaysia is one of the countries in South East Asia region that have highest rainfall annually is about 300 to 600mm/h (Malaysian Meteorological Department, 2005)

5.5 Material Used In Pre-stressing

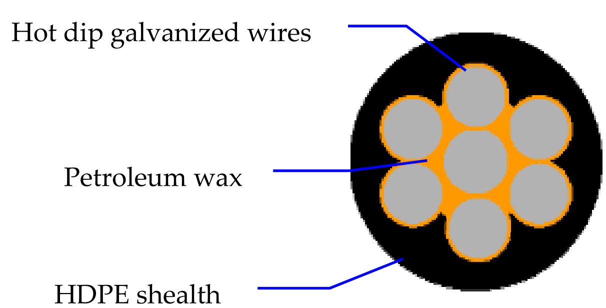
Pre-stressing requires adequate transfer length to transfer the stress from the tendon to concrete. Tendons for pre-stressing are therefore, designed to make the transfer in as short distance as possible. Slightly rusted wire or strand has several times better bond than bright wire; however, the degree of rust is difficult to control and the dangers of pitting corrosion generally rule against intentional rusting. Current best practice requires that the strand be in covered, protected storage until not more than 24 hours prior to concreting. Three types of tendons are normally used in pre-stressing, viz. wire, strands and bars. (Chin, M.P. 2000)

5.5.1 Pre-stressing strand

The most commonly used pre-stressing tendons in Malaysia are 12.7mm diameter pre-stressing strands of Grade 270 to ASTM A416-80. The strand is made up of six wires wound spirally round a central smaller, straight wire. The minimum-breaking load of the 12.7mm diameter strand is 183.7kN. The strand has a nominal steel area of 98.71mm^2. Hence the ultimate tensile stress of the strand is 1.86kN/mm^2, which translates to about 270,000 psi or 270 ksi. This is the meaning of the term "grade 270". (Chin, M.P. 2000)

The pre-stressing strands used in Seri Wawasan Bridge are 15.7mm nominal diameter Fressynet monostrands. The strand is made up of seven hot dip galvanized wires and arranged in parallel configuration. The strand is coated with a high-density polyethylene (HDPE) sheath and the voids are filled with petroleum wax (Figure 38). The HDPE sheath not only acts as a casing for the strand but it also protects the wires from corrosion. Meanwhile, the amount of wax is controlled so as to prevent the sheath from sliding on the strand under thermal variations and protect the HDPE from micro-cracking (Lecinq, B and Stubler, J. 2005). The design properties of 15.7mm nominal diameter Freyssinet monostrand are specified by the French standard NFA 35-035 and described below:

- The ultimate strength of the strand is 1860 kN/ mm^2 and the maximum load that can be carried is 279kN;
- Strain under maximum load A_{gt} at least 3.5%;
- Modulus of elasticity of the bundle of parallel strands: 195 000 N/mm^2;
- The nominal cross section of the steel is 150 mm^2;
- The coating is applied on the wires before stranding; the protective zinc costing is between 190 and 350g/m^2;
- The relaxation is less than2.5% at 1000 hours at 0.7 F_m (at 20°). When a pre-stressing tendon is under tendons, it wills losses part of the tension over time due to the gradual but permanent elongation of the metal. This phenomenon is known as relaxation. The purpose of using very low relaxation strand is to maintain the tension in the strand;
- The fatigue strength is 2 million cycles with maximum stress of 0.45 f_{GUTS} and stress variation of 300N/mm^2.



Source: Lecinq, B. and Stubler, J. (2000)

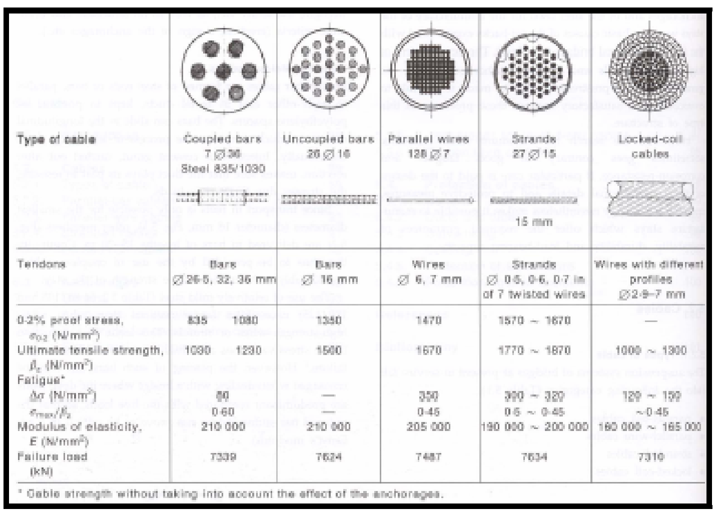
Figure 38: Cross -Section of the Typical Monostrand

5.5.2 Pre-stressing Wire

Pre-stressing wires are normally used for producing small pre-stressed concrete piles, pre-stressed concrete sleepers and for forming the cables in cable-stayed bridges and suspension bridges. Smooth wire is used only in smaller sizes, usually 3 to 5 mm diameter. Above this size, strands of 3, 7, or 19 wires are employed.

5.5.3 Pre-stressing Cables

The term cable is used to denote a group of pre-stressing wires or strands within the same duct and sharing a common anchorage. Generally, there are four types of cables that available and used in cable bridge. They are parallel-bar cables, parallel wire cables, stranded cables and locked-coil cables. Usually, the selection of the cable types will be made depend on the requirement of mechanical properties (e.g., modulus of elasticity, ultimate tensile strength, durability etc), structural and economic criteria. (Walther, R. and Hauriet, B. 1999)



Type of cable	Coupled bars 7 ∅ 36 Steel 835/1030	Uncoupled bars 26 ∅ 16	Parallel wires 128 ∅ 7	Strands 27 ∅ 15 (15 mm)	Locked-coil cables
Tendons	Bars ∅ 26·5, 32, 36 mm	Bars ∅ 16 mm	Wires ∅ 6, 7 mm	Strands ∅ 0·5, 0·6, 0·7 in of 7 twisted wires	Wires with different profiles ∅2·9–7 mm
0·2% proof stress, $\sigma_{0.2}$ (N/mm²)	835 1080	1350	1470	1570 ~ 1670	—
Ultimate tensile strength, β_z (N/mm²)	1030 1230	1500	1670	1770 ~ 1870	1000 ~ 1300
Fatigue*					
$\Delta\sigma$ (N/mm²)	80	—	350	300 ~ 320	120 ~ 150
σ_{max}/β_z	0·60	—	0·45	0·5 ~ 0·45	~0·45
Modulus of elasticity, E (N/mm²)	210 000	210 000	205 000	190 000 ~ 200 000	160 000 ~ 165 000
Failure load (kN)	7339	7624	7487	7634	7310

* Cable strength without taking into account the effect of the anchorages.

Source: Walther, R. and Hauriet, B. (1999)

Figure 39: The Principal Type of Cables and Their Design Properties

The figure above is showing the principal type of cables cross section and their design properties; further descriptions for each type of cables are done as below:

- Parallel-bar cables are stand from a group of steel rods or threaded bars which are arranged in parallel configuration within the metal ducts. Polyethylene spacers are placed within the duct to ensure the bars are in place and parallel to each other. Since the bars are independent, the process of tensioning can be done individually. The tensioning process will be more simplified. The length range of the bar is limited between 15 to 20meters due to transportations consideration. Thus, couplers are provided in most cases to continue the stays as well as to reduce the fatigue strength of the cable.
- Parallel-wire cables are comprise of high-strength drawn wire in a parallel configuration and held in either polyethylene or metal ducts. Once the tendons have been positioned correctly and tensioned, grout is injected to fill the remaining voids in the ducts. Usually cement grout is used for this type of cable.
- Stranded cables are formed from a group of 12.7mm or 17.78mm diameter strands twisted together. Usually each cable is spun from seven strands. The strands are encased in a polyethylene tube; grouting injection will be take place after the erection. Lateral stresses are produced during tensioning; this lateral stress will reduce fatigue resistance of the cables. The cables are more susceptible to corrosion because the surface area of the many individual strands is greater than that of a single circular member. The strands vary widely in quality, because different manufactures use different alloys and treatment methods. Therefore, it is necessary to test the cables in official labs before using the cables.

- Locked-coil cables are also formed from a group of wire with varying cross-section wound around a central core. These cables are easy to erect and comparably economic, because its not consist of ducts and grouting. Since no grout is required, the cables are susceptible to corrosion if the design and manufacture is not treated properly.

5.6 Conclusion

There is a wide range of erection techniques available to construct the cable-stayed bridge. The conventional method (construction on temporary support or scaffoldings) is used to erecting the Seri Wawasan Bridge in Putrajaya. Construction on temporary support method is very rarely used in now days. This method is not the preferable method to be used in cable-stayed bridge construction because investment on temporary supports is considered costly and slow progress. Beside this construction method, there are some other methods applicable to construct Seri Wawasan Bridge. They are such as progressive placement, incremental launching, balanced cantilevering, rotating method, etc. Balanced cantilevering and rotating methods are not discussed in this thesis because these methods are unsuitable and uneconomical for medium span bridge.

CHAPTER 6: PROBLEMS ENCOUNTERED DURING CONSTRUCTION

6.0 Introduction

Like any other type of bridge construction, problems do occur during construction or erection of the cable-stayed segmental box girder bridge. Such problems must be identified during the earlier life of the construction so that appropriate precautionary steps can be taken to overcome the problems. In this section, various problems encountered and possible solution to the problems during the construction or erection of the bridge will be discussed.

6.1 Alignment of Duct Joint Problems.

A pre-cast bridge deck segment to be installed may not fit previous segments exactly. The most common problem is that of duct alignment, where the ducts holding the post-tension tendons do not line up properly, resulting in the tendons not being able to pass through. This may be caused by poor quality control in the casting factory. Duct misalignment is a very serious problem because erection cannot proceed and work progress is delayed.

Possible Solution

According to Mr. Abdul Rahman (Asst. Manager of Bridge & Service, PJH Sdn. Bhd.), duct misalignment problems rarely occur due to the stringent quality control imposed on the casting process. Segments are produced using a 'match casting' process whereby fresh concrete for new segments is against the hardened surface of existing adjacent segments. A bond breaker is then applied to the concrete surface to ensure that the segments would come apart. With this method, the form remains stationary while the segments are moved from the casting position to the match casting position and then to storage.

6.2 Problems in Threading of the Strands into the Duct.

Concrete dropping inside the duct joints during the segment casting process might cause blockage, making the threading of the strands difficult.

<u>Possible Solution</u>

According to Mr. Chang Chee Cheung (Technical Manager, Muhibah Engineering Sdn. Bhd), when this type of problems occur on site, they will first try to insert the tendons into the duct as far as they will go. The blocked segment is marked, hacked open, and cleaned. Openings are then patched using non-shrink grout with chippings to maintain the strength of the segment. Mr. Chang said that this problem typically occurs only in segments where internal post-tensioning is used. For external post-tensioning, this problem does not exist since the ducts are inserted 'in-situ' into the concrete block inside the segment.

6.3 Stability of Pier Segment.

In the balanced cantilever method of erection, a segment is first placed on top of the pier to act as a guide for subsequent segments. The following segments are extended from either side of the pier, a pair at a time so that the structure remains balanced. The placement of the first pier segment is difficult as it might tip over (or become misaligned) as there are no supports or guides.

Possible Solution

In order to hold the pier segment securely in place, temporary stressing is used to fix the pier segment to the pier. The pier segment section is first set on wedges or flat jacks. Bar tendons are then used to stress it vertically against the pier shaft. When a fixed connection is no longer needed, the tendons can be released and the supports removed.

6.4 Problem Due to Segment Stability.

During the assembly process, the segments are lift up to position using either a launching girder or crane. When the segments are in place, temporary support must be provided in order to secure these segments.

Possible Solution

According to Mr. Abdullah Rahman (Asst. Manager of Bridge & Service, PJH Sdn. Bhd.), each newly placed pre-cast segment is fixed to the previous one with temporary post-tensioning bars until the cantilever tendons are installed and stressed. Alternatively, temporary stressing using post-tensioning tendons or bridge strands is also an effective means of temporary support. Tendons have been used inside box girders. Such temporary stressing may also be utilized to pull a segment into its final position or to counter temporary tensile stresses. Pre-stressing bars are well suited to temporary installation, stressing, and later removal for reuse.

6.5 Conclusion

Like in other types of construction, most problems arise due to a lack of quality control and/or incompetent workers. Other problems may also arise depending on the specific method. All problems mentioned above can be overcome by exercising good quality control and the constant monitoring of workmanship.

CHAPTER 7: CONCLUSION

In the hypothesis, it says that the use of cable-stayed bridge construction is new to Malaysia. Due to its lower construction cost and speed of construction, I believe that the construction of cable-stayed bridge will be more popular in Malaysia. From the study and research carried out, Seri Wawasan Bridge is the third cable-stayed bridge build in Malaysia. The first cable-stayed bridge is Penang Bridge which builds in 1980's and it was officially opened for public on September 14, 1985. Penang Bridge not only the first cable-stayed bridge in Malaysia, but also the longest bridge in South East Asia with 13.5km.

Basically there are five bridge types in common use now days. They are Girder Bridge, Arch Bridge, Rigid Frame Bridge, Suspension Bridge and Cable-stayed Bridge. The cable stayed bridge concept was evolved from the idea of supporting a beam by inclined rope or chains hanging from a mast or tower. The first bridge using such idea was built in 1600's where the bridge were wholly made of timber. Because of some failure in structure members due to use low strength material, this type of bridge design was abandoned. The cable stayed bridge revive after 1950, when the first two cable-stayed bridges had proven the idea of supporting a continuous girder by inclined cables is reliable, safe to be used, economical and simple to erect.

On the first sight, suspension bridge may look similar to cable-stayed bridge, where both of them are using cables as part of their structures. Nevertheless, they are very different in principles, and the method of construction. When designing the layout of cable stays, it is important to consider the number of planes, arrangement of the cables and the spacing of the stays. These influence the structures' performance and also the erection method.

Seri Wawasan is a single plane system in which the cables are attached to the both side of the deck. Since the pylon is inclined, using a fan pattern for the front stays is more efficient because of the shallow cable angles.

The construction method used in Seri Wawasan Bridge is temporary support method. This method is not preferable in most of the situation where it required erection of temporary support and it is more time consuming. However this method is used because there is no presence of man-made lake during the construction. The lake was made after the construction of the bridge. Actually there are some other methods that are available to construct cable-stayed bridge, but in the optional construction methods for this thesis is only discussed incremental launching method and progressive placement method. This two methods are considered as the best choice method as economical and commonly used in Malaysia. Since Seri Wawasan Bridge is an asymmetrical single pylon bridge, balanced cantilever method cannot be used.

In the future more focus have to be done mainly on vibration, internal damper and the anchorage of main tendon cables. As final conclusion, the design and construction technologies adopted in this bridge set a good example and standard in forwarding the design and construction of bridges in Malaysia, for both robustness and aesthetic values.

.

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[Assessed on: 3th Dec 2005]

Appendix-A

University of Southern Queensland

Faculty of Engineering and Surveying

ENG 4111/4112 Research Project

Project Specification

FOR:	**LEE CHANG LONG**
TOPIC:	Case Study in Seri Wawasan Bridge in Putra Jaya, Malaysia
SUPERVISOR:	Dr. DAVID ROSS
ENROLEMENT:	ENG 4111 – S1, D, 2005
	ENG 4112 – S2, D, 2005
PROJECT AIM:	To research the construction method and design of cable stay bridge.
PROGRAMME:	**Issue A, 16th March 2005**

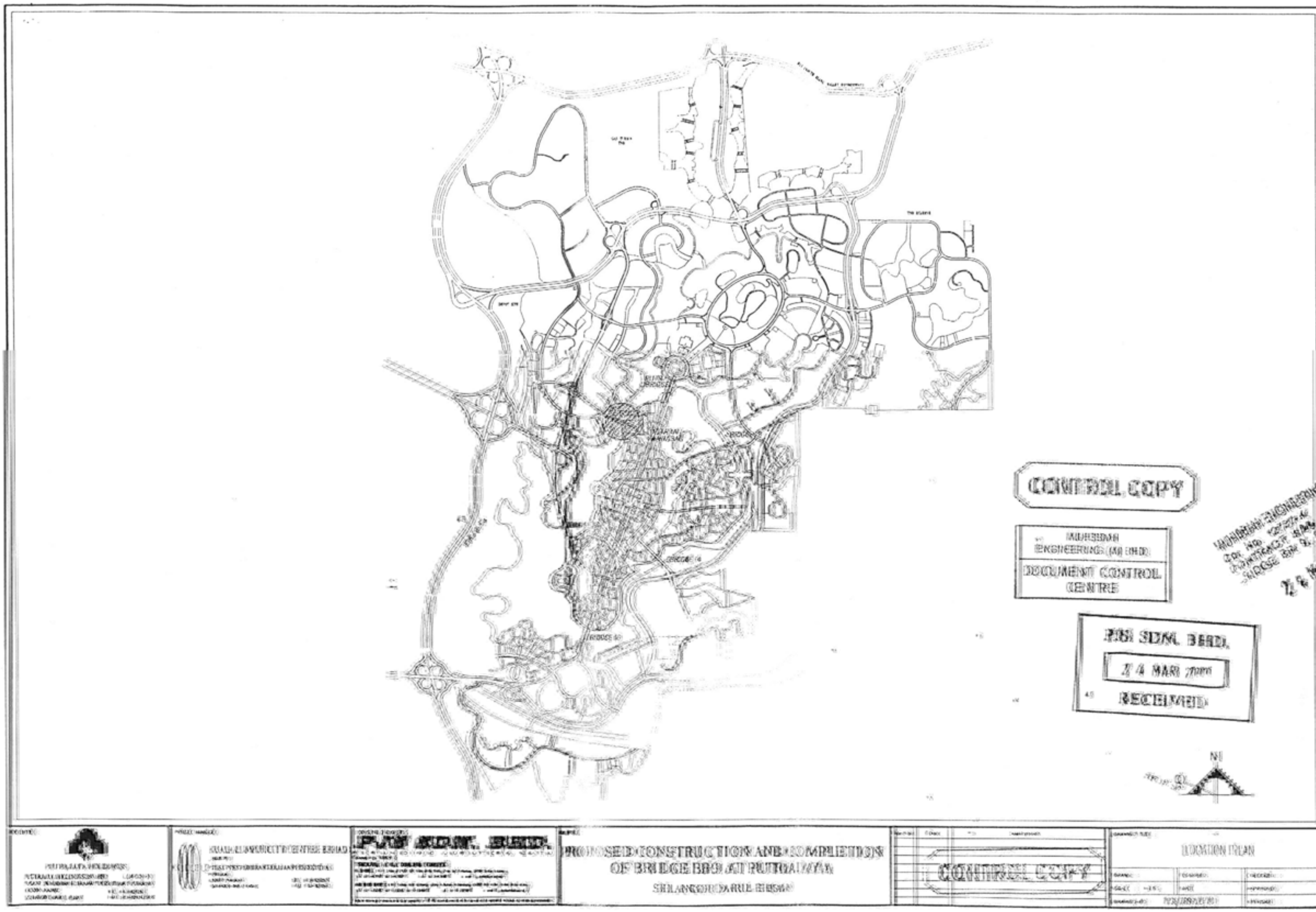
1. Research background information on the Seri Wawasan Bridge.
2. Study the bridge construction method.
3. Study the design of the bridge.
4. Investigate the suitability of the bridge.
5. Recommendation for further improvement.
6. Study the maintenance of the bridge. (As time permits)

AGREED: ___________________ ________________________

(Student) (Supervisor)

(date) ___ / ___ / _____ (date) ___ / ___ / _____

Appendix-B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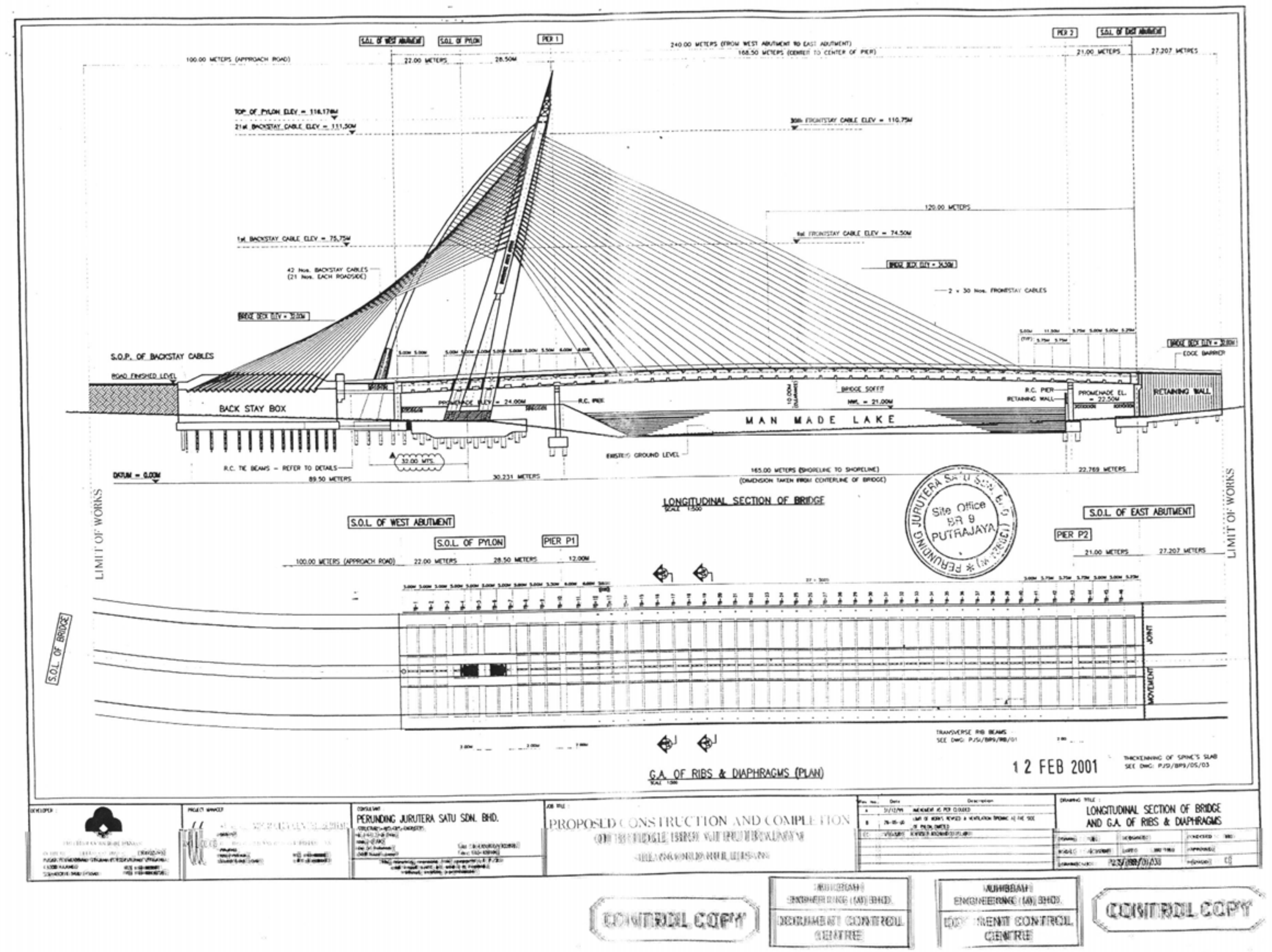
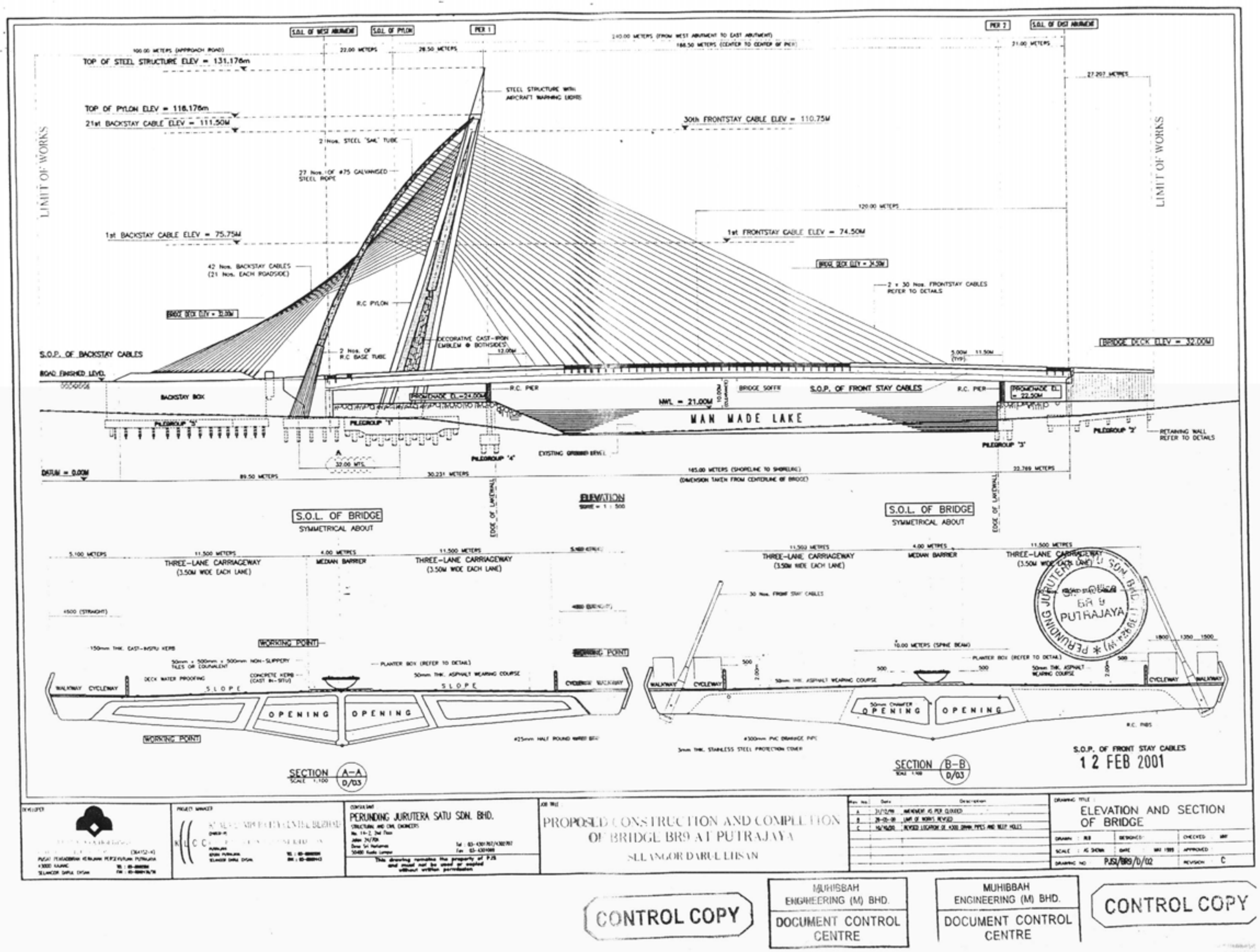
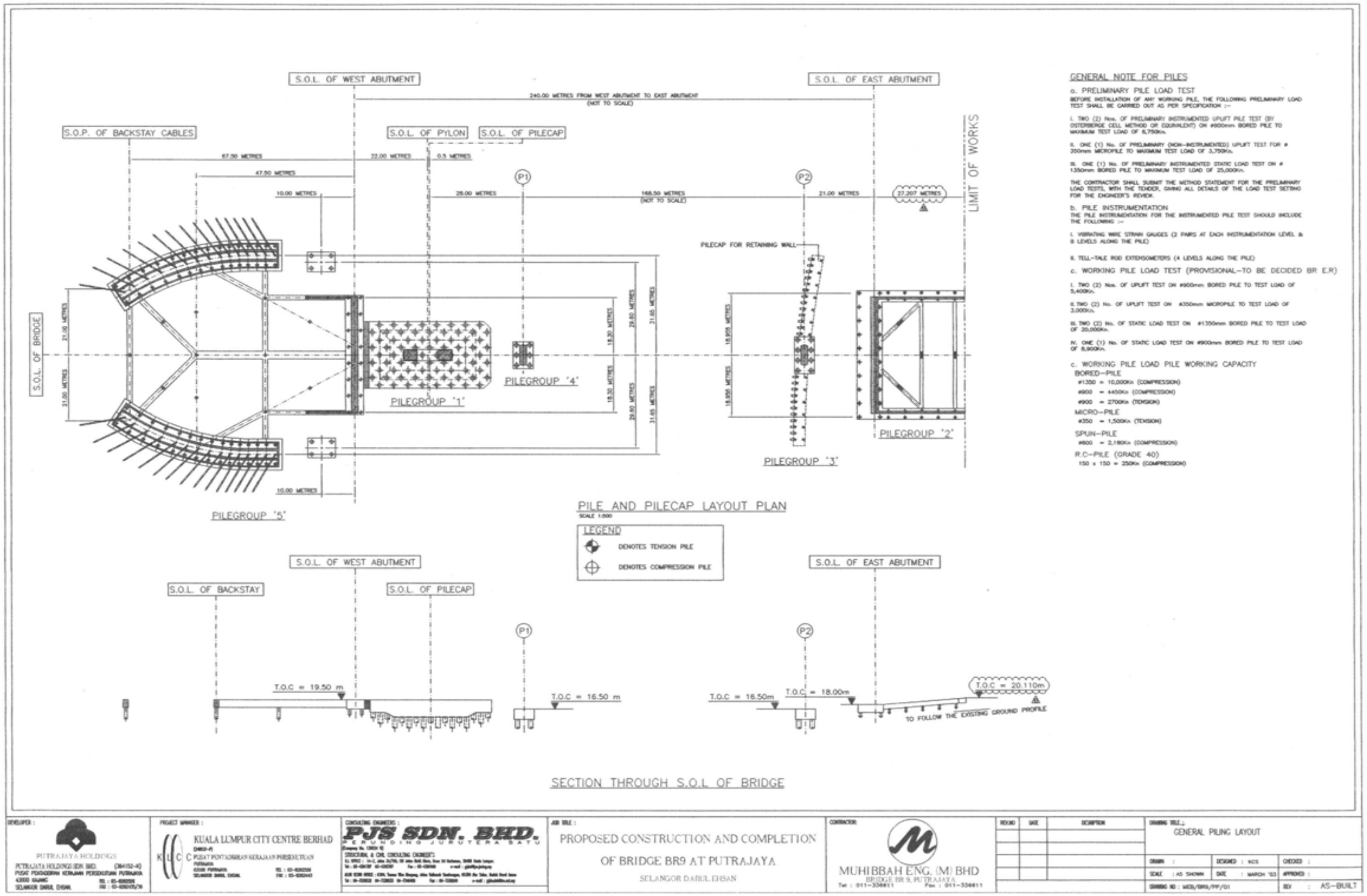
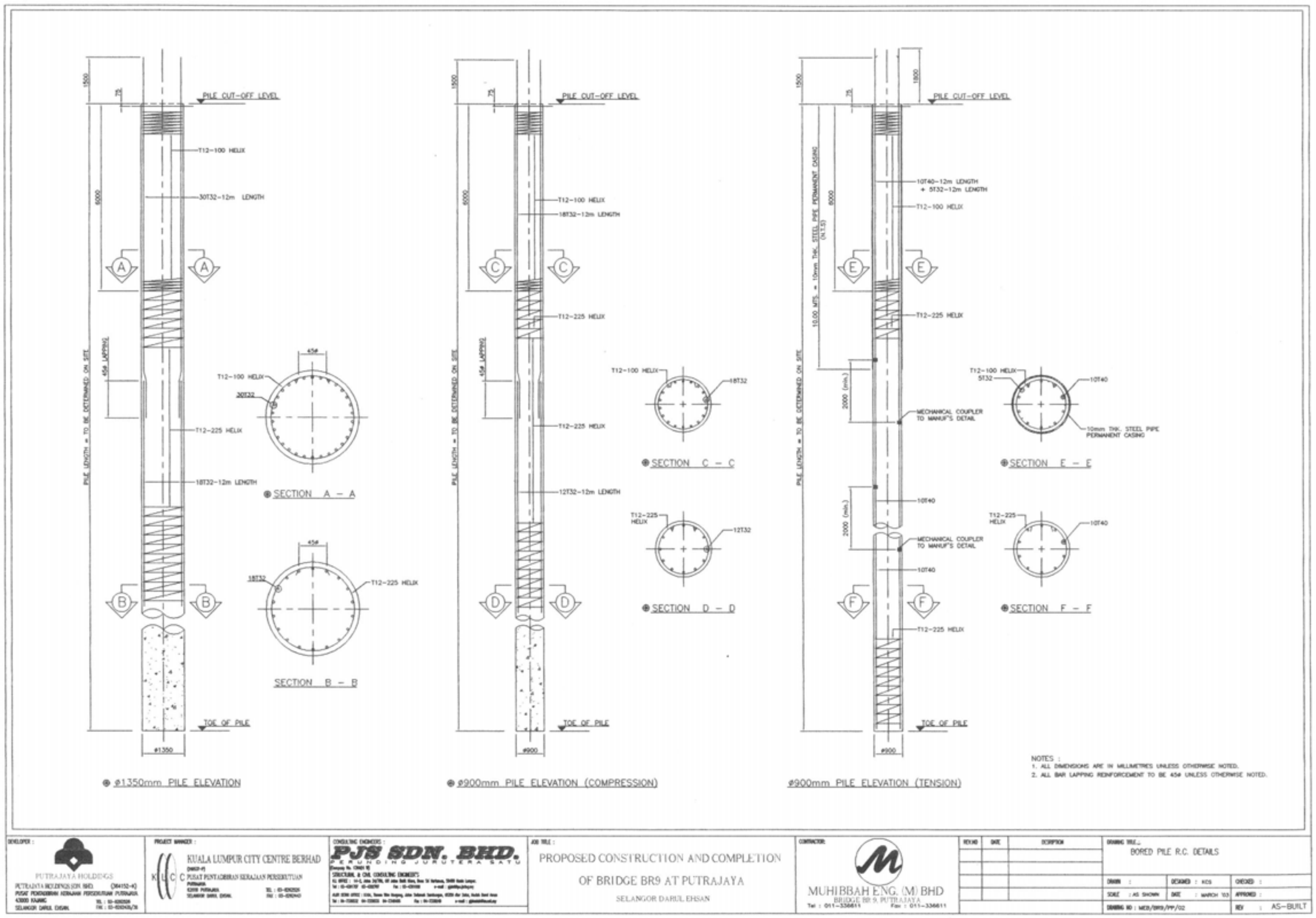
MUHIBBAH ENGINEERING (M) BHD.
DOCUMENT CONTROL CENTRE
PSI SDN. BHD.
24 MAR 2000
RECEIVED
24 MAR 2001
N
PUTRAJAYA HOLDINGS
PJS SDN. BHD.
PROPOSED CONSTRUCTION AND COMPLETION OF BRIDGE BB0 AT PUTRAJAYA
SELANGOR DARUL EHSAN
CONTROL COPY
LOCATION PLAN

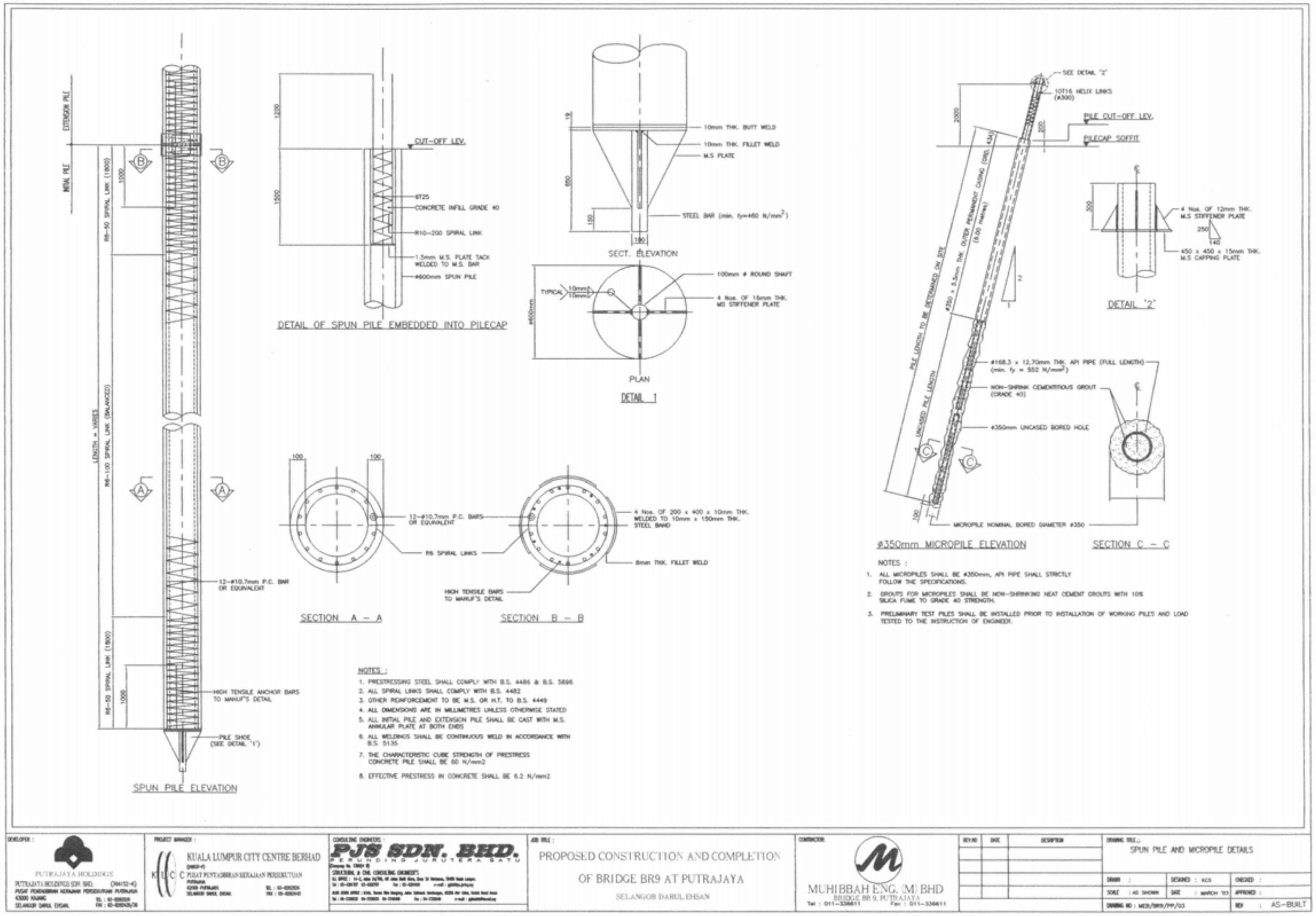


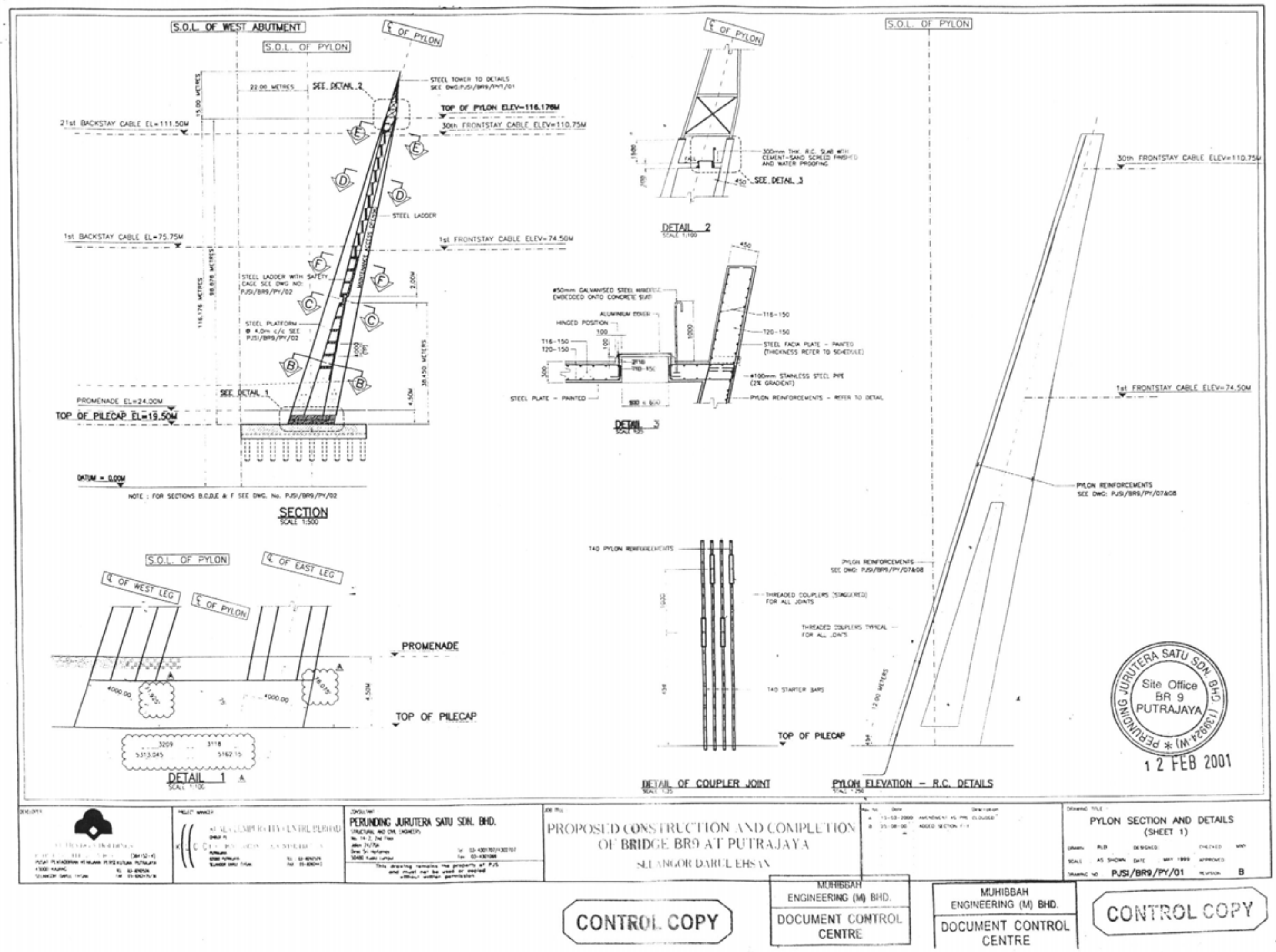
LONGITUDINAL SECTION OF BRIDGE
G.A. OF RIBS & DIAPHRAGMS (PLAN)
MAN MADE LAKE
BACK STAY BOX
RETAINING WALL
S.O.L. OF WEST ABUTMENT
S.O.L. OF PYLON
PIER P1
PIER P2
S.O.L. OF EAST ABUTMENT
S.O.L. OF BRIDGE
LIMIT OF WORKS
Site Office
BR 9
PUTRAJAYA
12 FEB 2001
PERUNDING JURUTERA SATU SDN. BHD.
PROPOSED CONSTRUCTION AND COMPLETION
LONGITUDINAL SECTION OF BRIDGE AND G.A. OF RIBS & DIAPHRAGMS
CONTROL COPY
ENGINEERING (M) BHD.
DOCUMENT CONTROL CENTRE


S.O.L. OF WEST ABUTMENT
S.O.L. OF PYLON
PIER 1
PIER 2
S.O.L. OF EAST ABUTMENT
TOP OF STEEL STRUCTURE ELEV = 131.176m
TOP OF PYLON ELEV = 118.176m
21st BACKSTAY CABLE ELEV = 111.50M
30th FRONTSTAY CABLE ELEV = 110.75M
1st BACKSTAY CABLE ELEV = 75.75M
1st FRONTSTAY CABLE ELEV = 74.50M
LIMIT OF WORKS
LIMIT OF WORKS
S.O.P. OF BACKSTAY CABLES
BACKSTAY BOX
R.C PYLON
R.C. PIER
MAN MADE LAKE
NWL = 21.00M
S.O.P. OF FRONT STAY CABLES
BRIDGE DECK ELEV = 32.00M
DATUM = 0.00M
ELEVATION
S.O.L. OF BRIDGE
SYMMETRICAL ABOUT
S.O.L. OF BRIDGE
SYMMETRICAL ABOUT
THREE-LANE CARRIAGEWAY
(3.50M WIDE EACH LANE)
MEDIAN BARRIER
THREE-LANE CARRIAGEWAY
(3.50M WIDE EACH LANE)
THREE-LANE CARRIAGEWAY
(3.50M WIDE EACH LANE)
MEDIAN BARRIER
THREE-LANE CARRIAGEWAY
(3.50M WIDE EACH LANE)
WORKING POINT
WORKING POINT
WORKING POINT
OPENING
OPENING
OPENING
OPENING
WALKWAY
CYCLEWAY
SLOPE
SLOPE
CYCLEWAY
WALKWAY
SECTION A-A
D/03
SECTION B-B
D/03
S.O.P. OF FRONT STAY CABLES
12 FEB 2001
PUTRAJAYA
PERUNDING JURUTERA SATU SDN. BHD.
PROPOSED CONSTRUCTION AND COMPLETION
OF BRIDGE BR9 AT PUTRAJAYA
SELANGOR DARUL EHSAN
ELEVATION AND SECTION
OF BRIDGE
CONTROL COPY
MUHIBBAH
ENGINEERING (M) BHD.
DOCUMENT CONTROL
CENTRE
MUHIBBAH
ENGINEERING (M) BHD.
DOCUMENT CONTROL
CENTRE
CONTROL COPY

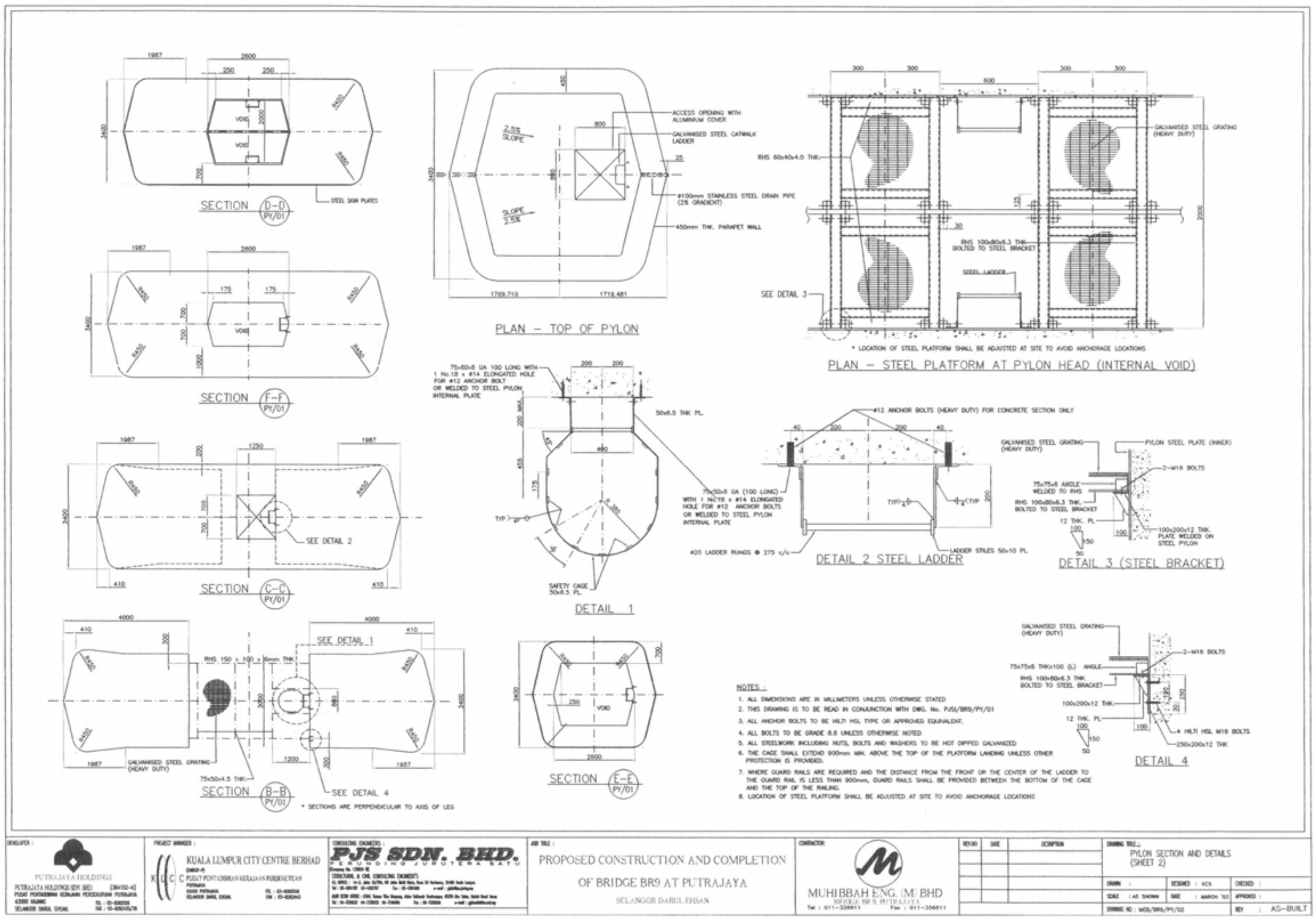

S.O.L. OF WEST ABUTMENT
S.O.L. OF EAST ABUTMENT
240.00 METRES FROM WEST ABUTMENT TO EAST ABUTMENT (NOT TO SCALE)
S.O.P. OF BACKSTAY CABLES
S.O.L. OF PYLON
S.O.L. OF PILECAP
LIMIT OF WORKS
S.O.L. OF BRIDGE
PILECAP FOR RETAINING WALL
PILEGROUP '1'
PILEGROUP '2'
PILEGROUP '3'
PILEGROUP '4'
PILEGROUP '5'
PILE AND PILECAP LAYOUT PLAN
LEGEND
DENOTES TENSION PILE
DENOTES COMPRESSION PILE
S.O.L. OF BACKSTAY
T.O.C = 19.50 m
T.O.C = 16.50 m
T.O.C = 16.50m
T.O.C = 18.00m
T.O.C = 20.110m
TO FOLLOW THE EXISTING GROUND PROFILE
SECTION THROUGH S.O.L OF BRIDGE
GENERAL NOTE FOR PILES
a. PRELIMINARY PILE LOAD TEST
BEFORE INSTALLATION OF ANY WORKING PILE, THE FOLLOWING PRELIMINARY LOAD TEST SHALL BE CARRIED OUT AS PER SPECIFICATION :-
i. TWO (2) Nos. OF PRELIMINARY INSTRUMENTED UPLIFT PILE TEST (BY OSTERBERGE CELL METHOD OR EQUIVALENT) ON #900mm BORED PILE TO MAXIMUM TEST LOAD OF 8,750Kn.
ii. ONE (1) No. OF PRELIMINARY (NON-INSTRUMENTED) UPLIFT TEST FOR # 350mm MICROPILE TO MAXIMUM TEST LOAD OF 3,750Kn.
iii. ONE (1) No. OF PRELIMINARY INSTRUMENTED STATIC LOAD TEST ON # 1350mm BORED PILE TO MAXIMUM TEST LOAD OF 25,000Kn.
THE CONTRACTOR SHALL SUBMIT THE METHOD STATEMENT FOR THE PRELIMINARY LOAD TESTS, WITH THE TENDER, GIVING ALL DETAILS OF THE LOAD TEST SETTING FOR THE ENGINEER'S REVIEW.
b. PILE INSTRUMENTATION
THE PILE INSTRUMENTATION FOR THE INSTRUMENTED PILE TEST SHOULD INCLUDE THE FOLLOWING :-
i. VIBRATING WIRE STRAIN GAUGES (2 PAIRS AT EACH INSTRUMENTATION LEVEL & 8 LEVELS ALONG THE PILE)
ii. TELL-TALE ROD EXTENSOMETERS (4 LEVELS ALONG THE PILE)
c. WORKING PILE LOAD TEST (PROVISIONAL-TO BE DECIDED BR E.R)
i. TWO (2) Nos. OF UPLIFT TEST ON #900mm BORED PILE TO TEST LOAD OF 5,400Kn.
ii. TWO (2) No. OF UPLIFT TEST ON #350mm MICROPILE TO TEST LOAD OF 3,000Kn.
iii. TWO (2) No. OF STATIC LOAD TEST ON #1350mm BORED PILE TO TEST LOAD OF 20,000Kn.
iv. ONE (1) No. OF STATIC LOAD TEST ON #900mm BORED PILE TO TEST LOAD OF 8,900Kn.
c. WORKING PILE LOAD PILE WORKING CAPACITY
BORED-PILE
#1350 = 10,000Kn (COMPRESSION)
#900 = 4450Kn (COMPRESSION)
#900 = 2700Kn (TENSION)
MICRO-PILE
#350 = 1,500Kn (TENSION)
SPUN-PILE
#600 = 2,180Kn (COMPRESSION)
R.C-PILE (GRADE 40)
150 x 150 = 250Kn (COMPRESSION)
DEVELOPER :
PUTRAJAYA HOLDINGS
PROJECT MANAGER :
KUALA LUMPUR CITY CENTRE BERHAD
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
CONSULTING ENGINEERS :
PJS SDN. BHD.
PERUNDING JURUTERA SATU
JOB TITLE :
PROPOSED CONSTRUCTION AND COMPLETION
OF BRIDGE BR9 AT PUTRAJAYA
SELANGOR DARUL EHSAN
CONTRACTOR:
MUHIBBAH ENG. (M) BHD
BRIDGE BR 9, PUTRAJAYA
DRAWING TITLE :
GENERAL PILING LAYOUT
SCALE : AS SHOWN
DATE : MARCH '03
REV : AS-BUILT

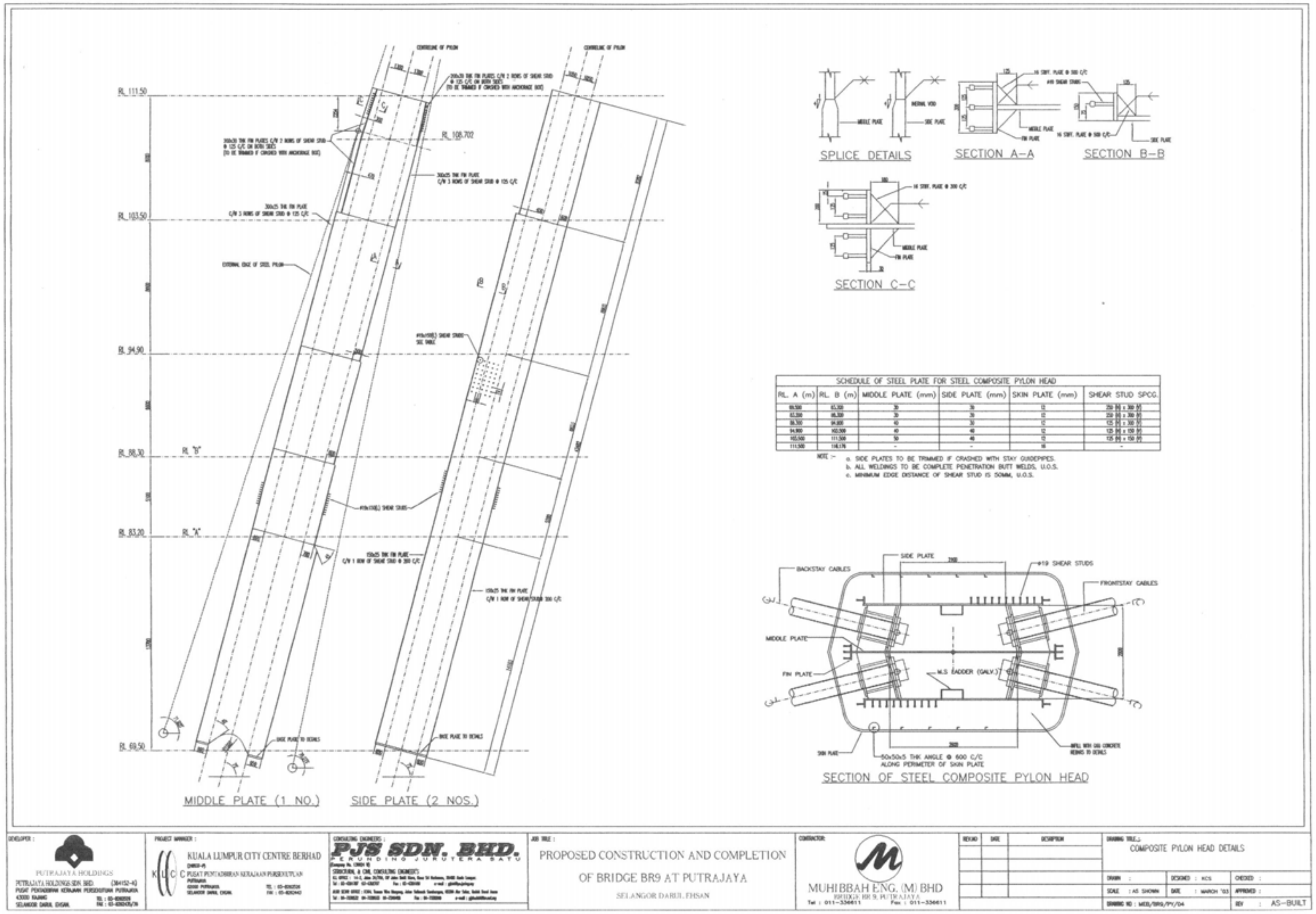

PILE CUT-OFF LEVEL
T12-100 HELIX
30T32-12m LENGTH
T12-225 HELIX
18T32-12m LENGTH
SECTION A – A
SECTION B – B
TOE OF PILE
ø1350mm PILE ELEVATION
18T32-12m LENGTH
12T32-12m LENGTH
SECTION C – C
SECTION D – D
ø900mm PILE ELEVATION (COMPRESSION)
10T40-12m LENGTH
+ 5T32-12m LENGTH
MECHANICAL COUPLER TO MANUF'S DETAIL
10mm THK. STEEL PIPE PERMANENT CASING
SECTION E – E
SECTION F – F
ø900mm PILE ELEVATION (TENSION)
PILE LENGTH = TO BE DETERMINED ON SITE
NOTES :
1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE NOTED.
2. ALL BAR LAPPING REINFORCEMENT TO BE 45ø UNLESS OTHERWISE NOTED.
DEVELOPER :
PUTRAJAYA HOLDINGS
PROJECT MANAGER :
KUALA LUMPUR CITY CENTRE BERHAD
CONSULTING ENGINEERS :
PJS SDN. BHD.
JOB TITLE :
PROPOSED CONSTRUCTION AND COMPLETION
OF BRIDGE BR9 AT PUTRAJAYA
SELANGOR DARUL EHSAN
CONTRACTOR:
MUHIBBAH ENG. (M) BHD
DRAWING TITLE :
BORED PILE R.C. DETAILS
SCALE : AS SHOWN
REV : AS-BUILT

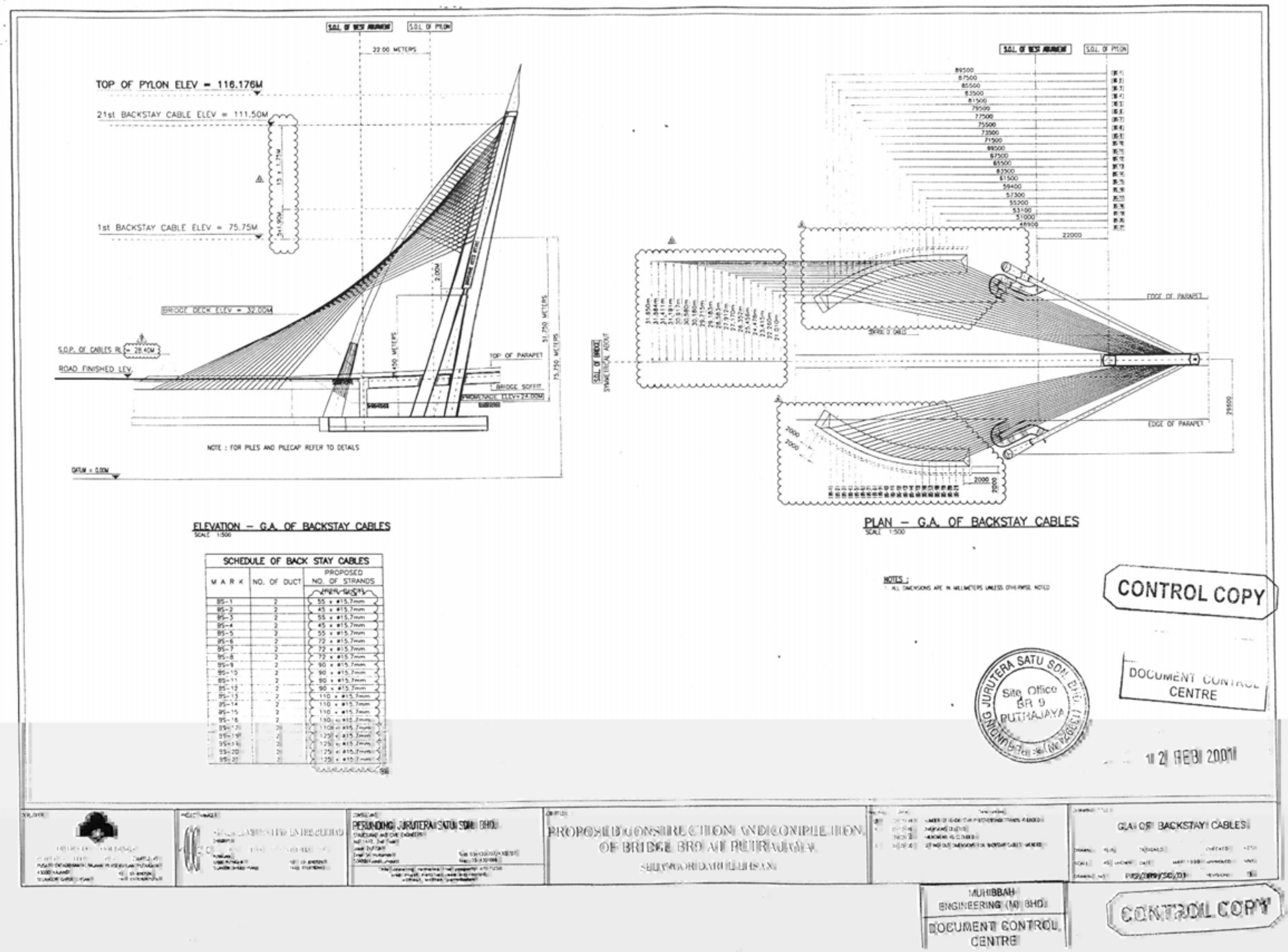

SPUN PILE ELEVATION
DETAIL OF SPUN PILE EMBEDDED INTO PILECAP
CUT-OFF LEV.
6T25
CONCRETE INFILL GRADE 40
R10-200 SPIRAL LINK
1.5mm M.S. PLATE TACK WELDED TO M.S. BAR
ø600mm SPUN PILE
SECT. ELEVATION
10mm THK. BUTT WELD
10mm THK. FILLET WELD
M.S PLATE
STEEL BAR (min. fy=460 N/mm2)
100mm ø ROUND SHAFT
4 Nos. OF 16mm THK. MS STIFFENER PLATE
PLAN
DETAIL 1
12-ø10.7mm P.C. BARS OR EQUIVALENT
R6 SPIRAL LINKS
HIGH TENSILE BARS TO MANUF'S DETAIL
4 Nos. OF 200 x 400 x 10mm THK. WELDED TO 10mm x 150mm THK. STEEL BAND
8mm THK. FILLET WELD
SECTION A - A
SECTION B - B
12-ø10.7mm P.C. BAR OR EQUIVALENT
HIGH TENSILE ANCHOR BARS TO MANUF'S DETAIL
PILE SHOE (SEE DETAIL "1")
NOTES :
1. PRESTRESSING STEEL SHALL COMPLY WITH B.S. 4486 & B.S. 5896
2. ALL SPIRAL LINKS SHALL COMPLY WITH B.S. 4482
3. OTHER REINFORCEMENT TO BE M.S. OR H.T. TO B.S. 4449
4. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED
5. ALL INITIAL PILE AND EXTENSION PILE SHALL BE CAST WITH M.S. ANNULAR PLATE AT BOTH ENDS
6. ALL WELDINGS SHALL BE CONTINUOUS WELD IN ACCORDANCE WITH B.S. 5135
7. THE CHARACTERISTIC CUBE STRENGTH OF PRESTRESS CONCRETE PILE SHALL BE 60 N/mm2
8. EFFECTIVE PRESTRESS IN CONCRETE SHALL BE 6.2 N/mm2
SEE DETAIL "2"
PILE CUT-OFF LEV.
PILECAP SOFFIT
DETAIL '2'
4 Nos. OF 12mm THK. M.S STIFFENER PLATE
450 x 450 x 15mm THK. M.S CAPPING PLATE
ø168.3 x 12.70mm THK. API PIPE (FULL LENGTH) (min. fy = 552 N/mm2)
NON-SHRINK CEMENTITIOUS GROUT (GRADE 40)
ø350mm UNCASED BORED HOLE
MICROPILE NOMINAL BORED DIAMETER ø350
ø350mm MICROPILE ELEVATION
SECTION C - C
NOTES :
1. ALL MICROPILES SHALL BE ø350mm, API PIPE SHALL STRICTLY FOLLOW THE SPECIFICATIONS.
2. GROUTS FOR MICROPILES SHALL BE NON-SHRINKING NEAT CEMENT GROUTS WITH 10% SILICA FUME TO GRADE 40 STRENGTH.
3. PRELIMINARY TEST PILES SHALL BE INSTALLED PRIOR TO INSTALLATION OF WORKING PILES AND LOAD TESTED TO THE INSTRUCTION OF ENGINEER.
DEVELOPER :
PUTRAJAYA HOLDINGS
PROJECT MANAGER :
KUALA LUMPUR CITY CENTRE BERHAD
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
CONSULTING ENGINEERS :
PJS SDN. BHD.
PERUNDING JURUTERA SATU
JOB TITLE :
PROPOSED CONSTRUCTION AND COMPLETION
OF BRIDGE BR9 AT PUTRAJAYA
SELANGOR DARUL EHSAN
CONTRACTOR
MUHIBBAH ENG. (M) BHD
BRIDGE BR 9, PUTRAJAYA
DRAWING TITLE :
SPUN PILE AND MICROPILE DETAILS
AS-BUILT

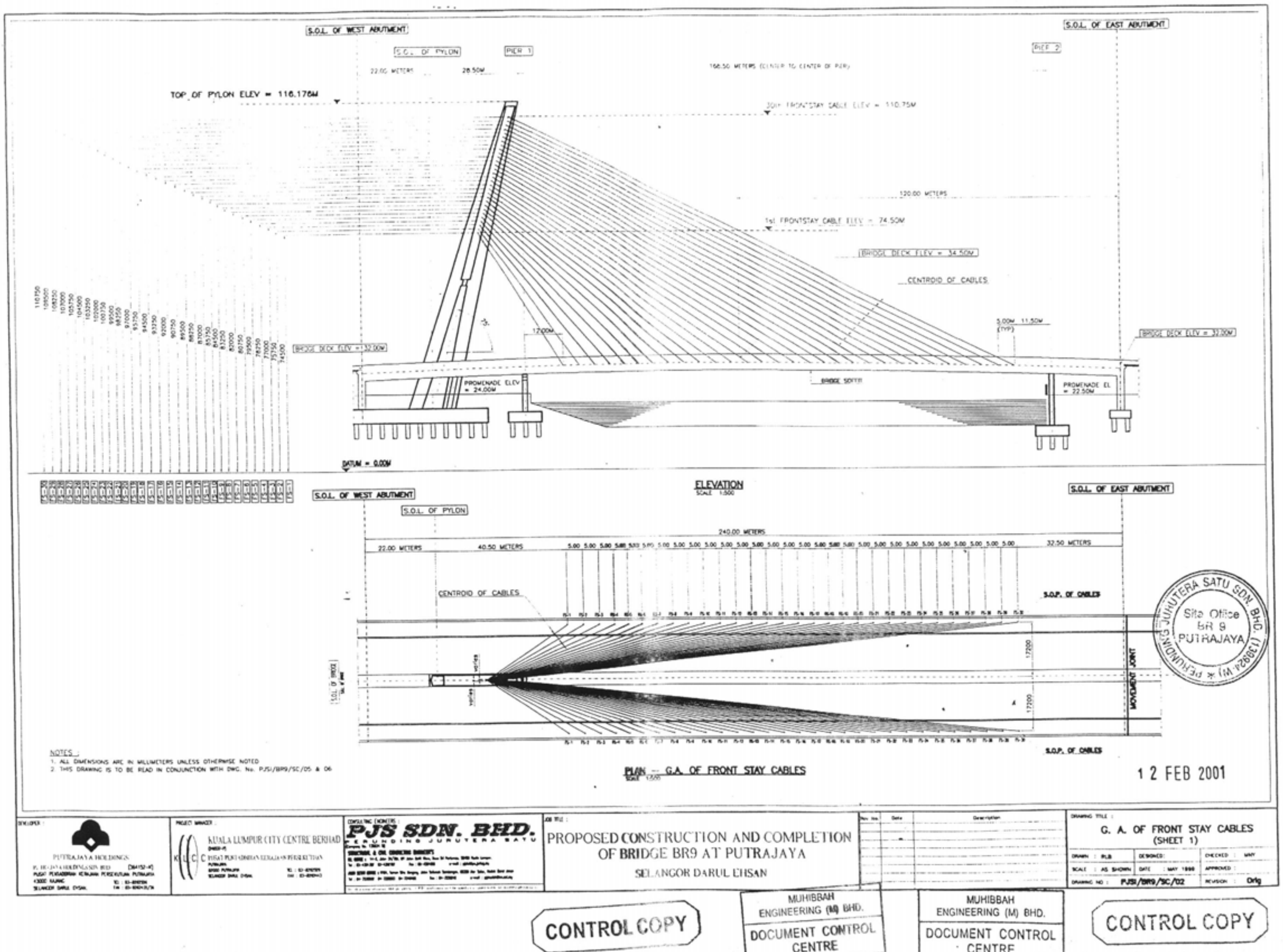


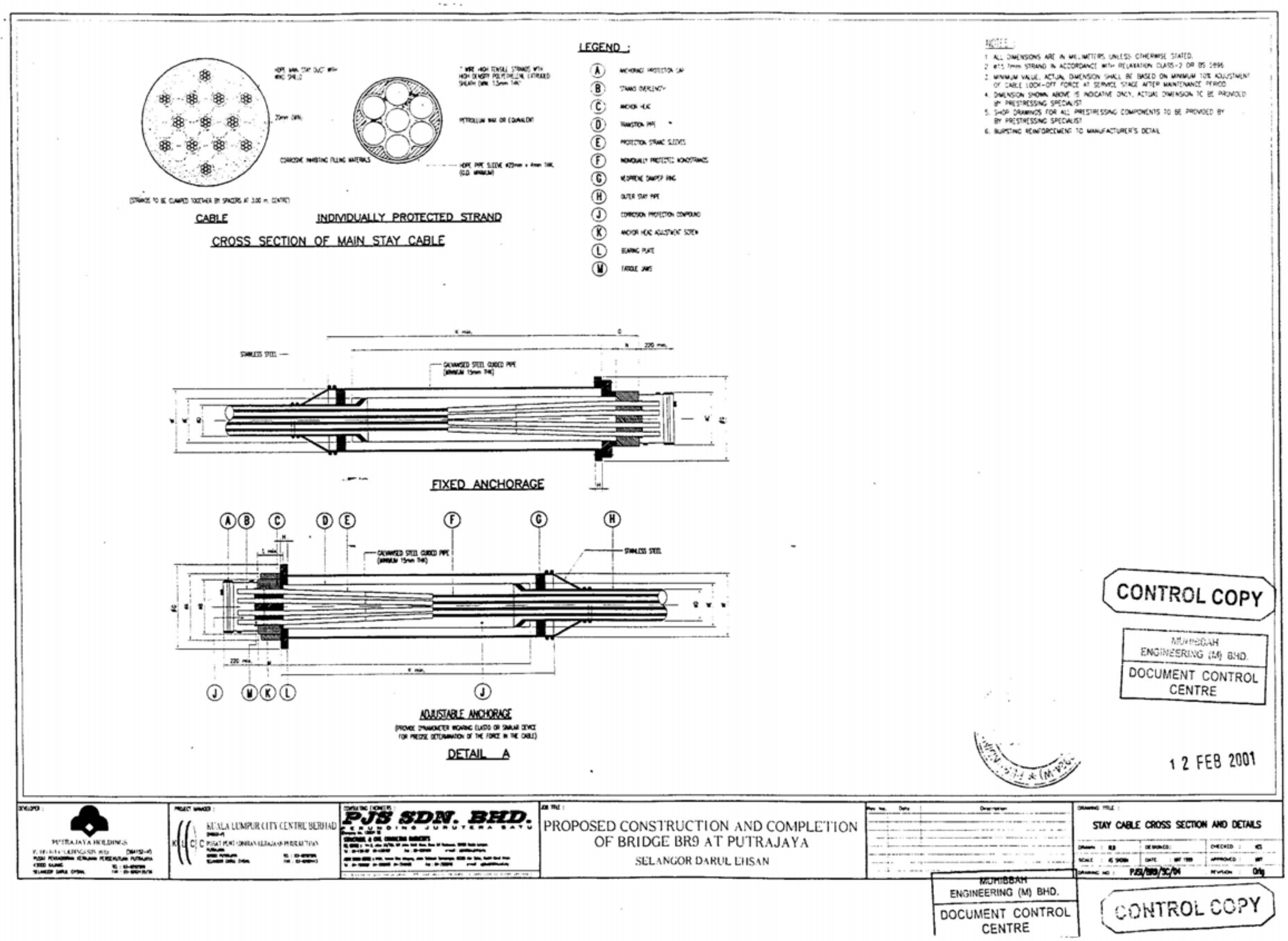
S.O.L. OF WEST ABUTMENT
S.O.L. OF PYLON
℄ OF PYLON
TOP OF PYLON ELEV=116.176M
21st BACKSTAY CABLE EL=111.50M
30th FRONTSTAY CABLE ELEV=110.75M
STEEL LADDER
1st BACKSTAY CABLE EL=75.75M
1st FRONTSTAY CABLE ELEV=74.50M
PROMENADE EL=24.00M
TOP OF PILECAP EL=19.50M
SEE DETAIL 1
SEE DETAIL 2
DATUM = 0.00M
SECTION
DETAIL 2
SEE DETAIL 3
DETAIL 3
℄ OF WEST LEG
℄ OF EAST LEG
PROMENADE
TOP OF PILECAP
DETAIL 1
T40 PYLON REINFORCEMENTS
T40 STARTER BARS
TOP OF PILECAP
DETAIL OF COUPLER JOINT
30th FRONTSTAY CABLE ELEV=110.75M
1st FRONTSTAY CABLE ELEV=74.50M
PYLON REINFORCEMENTS
PYLON ELEVATION – R.C. DETAILS
PERUNDING JURUTERA SATU SDN. BHD.
Site Office
BR 9
PUTRAJAYA
12 FEB 2001
PROPOSED CONSTRUCTION AND COMPLETION OF BRIDGE BR9 AT PUTRAJAYA
SELANGOR DARUL EHSAN
PYLON SECTION AND DETAILS
(SHEET 1)
PJSI/BR9/PY/01
MUHIBBAH ENGINEERING (M) BHD.
DOCUMENT CONTROL CENTRE
CONTROL COPY


SECTION D-D PY/01
SECTION F-F PY/01
SECTION C-C PY/01
SEE DETAIL 2
SECTION B-B PY/01
SEE DETAIL 1
SEE DETAIL 4
* SECTIONS ARE PERPENDICULAR TO AXIS OF LEG
PLAN – TOP OF PYLON
ACCESS OPENING WITH ALUMINIUM COVER
GALVANISED STEEL CATWALK LADDER
450mm THK. PARAPET WALL
DETAIL 1
SECTION E-E PY/01
PLAN – STEEL PLATFORM AT PYLON HEAD (INTERNAL VOID)
* LOCATION OF STEEL PLATFORM SHALL BE ADJUSTED AT SITE TO AVOID ANCHORAGE LOCATIONS
SEE DETAIL 3
DETAIL 2 STEEL LADDER
DETAIL 3 (STEEL BRACKET)
DETAIL 4
NOTES :
1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE STATED
2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH DWG. No. PJSI/BR9/PY/01
3. ALL ANCHOR BOLTS TO BE HILTI HSL TYPE OR APPROVED EQUIVALENT.
4. ALL BOLTS TO BE GRADE 8.8 UNLESS OTHERWISE NOTED
5. ALL STEELWORK INCLUDING NUTS, BOLTS AND WASHERS TO BE HOT DIPPED GALVANIZED
6. THE CAGE SHALL EXTEND 900mm MIN. ABOVE THE TOP OF THE PLATFORM LANDING UNLESS OTHER PROTECTION IS PROVIDED.
7. WHERE GUARD RAILS ARE REQUIRED AND THE DISTANCE FROM THE FRONT OR THE CENTER OF THE LADDER TO THE GUARD RAIL IS LESS THAN 900mm, GUARD RAILS SHALL BE PROVIDED BETWEEN THE BOTTOM OF THE CAGE AND THE TOP OF THE RAILING.
8. LOCATION OF STEEL PLATFORM SHALL BE ADJUSTED AT SITE TO AVOID ANCHORAGE LOCATIONS
PUTRAJAYA HOLDINGS
KUALA LUMPUR CITY CENTRE BERHAD
PJS SDN. BHD.
PERUNDING JURUTERA SATU
PROPOSED CONSTRUCTION AND COMPLETION OF BRIDGE BR9 AT PUTRAJAYA
SELANGOR DARUL EHSAN
MUHIBBAH ENG. (M) BHD
PYLON SECTION AND DETAILS (SHEET 2)
AS-BUILT


SPLICE DETAILS
SECTION A–A
SECTION B–B
SECTION C–C
SCHEDULE OF STEEL PLATE FOR STEEL COMPOSITE PYLON HEAD
RL. A (m)
RL. B (m)
MIDDLE PLATE (mm)
SIDE PLATE (mm)
SKIN PLATE (mm)
SHEAR STUD SPCG.
NOTE :-
a. SIDE PLATES TO BE TRIMMED IF CRASHED WITH STAY GUIDEPIPES.
b. ALL WELDINGS TO BE COMPLETE PENETRATION BUTT WELDS, U.O.S.
c. MINIMUM EDGE DISTANCE OF SHEAR STUD IS 50MM, U.O.S.
RL 111.50
RL 108.702
RL 103.50
RL 94.90
RL 88.30
RL 83.20
RL 69.50
RL "B"
RL "A"
BACKSTAY CABLES
SIDE PLATE
Ø19 SHEAR STUDS
FRONTSTAY CABLES
MIDDLE PLATE
FIN PLATE
M.S LADDER (GALV.)
SKIN PLATE
50x50x5 THK ANGLE @ 600 C/C
ALONG PERIMETER OF SKIN PLATE
SECTION OF STEEL COMPOSITE PYLON HEAD
MIDDLE PLATE (1 NO.)
SIDE PLATE (2 NOS.)
PUTRAJAYA HOLDINGS
KUALA LUMPUR CITY CENTRE BERHAD
PJS SDN. BHD.
PROPOSED CONSTRUCTION AND COMPLETION
OF BRIDGE BR9 AT PUTRAJAYA
SELANGOR DARUL EHSAN
MUHIBBAH ENG. (M) BHD
COMPOSITE PYLON HEAD DETAILS
AS-BUILT


TOP OF PYLON ELEV = 116.176M
21st BACKSTAY CABLE ELEV = 111.50M
1st BACKSTAY CABLE ELEV = 75.75M
BRIDGE DECK ELEV = 32.00M
ROAD FINISHED LEV.
TOP OF PARAPET
BRIDGE SOFFIT
NOTE : FOR PILES AND PILECAP REFER TO DETAILS
DATUM = 0.00M
ELEVATION – G.A. OF BACKSTAY CABLES
SCALE 1:500
EDGE OF PARAPET
EDGE OF PARAPET
PLAN – G.A. OF BACKSTAY CABLES
SCALE 1:500
SCHEDULE OF BACK STAY CABLES
MARK
NO. OF DUCT
PROPOSED NO. OF STRANDS
BS-1 2 55 x #15.7mm
BS-2 2 45 x #15.7mm
BS-3 2 55 x #15.7mm
BS-4 2 45 x #15.7mm
BS-5 2 55 x #15.7mm
BS-6 2 72 x #15.7mm
BS-7 2 72 x #15.7mm
BS-8 2 72 x #15.7mm
BS-9 2 90 x #15.7mm
BS-10 2 90 x #15.7mm
BS-11 2 90 x #15.7mm
BS-12 2 90 x #15.7mm
BS-13 2 110 x #15.7mm
BS-14 2 110 x #15.7mm
BS-15 2 110 x #15.7mm
BS-16 2 110 x #15.7mm
CONTROL COPY
JURUTERA SATU SDN. BHD.
Site Office
PUTRAJAYA
DOCUMENT CONTROL CENTRE
12 FEB 2001
PERUNDING JURUTERA SATU SDN. BHD.
G.A. OF BACKSTAY CABLES
MUHIBBAH ENGINEERING (M) BHD.
DOCUMENT CONTROL CENTRE
CONTROL COPY


S.O.L. OF WEST ABUTMENT
S.O.L. OF EAST ABUTMENT
S.O.L. OF PYLON
PIER 1
PIER 2
TOP OF PYLON ELEV = 116.176M
120.00 METERS
1st FRONTSTAY CABLE ELEV = 74.50M
BRIDGE DECK ELEV = 34.50M
CENTROID OF CABLES
BRIDGE DECK ELEV = 32.00M
BRIDGE SOFFIT
PROMENADE ELEV = 24.00M
PROMENADE EL = 22.50M
DATUM = 0.00M
ELEVATION
240.00 METERS
22.00 METERS
40.50 METERS
32.50 METERS
CENTROID OF CABLES
S.O.P. OF CABLES
MOVEMENT JOINT
17200
NOTES :
1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED.
2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH DWG. No. PJS/BR9/SC/05 & 06
PLAN - G.A. OF FRONT STAY CABLES
12 FEB 2001
PERUNDING JURUTERA SATU SDN. BHD.
Site Office
BR 9
PUTRAJAYA
PUTRAJAYA HOLDINGS
KUALA LUMPUR CITY CENTRE BERHAD
PJS SDN. BHD.
PERUNDING JURUTERA SATU
PROPOSED CONSTRUCTION AND COMPLETION
OF BRIDGE BR9 AT PUTRAJAYA
SELANGOR DARUL EHSAN
G. A. OF FRONT STAY CABLES
(SHEET 1)
PJS/BR9/SC/02
Orig
CONTROL COPY
MUHIBBAH
ENGINEERING (M) BHD.
DOCUMENT CONTROL
CENTRE
MUHIBBAH
ENGINEERING (M) BHD.
DOCUMENT CONTROL
CENTRE
CONTROL COPY


LEGEND :
CABLE
INDIVIDUALLY PROTECTED STRAND
CROSS SECTION OF MAIN STAY CABLE
NOTES :
1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE STATED.
3. MINIMUM VALUE. ACTUAL DIMENSION SHALL BE BASED ON MINIMUM 10% ADJUSTMENT OF CABLE LOCK-OFF FORCE AT SERVICE STAGE AFTER MAINTENANCE PERIOD
4. DIMENSION SHOWN ABOVE IS INDICATIVE ONLY. ACTUAL DIMENSION TO BE PROVIDED BY PRESTRESSING SPECIALIST
5. SHOP DRAWINGS FOR ALL PRESTRESSING COMPONENTS TO BE PROVIDED BY BY PRESTRESSING SPECIALIST
6. BURSTING REINFORCEMENT TO MANUFACTURER'S DETAIL
FIXED ANCHORAGE
ADJUSTABLE ANCHORAGE
DETAIL A
CONTROL COPY
MUHIBBAH ENGINEERING (M) BHD.
DOCUMENT CONTROL CENTRE
12 FEB 2001
PUTRAJAYA HOLDINGS
KUALA LUMPUR CITY CENTRE BERHAD
PJS SDN. BHD.
PROPOSED CONSTRUCTION AND COMPLETION OF BRIDGE BR9 AT PUTRAJAYA
SELANGOR DARUL EHSAN
STAY CABLE CROSS SECTION AND DETAILS
MUHIBBAH ENGINEERING (M) BHD.
DOCUMENT CONTROL CENTRE
CONTROL COPY