Design of Reinforced Concrete Beam Bridge

by

Aric Chye Chang Sheng

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Supervisor: Dr. Panjehpour
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1.0 Acknowledgement

There are many people who helped me a lot in this final project with various useful suggestions in many aspects. Thus, I would like to take this chance to thank them with the deepest appreciation.

First of all, I would like to express my sincere appreciation to my supervisor, Dr. Panjehpour. Through this project, I have learnt some extra knowledge and technique which is beyond the outline of my course. Besides, he also provided me some useful information such as BS codes which is the important manual for the referring of my calculations.

Secondly, I would like to send a special thank for my former lecturer, Ms. Susan Chong. She gave me a lot of suggestion for my bridge design and because of this, I have successfully finish the design. Also, she borrowed me some reference books and willingly explains the questions that I had during my design even though she is not my supervisor.

Moreover, I would like to thank my examiners, Mr. Cheah and Dr. Lee for giving me some criticises and suggested me some improvements that I could make for my final project. Furthermore, I also would like to send the best regard for my friends, who have been helping me along the course especially the project. Lastly, I want to thank my parents for providing me finance support of buying the materials that is needed in this project.

In a nutshell, I would like to give the kindest regard for those who I had mentioned above. Without their help, there is a very huge possible I will not finish the project in time.

I declare that this project is entirely my own work except where due references are made

Aric Chye Chang Sheng

8th April 2015

3.0 Abstract

The purpose of the project is to design a Reinforced Concrete Beam Bridge.

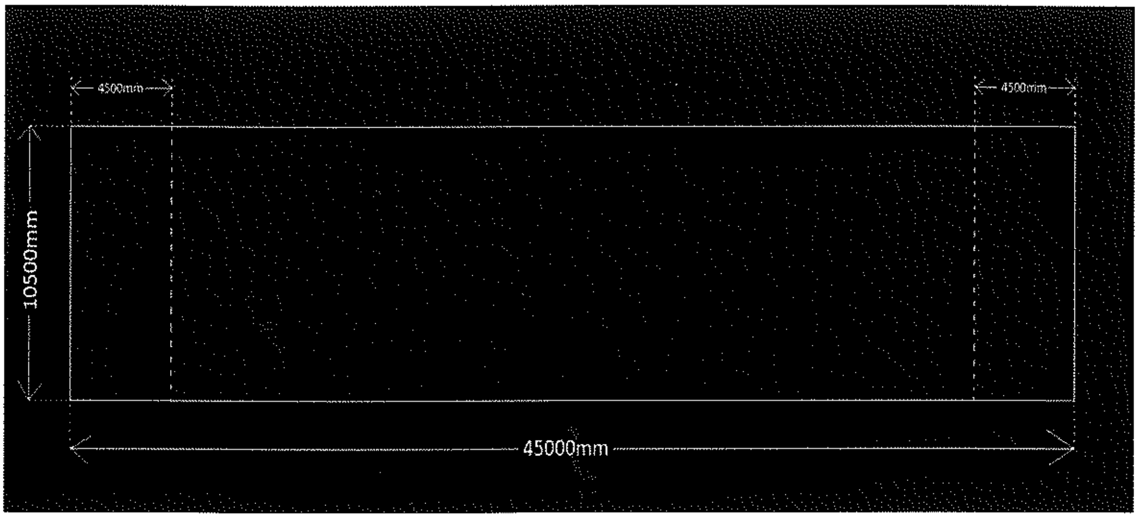
In Malaysia, the most popular bridge that can be found is the concrete beam bridge. There are many parts of design for a bridge which including foundation, abutment, pier, tendons, girder, bridge deck, and more depending on the type of the bridge. For this project, I will only need to focus to the bridge deck and girder. For calculation of box girder, BS8110 is referred. However, since prestressed topic is beyond my area of study, a specification of the box girder which is prepared by using a software called 'Response 2000'.

For information, my design of this 45m-long and 10.5m-wide bridge is crossing a river without any pier in between of the span and it is a post-tensioning bridge as to reduce the reinforcement for bridge elements. The design load is basically according to BS 5400 which only HA and KEL loading is concerned in the project. BS 8110 also being used for the design of my bridge deck.

Some research on the UHPC and post-tensioning process also have been conducted for this project. It is because UHPC is the material used for my box girder.

Content | Page

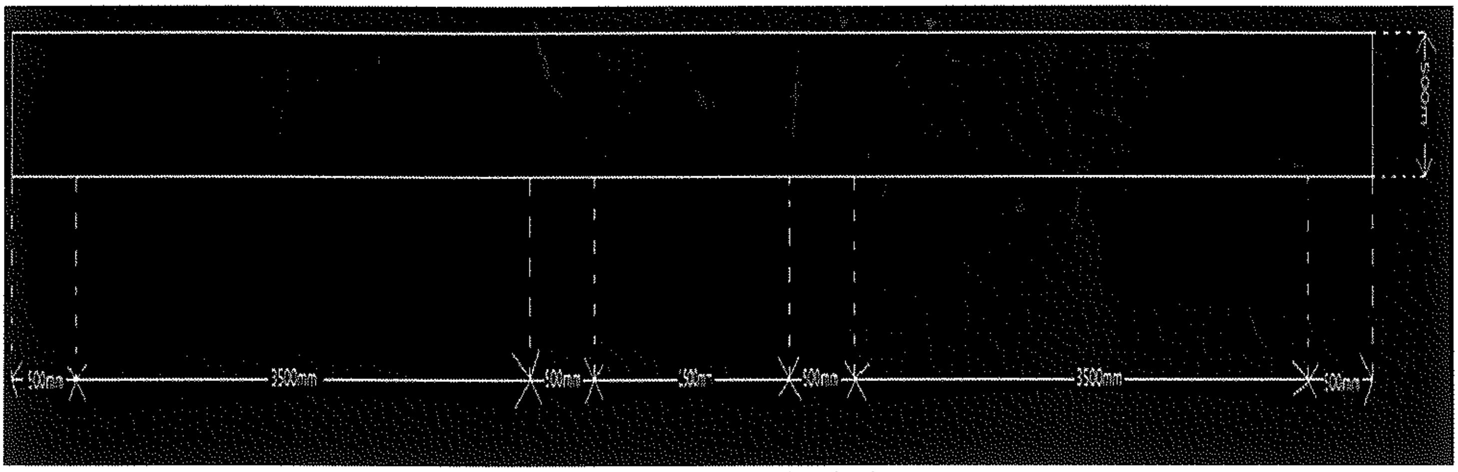
4.0 List of illustration



Plane view of the beam bridge

Scale

1:50



Elevation view of the deck

Scale

1:1

5.0 Introduction

5.1 History/ background

In ancient times, bridge is just a structure which built to connect two areas of land over an obstacle such as valley or a body of water like rivers, lakes and oceans. However, people in this sophisticated century, also built a bridge to go over traffic junction and shortening the distance between places.

When designing bridges, engineers must really understand the properties of the materials they have available. And the strength of the material is usually the first thing engineers will consider. For example, stone is only useful in handling compression forces and therefore is most often used in arch bridges; wood was often used to make bridges that required shorter spans, such crossing streams or ravines.

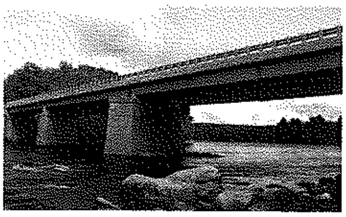
Nowadays, the reinforced concrete is the most common material that used for construction in bridges. The reason that engineers doesn't use iron to build the bridge is iron bridge will not give any signs if they cannot sustain the load as iron is a brittle material. Thus, people are using steel for reinforcement of concrete instead of iron. However, if the engineers are building the bridges with the reinforced concrete, the bridges will crack first before they fail to withstand the load.

Furthermore, when engineers want to build a bridge, they will also consider and think about the most suitable type of bridges that should construct. As said, there are several types of bridges which will be commonly seen by us in daily life:

i. Beam bridge
ii. Arc bridge
iii. Cable-stayed bridge
iv. Suspension bridge
v. Truss bridge

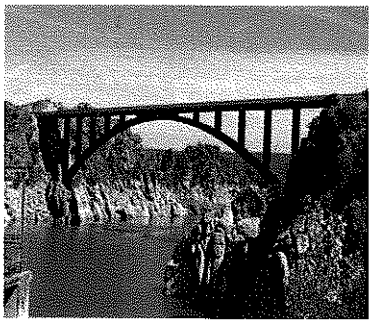
Type of Bridges

Beam Bridge



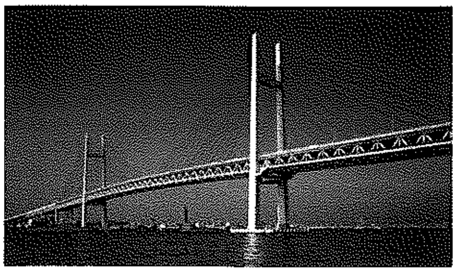
Beam bridges are the simplest bridge spans structure among all of different types of bridge. The simplest beam bridge could be a stone slab or wood plank which laid across a stream. For modern infrastructure, bridge has been constructed by steel, reinforced concrete, box or plate girders. When there are multiple segments (spans, such as girders), these segments will be connected with tendons through the process of pre-stressing or post-tensioning.

Arc Bridge



An arch bridge is a bridge with abutments at each end shaped as a curved arch. Arch bridges work by transferring the weight of the bridge and its loads partially into a horizontal thrust restrained by the abutments. To build an arc bridge, normally the workers need to construct a falsework first, to give a temporary support to the arc.

Cable-stayed Bridge

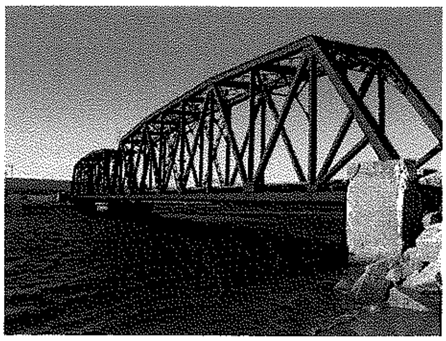


A cable-stayed bridge has one or more towers from which cables support the bridge deck. There are two major classes design: harp and fan designs. In harp design, the cables are nearly parallel so that the height of their attachment to the tower is proportional to the distance from the tower to their mounting on the deck; in fan design, the cables are all connect to or pass over the top of the towers. This superior design allow better termination to the top of the tower, improved environmental protection, and ease to access to individual cables for maintenance.

Suspension Bridge

Just like cable-stayed bridge, it also held by the cable. This type of bridge has cables suspended between towers, plus vertical *suspender cables* that carry the weight of the deck below, upon which traffic crosses. This arrangement allows the deck to be level or to arc upward for additional clearance.

Truss Bridge



A truss bridge is composed of a truss, which is a structure of usually connected by metal in triangular shaped. The connected elements (typically straight) may be stressed from tension, compression, or sometimes both in response to dynamic loads. Besides, truss bridge also consists of various type depends on their truss designs, such as Allan truss, Warren truss and Pratt truss.

Lastly, engineers will select the suitable type of the bridges as different type of them will have different application, such as the reinforced concrete girder bridge will have more resistant to torsion and it eases the workers to carry out the maintenance.

5.2 Project overview

For this in-coming project, the design of reinforced concrete beam bridge will be carried out. In this design project, a short-term analysis for the beam bridge will be conducted such as the calculations for the deflections of bridge. Moreover, for all the calculations in this project, British BS code 5400 and 8110 will be refer to. Besides, the 'GUIDELINES FOR MALAYSIA TOLL EXPRESSWAY SYSTEM - DESIGN STANDARDS OF CHAPTER 6 - BRIDGES' will be discussed in the project. Next, the pre-stressing process for the segment (post-tensioning) and material, UHPC will also be discussed about.

5.3 <u>Objective</u>

The objective of this project is to:

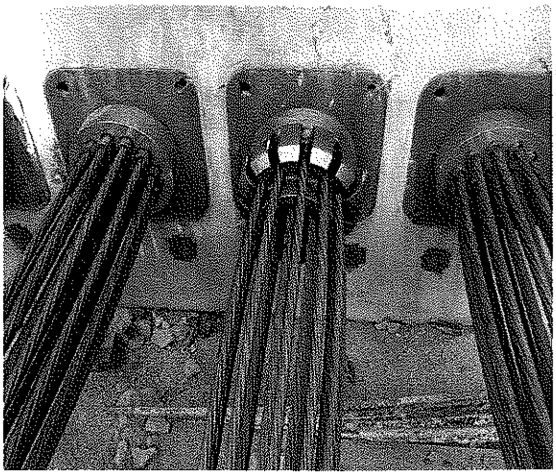
i. Design an ultra high performance concrete (UHPC) beam bridge crossing a river.
ii. Conduct a short-term analysis in order to design a beam segment bridge to BS 5400 and BS 8110.
iii. Research information about UHPC and Post-tensioning

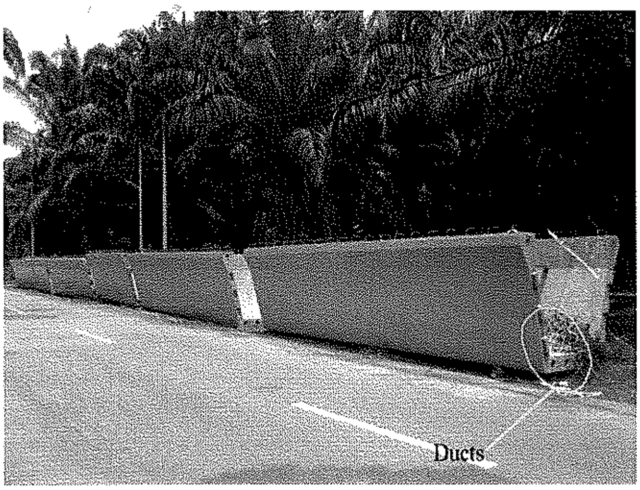
6.0 Methodology

This project has included two part, that is: Bridge deck and U-shaped box girder.

For the design of bridge deck, the method that is used to determine is called the limit state design. The principle behinds the limit state design is Ultimate Limit State (ULS) and also the Serviceability Limit State (SLS). From ULS, this principle will require that the structure is able to withstand the load which has been designed. In SLS, the engineer who is going to design a structure, need to be concerned about the deflection, cracking, fire resistance, fatigue and also the durability of the structure. For the analysis for prestressed box girder, the 'RESPONSE 2000' software has been used for this part of the project.

In this project, UHPC is the material that will be used to reduce steel reinforcement while the post-tensioning is a major construction process for this project.





6.1.1 Post-tensioning

In prestressing system, it has divided into two parts of method to join all of the girders together: Pretensioning/Prestress and Post-tensioning.

In post-tensioning, usually the precast concrete elements will be involved. The ducts allow tendons (could be wires, strands or bars) to pass through. After the tendons have been placed within the precast elements, the stressing force will transfer through the whole span. To carry out the whole process, a jacking system will be needed. The grouting of the tendons must be done to provide a permanent protection for the tendons.

The concrete part of the girder is usually to withstand the compression force transfer through the bridge deck, while the tendons will take care of tensioning force. The strength of the bridge will be differ and various with the steel characteristic (for tendons) , the type of concrete, and the amount of stressing force by the jacking machine.

6.1.2 UHPC

Ultra high performance concrete (UHPC) is being use widely to make precast segments for heavy construction structures. The basic ingredients to make the UHPC include sand, cement, silica fume, steel fibre, and superplasticiser, no steel reinforcement is needed for this type of concrete as the steel fibre inside will provide the enough design strength. The f_{cu} of the UHPC will depends to the tensile strength of the steel fibre used.

Type of steel	Tensile strength, Mpa
Mild steel	250
High Yield steel	460
Strand	1860
UHPC steel fibre	2700

The above table shows the tensile strength of different steel type (the tensile strength of UHPC steel fibre may be various as this is taken from one of the precast company, DURA).

For now, the UHPC can reach until 125 to 180 N/mm^2. Below are the photo that I took from the concrete lab. Figure A is the sample that I have made. Figure B is the materials for the mixed concrete. According to BS code, at least three mould of concrete sample had been prepared and done. Below is the table showing my concrete mix design.

Sand	Silica fume	Cement	Steel fibre	Water	Superplasticiser
15.44kg	0.43kg	6.45kg	0.5kg	5.2kg	15g

Figure A

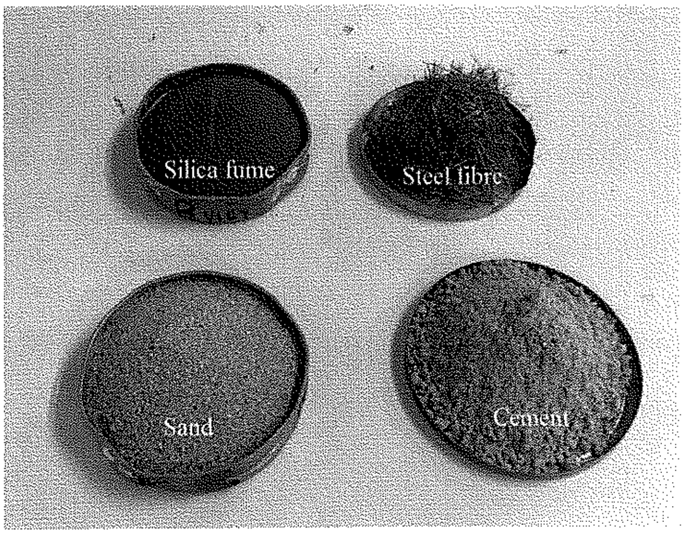


Figure B

7.0 Results and analysis

7.1 Structural design

7.1.1 Specification

i. Concrete Strength; grade 40 = $f_{cu} = 40N/mm^2$
ii. Nominal cover based on moderate exposure conditions = 35mm
iii. Unit weight of concrete = 24 kN/mm^2
iv. Reinforcement – high tensile steel (fy => 460N/mm^2)
v. Imposed Loading based on BS 5400
   - HA loading = 26.22kN/m
   - KEL(Knife-edge load) = 120kN/lane

7.1.2 Bridge Deck Design

My bridge deck is a reinforced concrete slab which similar to the floors of the building. For this project, I am designing a one-way slab which is determine by:

$$\frac{Ly}{Lx} \geq 2 \text{ ; one-way solid slab}$$

(Where Ly is the longer span and Lx is the shorter span, in this case, my Ly is 45m, hence my Lx should be less than or equal to 22.5m)

Also, from JKR's manual 'A Guide on Geometric Design of Roads (ARAHAN TEKNIK JALAN 8/86)', and by following the conditions in it, my lane specification is:

i. Rural area
ii. Design speed: 100km/h
iii. Terrain: Flat

∴ Design standard: R5 → Lane width: 3.5m

Marginal strip width: 0.5m

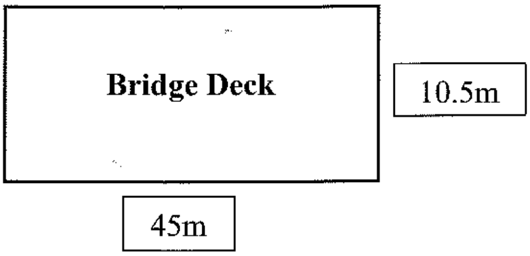
Divider width(assumed): 1.5m

Therefore, the effective width of my bridge which has two lanes

= 3.5x2 + 0.5x4 + 1.5

=10.5m

Bridge Deck



f_{cu} = 40N/mm^2

f_y = 460N/mm^2

Nominal cover = 35mm, moderate, fire resistance 3 hours

ϕ_{bar} = 25mm

$l = 10.5$

$$\frac{l}{d} = 26$$

$$d = 0.404m$$

Thickness, h = 404 + 35 + 25/2 = 452 ≈ 500mm