CONSTRUCTION OF PRECAST SEGMENTAL BOX GIRDER BRIDGE USING OVERHEAD GANTRY – A CASE STUDY

JAZLAN BIN SALLEH @ MOHAMED SALLEH

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Science (Construction Management)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

NOVEMBER 2006

To my beloved wife, Siti Shairra Zakaria, my children Nurul Asyikin, Mohd Amir Arif, Nurul Amira, Mohd Amir Afiq……..
……..thank you for your love, support and patience during this hard time.

I love you so much!!
7november2006

ACKNOWLEDGEMENT

I would like to express my sincere appreciation and thousands of thank you to my project supervisor, Professor Madya Dr. Mohamad Ibrahim Mohammad for being patience with me, for his encouragement, guidance, critics, advice and motivation and last not least the valuable friendship.

While preparing this project, I was in contact with many people, academicians, and construction professionals in construction firm, consultants and suppliers. They have contributed towards my understanding and thoughts. In particular, I am also very thankful to all of them for their willingness to share their valuable knowledge, expertise and technical know-how which assist me a lot in preparing this project. Without their continued support and interest, this project would not have been the same as presented here.

I am also would like to thank all the lecturers who have conducted the course from the beginning and not hesitating to share their knowledge with us. I am grateful to all my family members who are very understanding and have been patience with me during my hard time. My fellow postgraduate students should also be recognized for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space.

ABSTRACT

The bridge construction utilizing the concept of erecting the precast segmental panel has been a chosen method for bridge construction within restricted area. This method has been successfully exhibit the constructability within the urban area and also crossing the wide water body, valley and existing highway or railroad. The suitability of this method of construction is depending on the availability of working space, which govern the major cause in selection of this construction method. The aim and objective are to study the problem in the manufacturing the segment and segment erection. This master project has studied the procedures in construction of precast segmental box girder bridge by balance cantilever method using the overhead gantry. This project also studied the segment manufacturing procedures and discovers some problem problems faced in segment manufacturing that is interesting and need to expose for awareness to the bridge professional. The segment erection procedures and sequence also has been studied and the related problems have been highlighted and need further study by the professional bridge designers and constructors. The study has been conducted by direct structured interview and questionnaire with the bridge expertise. The bridge professional from consultants, segment manufacturer, main contractors and specialist sub contractor have shared their knowledge, technical know-how and experience and has been elaborated in details in this project. The finding is very interesting and it has exposed the problem related to the segmental bridge construction that need further study by the bridge expertise. This study also recommended some idea about working concurrently and simultaneously without fragmentation that could lead to errors. It is expected that by addressing the problem at early stage could assist the designer, manufacturer and constructor to foresee the problem and find the mitigation measures thus could eliminate the errors that may occurs in manufacturing the segment and erection on site.

ABSTRAK

Pembinaan jambatan menggunakan konsep pemasangan panel segmen pratuang telah menjadi pilihan utama dalam pembinaan jambatan dikawasan tapak yang terhad. Kaedah ini telah mepamirkan kebolehbinaan dalam kawasan bandar, merentasi laluan air, lembah, dan laluan keretapi atau lebuhraya. Kesesuaian kaedah ini bergantung kepada keadaan kawasan tapak kerja, yang menjadi faktor utama dalam pemilihan kaedah ini. Tujuan dan objektif kajian kes ini adalah untuk mengkaji masalah dalam pembuatan panel segmen pratuang dan pemasangan panel tersebut. Projek Sarjana ini mengkaji prosidur pemasangan panel segmen pratuang dengan kaedah *Balance Cantilever* menggunakan *overhead gantry*. Projek ini juga mengkaji prosidur dalam pembuatan panel segmen pratuang dan telah menemui beberapa masalah yang sangat menarik untuk dikaji dan perlu diumumkan kepada pakar-pakar dalam pembinaan jambatan. Kaedah pemasangan juga telah dikaji dan beberapa masalah telah dibangkitkan dan perlu pemerhatian dari pakar-pakar bidang jambatan. Kajian telah dijalankan secara temuduga yang terancang dan soal-selidik dengan pakar-pakar jambatan. Pakar-pakar jambatan dari pihak perunding, pembuat panel segmen, kontraktor utama, kontraktor pakar dalam bidang jambatan dan pakar dalam bidang pra-tegasan telah berkongsi kepakaran teknikal, pengetahuan dan pengalaman masing-masing dalam projek Sarjana ini. Hasil kajian amat menarik dan telah mendedahkan masalah yang berkaitan dan kajian lanjut perlu dibuat. Projek ini juga telah mengemukakan beberapa cadangan kepada pihak-pihak yang terlibat untuk membentuk kerjasama dalam satu pasukan tanpa pembahagian kerja yang merumitkan Adalah diharapkan dengan mengenalpasti masalah diperingkat awal dapat membantu pihak yang terlibat mengurangkan kesilapan dalam pembuatan segmen dan pemasangannya.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Bridge construction using the precast post tension segmental box girder is considered a new trend in Malaysia. This method of construction started with construction of Light Rail Transit (LRT) viaduct in 1997, post tension box girder start to gain recognition as a preferred method of construction of bridge within the urban area. This similar construction follows by construction of Second Link Bridge to Singapore, Bayan Baru By-pass, Butterworth Offshore ring Road, several bridges in Kuala Lumpur such as Ampang-Kuala Lumpur Elevated Highway, SPRINT Highway, Kerinci Link, New Pantai Expressway, Subang Kelana Link and so on. The constructed box girder bridge has been utilizing several methods such as Span-by-Span, Balanced Cantilever and Incremental Launching. This master project explores the process of manufacturing the segmental box girder and the construction/erection of the post tension precasted segmental box girder bridge using balance cantilever method.

1.2 Problem Statement

During the design stage, in normal practice, the main consultant design normally will cater for permanent structure only. Any design for temporary work such as temporary pre-stressing, segment modification, additional blister, check for segment lifting, check for segment's reinforcement for additional load, thickening of

top slab, etc, being carried out by the contractor and / or bridge specialist contractor. The process of preparing shop drawing, review by consultant, resubmitting the revised shop drawings, getting the shop drawing endorsed by Professional Engineer always take a few round and time consuming before it could be approved and use for manufacturing the segment.

During segment production at casting yard, the problems arise in fabricating the mould and reinforcement. Due to short size of the segment, longitudinally, the reinforcement become congested, the reinforcement may collide with the tendon conduit and other insertions item. The reinforcement also clashes between them and the gap is very close, make it limited access for concrete to fill up the formworks. Wollman *et. al*. (2000) reported that the end diaphragm segment where the tendon is anchored, which is also the Pier Segment always experience the cracks occurred. One of the reason mentioned is due to detailing of the congested reinforcement which limited the access of the concrete to compact, thus created a localise improper and incomplete compaction to the concrete. This phenomenon created the crack when stressing applied to the tendon.

FHWA (2005) in their Task Number 7.11 – Proper Detailing had addressed the common problem in detailing of the segment that result in problem during casting such as:

1. Reinforcing fit-up. Conflicts can occur at anchorages, blisters, deviation beams and bearing diaphragms. The three-dimensional space requirements of tendon anchors and spirals need to be accounted for. Reinforcing should be arranged to accommodate horizontal and vertical tendon profiles. All reinforcing bends with the actual curve radius should be drawn to scale.

2. Nodes. All tensile reinforcing entering a structural node (Strut & Tie design) should be adequately developed. Post-tensioning bars require some distance from the free, perpendicular edge to become developed; cover requirements, bar extension, nut and plate thickness can combine to shift a node off of the center of the neutral axis of an entering thin wall element (e.g. web or slab entering a diaphragm).

3. Appurtenances. Details for access openings, drains, lighting fixtures etc. are often presented as separate details at the end of a plan set. These too should be drawn to scale with the reinforcing from typical plan sheets prior to final plan preparation. In complex projects, fully-integrated drawings may be necessary. Access hatches should swing free of external tendons, plumbing etc. Plumbing should be positioned so that it creates the least interference with passageways in the box. Additional reinforcing should be added if the element creates a disturbance in the flow of forces.

4. Short tendons. Post-tensioning bars should be used if the losses in short tendons are too great.

5. Tolerances. Details need to be buildable by conventional practices. A large, circumferential stirrup that engages both webs and flanges may need to be spliced into two telescoping U-shaped bars. Cast-in-place closures joining two soon-to-be prestressed elements should be wide enough to accommodate precast duct misalignments.

6. Jack Fit-Up. Hydraulic ram dimensions and stroke need to be accounted for when locating tendon anchors within the box.

7. Water Control. Methods to control water from broken plumbing and expansion joint seals should be integrated into the design. Holes cast into the bottom slab adjacent to bearing diaphragms and deviation beams will both remove the water from the box and serve as a tattletale for maintenance inspectors. These holes can easily be clogged with construction debris or grout and should be cleared before the contractor finishes the project. Transverse drip beads on the web and underside of the wings located one inch from the expansion joint should contain the longitudinal spread of stains resulting from a broken seal. Unsightly column staining can be controlled with either creative column detailing to channel water or an umbrella (drip pan) perched on top.

8. Temporary Drain Caps. Plans should specify a temporary plumbing line cap at the top of the column to discourage solid waste disposal by construction personnel.

9. Critter Guards. Roosting birds and varmints need to be kept out of the girder. Expanded metal mesh mounted to a metal frame on the inside circumference of the box (i.e. oriented in the planes of the webs and flanges) at expansion joints has worked well. Transverse screens impede movement of maintenance personnel through the box and should be avoided.

10. Future Post-Tensioning. During the design of the very first segmental bridges, long-term moment redistribution was an unknown phenomenon. To counteract unexpected deflections, additional post-tensioning was added after the bridges were in service. This was accomplished with some difficulty. Today the more likely cause of future additions of post-tensioning (although this is very rare in a well-detailed bridge) is from tendon corrosion. Bridge designs of today should have provisions for easily adding supplemental post-tensioning. Casting additional, empty post-tensioning anchorages and deviation pipes into diaphragms is the most common method. Allowances need to be made for transporting and positioning hydraulic stressing rams inside the bridge.

Problem during construction is expected when the segment is delivery. For erection using the gantry launcher, assembling the gantry takes more than two months, the kinematic drawing for gantry movement during launching should be prepare for every span. During tendon stressing, the tendon may fail to achieve the calculated elongation. The segment erected might be difficult to set at design level and alignment. After stressing, the tendons need to be grouted. The grout materials shall comply with stringent specification in order to ensure the grout filled up the whole tendon conduit.

1.3 Objective

The aim of this master project is to study the system of the construction of post tension precast box girder bridge using gantry launcher by Balance Cantilever method.

The objectives of this master project are:

1. To determine the problems in manufacturing/fabricating the segmental box girder at casting yard before deliver to site.

2. To determine the problem in precast segment erection/construction using the overhead gantry launcher at site.

3. To propose the strategy for coordinated design procedure between consultant and specialist contractor.

1.4 Scope and Limitation

This master project focused on the construction of bridge using precast segmental box girder. The study is subjected to the following scopes and limitation:

1. This study is limited to the manufacturing of the segment by the short line match-casting method.

2. The study is limited to the bridge construct using Post Tension Precasted Segmental Box Girder erected using the gantry launcher by Balanced Cantilever method.

Even though there are several method of construction of bridge for segmental bridge, but the other method does not affected the modification of the segment and structure.

1.5 Brief Research Methodology

The methodology used in conducting this research is through literature search, structured interview with selected personnel that have direct involvement with the manufacturing and erection of the segment and questionnaire survey among the other person involved. The literature search explored the system used in constructing the segmental bridge by Balance Cantilever Method as well as other method available, advantages and disadvantages of the bridge construction method, the history of it and the problem faced by the works that have been establish somewhere else. Literature review is referred to the published journal, technical paper and relevant book on the design, related and reliable website regarding the construction, management and maintenance of the bridge.

The questionnaire survey has been conducted among the selected person from the segment manufacturer and contractors in Malaysia to establish the problem they faced in manufacturing the precast segment and erection of the segmental bridge using the gantry launcher. A structured interview also has been conducted with the segment manufacturer, contractors, consultant and the consultant's representative at site to seek their opinion and suggestion on how to improve the construction procedures. The data compiled are analysed using simple frequency method and Relative Index Analysis. Figure 1.1 shows the research methodology procedure and sequence in this study.

Based on the analysis and finding, several recommendation have been made in according to the objective that have been set off earlier. The recommendation represent constructive proposals and suggestions on how to eliminate or at least

minimise the problem that have been determine, thus could also eliminate the problem that may occurs during operation and maintenance.

1.6 Limitation of the study

The limitation of the study is confined to construction of segmental box girder bridge that being built in Malaysia by Balance Cantilever method only. Even though there is several method of construction for segmental bridge such as span-by-span, incremental launching, cast-in-situ segmental and normal cast-in-situ, but these method do not involved modification carried out to the segmental box girder and pier and no checking need to be done by contractor. The final construction drawing has been incorporated all the designs and construction requirement by consultant.

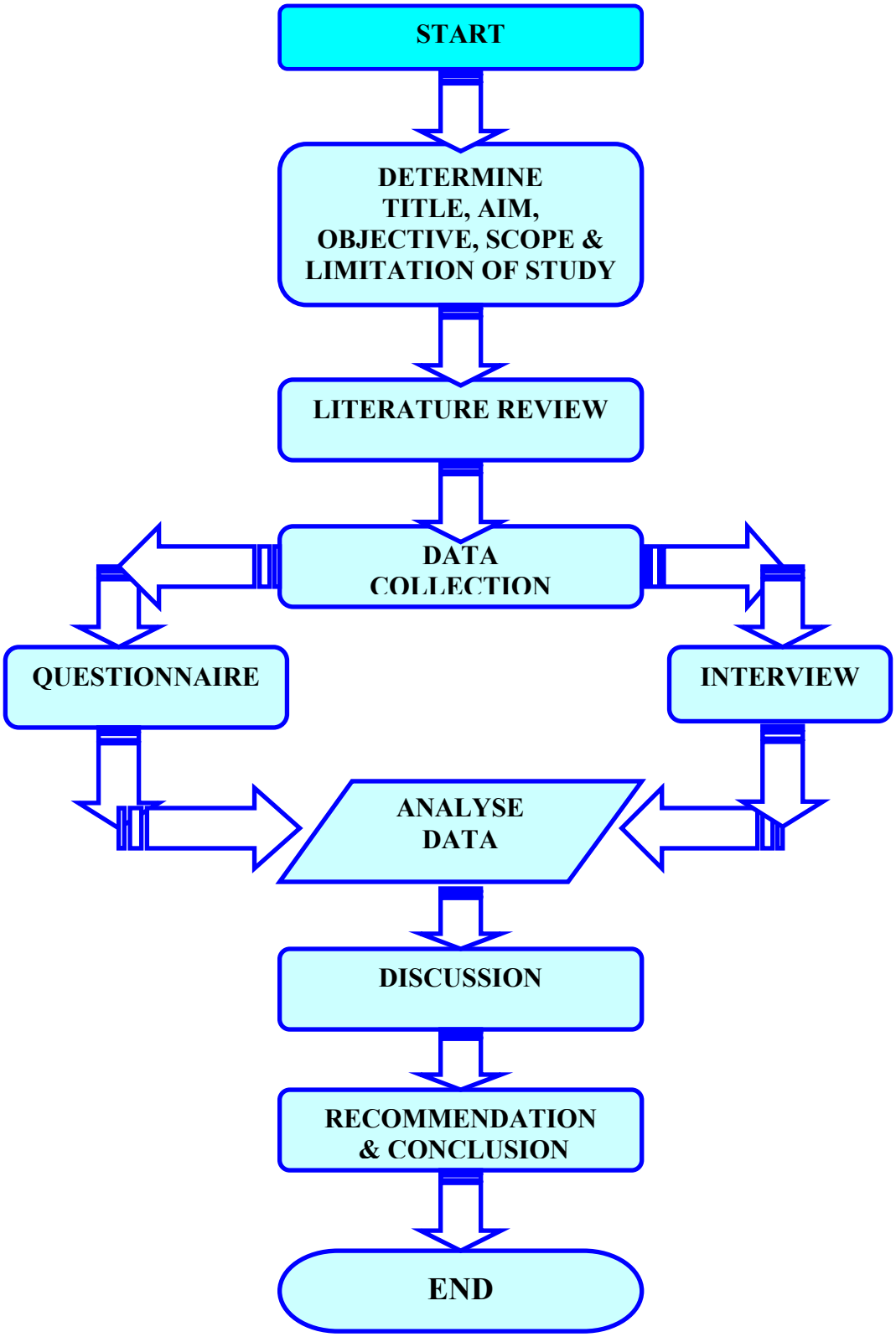

Figure 1.1 Research methodology sequence

REFERENCES

American Segmental Bridge Institute (2006). *Grouting Recertification*, American Segmental Bridge Institute Magazine (SEGMENTS) Vol. 47, Winter.

Andrew C., Raymond S. (2006). "*Method Statement for Segment Erection*", VSL Engineers Sdn Bhd & Projalma Sdn Bhd JV (VPJV), Subang Kelana Link Project. unpublished

Arthur M. P. (2004). "*Precast Segmental Casting Yards: Past, Present And Future*", PB Networks Online Magazine, Issue No. 57, Vol. XIX, Number 1. Feb. Website: http://www.pbworld.com

Cliff F. ed. (2006). "*Design and Construction of Segmental Concrete Bridges for Service Life of 100 to 150 Years*", American Segmental Bridge Institute Magazine (SEGMENTS) Vol. 47, Winter.

Federal Highway Administration (2003). "*Task 15.2 Research Synthesis Statement: Segmental Concrete Bridge Design and Construction Practices*." Washington D.C., Federal Highway Administration, U.S. Department of Transportation.
Website http://fhwa.dot.gov/BRIDGE/segmental/task15.2.htm

Federal Highway Administration (2003), "*Segmental Concrete Bridge Technology – Is a Segmental Bridge Right for You*?" Federal Highway Administration, U.S. Department of Transportation.
Website : http://fhwa.dot.gov/bridge/segmental/right.htm

Federal Highway Administration (2003), "*Segmental Concrete Bridge Technology – Is a Segmental Bridge Right for You*?", Federal Highway Administration, U.S. Department of Transportation.
Website : http://fhwa.dot.gov/bridge/segmental/right.htm

Frank B., Scott W. D. (1997), "*Fast Track Segmental Concrete Bridge*", PB Networks Online Magazine, Issue No. 38, Vol. XI, Number 2. Spring,
Website: http://www.pbworld.com

Gunnar L., Jesus M.de la Garza. (2003). "Constructability Consideration for Balanced Cantilever Construction", *Journal Practice Periodical on Structural Design and Construction*, Feb, pg 47-56.

Joseph K. T. (2004). "*Considering Segmental Concrete Bridge*", PB Networks Online Magazine, Feb, Issue No. 57, Vol. XIX, Number 1.
Website: http://www.pbworld.com

Juan A. M., Joseph I. S. (2004). "*Brief History of Segmental Concrete Bridge Construction*", PB Networks Online Magazine, Feb, Issue No. 57, Vol. XIX, Number 1.
Website: http://www.pbworld.com

Juan A. M. (2004). "*Advantages of Segmental Construction*", PB Networks Online Magazine, Feb, Issue No. 57, Vol. XIX, Number 1.
Website: http://www.pbworld.com

Lee K. M., Raymond S. (2005) "*Method Statement for Precast Segment Manufacturing*", VSL Engineers Sdn Bhd & Projalma Sdn Bhd JV (VPJV), Subang Kelana Link Project. unpublished.

LoBuono, J. (2005). " *Assembly required – The instruction for building New Jersey's first segmental bridge*." Chicago, Illinois: BridgesMagazineOnline.com Sept/Oct.
Website : http://www.brisgebuildermagazine.com/

Low S. P., Choong J. C. (2001) "Just in Time Management of Precast Concrete Components", *Journal of Construction Engineering and Management*, Nov/Dec.

Maurice D. M. (2001). "Durability of Segmental Concrete Bridges" *Journal of Bridge Engineering*, Vol. 6, No. 6, November/December, pg.539-542.

Poh B. S., Raymond S. (2006). "*Method Statement for Gantry Assembly*", VSL Engineers Sdn Bhd & Projalma Sdn Bhd JV (VPJV), Subang Kelana Link Project, April. unpublished.

Public Works Department of Malaysia (2004), *Contract Document, Volume II, Specification - Section 16, "Segmental Construction"* for Projek Membina Jalan Penyambung Subang Kelana, Public Works Department of Malaysia (PWD), Road Division, Special Project Unit.

Raymond S., Lee K. M. (2005). "*MS PowerPoint Presentation for segment fabrication at Casting Yard, Batu Gajah, Perak*", VSL Engineers Sdn Bhd & Projalma Sdn Bhd JV (VPJV) July . unpublished.

Raymond S., (2005). "*MS PowerPoint Presentation for segment erection*". VSL Engineers Sdn Bhd & Projalma Sdn Bhd JV (VPJV), July. unpublished.

Richard M. B., Mark L. H., Martha C. (2002), "50-year-old prestressed segmental concrete bridge", *Journal of Professional Issues in Engineering Education and Practice*, April, pg 83-87

Poston R.W., Wouters J.P. (1998). "*Durability of Precast Segmental Bridges" Final Report for National Cooperative Highway Research Program*, Transportation Research Board, National Research Council, United State of America, June.

Wollman G. P., Breen J. E., Kreger M. E. (2000). "Anchorage of External Tendon in End Diaphragms", *Journal of Bridge Engineering*, August, pg 208-215

Vijay C., Peter A., Paul J. T. (2004), "*South Bay Interchange: New Frontiers in Segmental Construction*", PB Networks Online Magazine, Feb, Issue No. 57, Vol. XIX, Number 1.
Website: http://www.pbworld.com

VSL Far East (2005) "*Post tensioning Systems*", VSL Engineering Pte. Ltd., Hong Kong.