In Prestressed Concrete Bridge Construction

The concept of prestressed concrete appeared in 1888 when P.H. Jackson was granted the first patent in the United States for prestressed concrete design. Jackson's idea was perfect, but the technology of high strength steel that exhibited low relaxation characteristics was not yet available. It was not until Eugene Freyssinet defined the need for these materials that prestressed concrete could be used as a structural building material. Unfortunately, although Freyssinet, a brilliant structural designer and bridge builder, lacked the teaching qualities necessary to communicate his ideas to other engineers. It would take Gustave Magnel to write the first book of design in prestressed concrete, communicating this idea to designers worldwide. Magnel designed and built the legendary Walnut Lane Bridge in Philadelphia, which revolutionized prestressed concrete in America. Simultaneously, Urlich Finsterwalder, the German bridge builder and designer, was revolutionizing the construction means and methods for prestressed concrete bridges. For example, Finsterwalder invented the free-cantilever construction method of prestressed concrete bridges, which allowed long span bridges to be constructed without stabilized shoring. He then designed stress-ribbon bridges, which would eventually allow prestressed concrete to span distances only steel suspension bridges could achieve. However, it wasn't until Paul Abeles and his peer, H. von Emperger studied and tested prestressed concrete that the idea of 0?partial prestressing0?+ emerged. Initially, Freyssinet and Magnel were adamant that prestressed concrete should not be allowed to exhibit any tensile forces at sustained loading. Later, the Roebling family developed the first stress--relieved wire followed by the first stress-- relieved strand. T.Y. Lin once again brought prestressed concrete back into the spotlight when he organized the First Prestressed Concrete World Conference in 1957. Shortly after this conference, Lin published a technical paper in the Prestressed Concrete Institute (PCI) Journal that introduced a new Load Balancing technique which allowed most structural engineers to design prestressed concrete very easily.

Since the first prestressed concrete bridge was built and launched by Freyssinet in 1941, such structures have soared to greater heights due to computer-aided design and innovative materials. Rosignoli, a consulting engineer practicing in Italy and abroad, distills aesthetic/environmental consciousn

Prestressed concrete decks are commonly used for bridges with spans between 25m and 450m and provide economic, durable and aesthetic solutions in most situations where bridges are needed. Concrete remains the most common material for bridge construction around the world, and prestressed concrete is frequently the material of choice. Extensively illustrated throughout, this invaluable book brings together all aspects of designing prestressed concrete bridge decks into one comprehensive volume. The book clearly explains the principles behind both the design and construction of prestressed concrete bridges, illustrating the interaction between the two. It covers all the different types of deck arrangement and the construction techniques used, ranging from in-situ slabs and precast beams; segmental construction and launched bridges; and cable-stayed structures. Included throughout the book are many examples of the different types of prestressed concrete decks used, with the design aspects of each discussed along with the general analysis and design process. Detailed descriptions of the prestressing components and systems used are also included. Prestressed Concrete Bridges is an essential reference book for both the experienced engineer and graduate who want to learn more about the subject. Prestressed Concrete is a very efficient form of construction; it takes advantage of the strength of concrete in compression. Developed mainly over the second part of the 20th century, it has proven to be reliable and durable. However, in the 1990's some cause for concern was discovered, first in the UK and followed by many other countries of the world. It appeared that the grout, an important means of protection of the steel against corrosion for internally ducted tendons, was in some cases inadequate. Major investigations followed including physical intrusive examination of ducts, mainly in bridges, and re-writing of procedures, processes and specifications, and in 1998 FIP launched a Task Group to review their advice note "Guidelines for Grouting" which had first been published in 1990. The merger of FIP and CEB in 1998 brought this under the auspices of fib. Structural deficiencies have only been found in a small number of bridges and in most of these cases the cause is clearly identifiable as either design detailing, workmanship or materials. In the UK, the Concrete Society report TR47 "Durable Post-tensioned Concrete Bridges" had been published in 1996, which was the culmination of four years of investigative research, and contained major new specifications and procedures aimed at improving the quality of grouting. In the USA, the Post Tensioning Institute published in 2001 their guide "Specification for Grouting of Post-Tensioned Structures", which also represented major steps forward in materials and testing requirements. The American Segmental Bridge Institute has set up a Committee to re-examine their guidelines, as have many other National Bodies worldwide. In Europe, France has issued a "Fascicule No. 65A" covering requirements for grouting and there are many developments in hand in other countries. Also in Europe, a European Technical Approval

Guideline (ETAG) has been published for approval of post-tensioning systems which covers several aspects of grout and grouting. In November 2001 an international workshop was held in Ghent, Belgium on "Durability of Post-Tensioning Tendons" [see fib Bulletin 15] at which international experience was exchanged. The theme was clearly apparent; those bridge owners that have looked, have found some problems with a few of their post-tensioned bridges. In most cases steps are being taken to repair existing bridges, where considered necessary, and to improve future construction by reviewing national specifications. Emphasis is being put on a multi-layer protection strategy whereby protection against corrosion is provided by waterproofing, dense impermeable concrete, sealed ducts and good quality grout. Design detailing and rain water management are seen as important aspects. It was, therefore, timely for fib to publish state-of-the-art guidelines to assist in developing and improving the quality of a major line of defence against corrosion, the cement grout. This document represents a consensus view of current practitioners of what is a rapidly developing awareness of some of the shortcomings of previous practice and suggests improvements. This document is a major update of the previous FIP Guidelines and may be taken as a future basis for updating EN 445-447. New areas include understanding of the deleterious effects of an unstable grout, bleeding and how to avoid it, the importance of training and proper procedures, mix design and testing/trials and some new test procedures. It is now understood and generally accepted that the properties of common grout made from cement and water can be very variable and sometimes unpredictable and such grout is not recommended.

A literature review concerning the objectives of the project was completed. A significant number of published papers, reports, etc., were examined to determine the effectiveness of full depth precast panels for bridge deck replacement. A detailed description of the experimental methodology was developed which includes design and fabrication of the panels and assembly of the bridge. The design and construction process was carried out in cooperation with the project Technical Review Panel. The major components of the bridge deck system were investigated. This includes the transverse joints and the different materials within the joint as well as composite action. The materials investigated within the joint were polymer concrete, non-shrink grout, and set-45 for the transverse joint. The transverse joints were subjected to direct shear tests, direct tension tests, and flexure tests. These tests exhibited the excellent behavior of the system in terms of strength and failure modes. Shear key tests were also conducted. The shear connection study focused on investigating the

composite behavior of the system based on varying the number of shear studs within a respective pocket as well as varying the number of pockets within a respective panel. The results indicated that this shear connection is extremely efficient in rendering the system under full composite action. Finite element analysis was conducted to determine the behavior of the shear connection prior to initiation of the actual full scale tests. In addition, finite element analysis was also performed with respect to the transverse joint tests in an effort to determine the behavior of the joints prior to actual testing. The most significant phase of the project was testing a full-scale model. The bridge was assembled in accordance with the procedures developed as part of the study on full-depth precast panels and the results obtained through this research. The system proved its effectiveness in withstanding the applied loading that exceeded eight times the truck loading in addition to the maximum negative and positive moment application. Only hairline cracking was observed in the deck at the maximum applied load. Of most significance was the fact that full composite action was achieved between the precast panels and the steel supporting system, and the exceptional performance of the transverse joint between adjacent panels.
The use of external prestressing is becoming more popular throughout Europe due to their expected higher durability and the possibility of active maintenance of

the prestressing cables. Questions have been raised about the behaviour of these structures beyond service loads. A comprehensive numerical analysis has been carried out comparing the behaviour of three different types of externally prestressed bridges to a conventionally internally prestressed bridge. The external types are a monolithically built bridge with external tendons, a monolithically built bridge with external tendons and blocked deviators, and a precast segmental bridge with external tendons. The internally prestressed bridge is monolithic. The primary objectives are to determine whether or not ductile failure occurs, i.e. the load-deflection response, and the tendon stress increase at ultimate stage. The results show that the monolithically built bridges have a considerable higher ultimate moment capacity as well as deflection. This shows the advantage of using continuous ordinary reinforcement. All externally prestressed types did not reach the capacities of the internally prestressed bridge. It was found that ductility depends mostly on the reinforcement within the cross-section. Externally prestressed girders have no prestressing cables in the cross-section and need sufficient ordinary reinforcement in order to deform ductile. Although the tendon stress increase up to failure in the actual analysis is remarkable, the discussion shows that the magnitude varies greatly depending on the layout of the whole structure.

This report was drafted by fib Task Group 6.4, Precast bridges: José Calavera (Convenor, Spain) André De Chefdebien (CERIB, France), David Fernández-Ordóñez (Prefabricados Castelo, S.A., Spain, Secretary), Antonello Gasperi (Consulting engineer, Italy), Jorge Ley (INTEMAC, Spain), Fritz Mönnig (Prof. Bechert & Partner, Germany), Pierre Passeman (CERIB, France), C. Quartel (Spanbeton BV, The Netherlands), Ladislav Sasek (VPU DECO Praha, Czech Republic), George Tootell (Buchan Concrete Ltd., UK), Arnold Van Acker (Belgium)

This book was written to make the material presented in my book, Stahlbetonbrucken, accessible to a larger number of engineers throughout the world. A work in English, the logical choice for this task, had been contemplated as Stahlbetonbrucken was still in its earliest stages of preparation. The early success of Stahlbetonbrucken provided significant impetus for the writing of Prestressed Concrete Bridges, which began soon after the publication of its predecessor. The present work is more than a mere translation of Stahlbetonbrucken. Errors in Stahlbetonbrucken that were detected after publication have been corrected. New material on the relation between cracking in concrete and corrosion of reinforce ment, prestressing with unbonded tendons, skew-girder bridges, and cable-stayed bridges has been added. Most

importantly, however, the presentation of the material has been extensively reworked to improve clarity and consistency. Prestressed Concrete Bridges can thus be regarded as a thoroughly new and improved edition of its predecessor.
This book gives bridge engineers clear guidance on design and includes 88 data sheets of design information, charts and check lists.
Also available via the Internet.
On a summer visit to her grandmother's cottage by the ocean, twelve-year-old Martha gains perspective on the death of a classmate, on her relationship with her grandmother, on her feelings for an older boy, and on her plans to be a writer.
Explores recommended guidelines for the use of self-consolidating concrete (SCC) in precast, prestressed concrete bridge elements. The report examines the selection of constituent materials, proportioning of concrete mixtures, testing methods, fresh and hardened concrete properties, production and quality control issues, and other aspects of SCC.
Precast pre-tensioned concrete bridge construction became common in New Zealand in the 1950s and a large number of pre-tensioned concrete bridges were constructed between 1953 and 1980. These bridges do not meet today's durability requirements and as such many are at risk of chloride induced pre-

tensioned reinforcement corrosion. This deterioration can be difficult to detect and has immediate structural implications, so identification of at-risk structures is critical for bridges to achieve their required service lives. This study aimed to expand on previous research into the deterioration of pre-tensioned I-Beam bridges, to obtain an accurate assessment of the severity, prevalence and distribution of corrosion risk to all of New Zealand's pre-tensioned prestressed concrete bridge assets. The NZ State Highway pre-tensioned bridge stock was analysed, and pre-tensioned bridges were categorised by construction era and beam type. The number of bridges in each category was assessed, and standard drawings and typical details are presented for common bridge types in New Zealand. A computer based distribution and exposure classification tool was developed that draws from international best practice asset management techniques and allows remote assessment of both individual bridges, and of the bridge stock as a whole. The exposure classification of each pre-tensioned concrete bridge on the State Highway network was remotely estimated using the tool, and these results were used to further categorise the bridge stock. A representative sample of 30 bridges was selected and subjected to a non-destructive testing regime. Trends identified in the inspections were applied back to the other bridges using the construction eras and beam types identified in this thesis. A key objective of this study was to identify pre-tensioned bridges in the wider bridge stock that were likely to be at risk of chloride induced corrosion, and recommend that they each be subjected to more thorough investigations to quantify and manage the corrosion risk to each structure. The tools developed in this thesis were intended to be used by asset managers and bridge inspectors in future assessments of New Zealand pre-tensioned bridges. The construction eras and beam types developed can be used to identify standard bridge plans and other design documents relevant to a given bridge, and to quickly discern general information about the structure. The distribution and exposure classification tool can be used to remotely assess bridges using road level and satellite photography. This thesis provided insight into the condition and durability of the New Zealand pre-tensioned concrete bridge stock. It is anticipated that the information presented will be used to identify at-risk bridges nationwide so that inspection schedules and mitigation or remediation works can be designed and performed effectively.

Accelerated Bridge Construction (ABC) has gained substantial popularity in new bridge construction and bridge deck replacement because it offers innovative construction techniques that result in time and cost savings when compared to traditional bridge construction practice. One technology commonly implemented

in ABC to effectively execute its projects is the use of prefabricated bridge components (precast/prestressed bridge components). Precast/prestressed bridge components are fabricated offsite or near the site and then connected on-site using small volume closure pour connections. Diaphragms are also commonly used to strengthen the connection between certain prefabricated components used in ABC, such as beam elements. Bridges containing closure pour connections and diaphragms can be designed using AASHTO LRFD live-load distribution factor formulas under the condition that the bridge must be sufficiently connected. However, these formulas were developed using analytical models that did not account for the effects of closure pours and diaphragms on live-load distribution. This research study investigates live-load distribution characteristics of precast/prestressed concrete bridges with closure pour connections and diaphragms. The investigation was conducted using finite element bridge models with closure pour joints that were calibrated using experimental data and different configuration of diaphragms. The concrete material used for the closure pour connections was developed as part of a larger project intended to develop high early-strength concrete mixtures that specifically reach strength in only 12 hours, a critical requirement for ABC projects.
In July 2006, construction began on an accelerated bridge project in Boone

County, Iowa that was composed of precast substructure elements and an innovative, precast deck panel system. The superstructure system consisted of full-depth deck panels that were prestressed in the transverse direction, and after installation on the prestressed concrete girders, post-tensioned in the longitudinal direction. Prior to construction, laboratory tests were completed on the precast abutment and pier cap elements. The substructure testing was to determine the punching shear strength of the elements. Post-tensioning testing and verification of the precast deck system was performed in the field. The forces in the tendons provided by the contractor were verified and losses due to the post-tensioning operation were measured. The stress (strain) distribution in the deck panels due to the post-tensioning was also measured and analyzed. The entire construction process for this bridge system was documented. Representatives from the Boone County Engineers Office, the prime contractor, precast fabricator, and researchers from Iowa State University provided feedback and suggestions for improving the constructibility of this design.

Throughout the United States accelerated bridge construction is becoming increasingly popular to meet growing transportation demands while keeping construction time and costs to a minimum. This research focuses on eliminating the need to form full-depth concrete bridge deck overhangs, accelerating the construction of concrete bridge decks, by using full-depth

precast prestressed concrete deck panels. Full-depth precast overhang panels in combination with cast-in-place (CIP) reinforced concrete are experimentally and analytically investigated to assess the structural performance. Experimental loaddeformation behavior for factored AASHTO LRFD design load limits is examined followed by the collapse capacity of the panel-to-panel seam that exists in the system. Adequate strength and stiffness of the proposed full-depth panels deem the design safe for implementation for the Rock Creek Bridge in Fort Worth, Texas. New failure theories are derived for interior and exterior bridge deck spans as present code-based predictions provide poor estimates of the ultimate capacity. A compound shear-flexure failure occurs at interior bays between the CIP topping and stay-in-place (SIP) panel. Overhang failure loads are characterized as a mixed failure of flexure on the loaded panel and shear at the panel-to-panel seam. Based on these results design recommendations are presented to optimize the reinforcing steel layout used in concrete bridge decks.
Prestressed Concrete BridgesDesign and ConstructionThomas Telford
The Texas Department of Transportation designs typical highway bridge structures as simple span systems using standard precast, pretensioned girders. Spans are limited to about 150 ft due to weight and length restrictions on transporting the precast girder units from the prestressing plant to the bridge site. Such bridge construction, while economical from an initial cost point of view, may become somewhat limiting when longer spans are needed. This project focused on developing additional economical design alternatives for longer span bridges with main spans ranging from 150-300 ft, using continuous precast, prestressed concrete bridge structures with in-span splices. Phase 1 of this study focused on evaluating the current state-of-the-art and practice relevant to continuous precast concrete girder bridges and recommending

suitable continuity connections for typical Texas bridge girders; the findings are documented in the Volume 1 project report. This report summarizes Phase 2 of the research including detailed design examples for shored and partially shored construction, results of a parametric design study, and results of an experimental program that tested a full-scale girder containing three splice connections. The parametric design study indicated that for bridges spanning from 150-300 ft, continuous precast, prestressed concrete girder bridges with in-span splices can provide an economical alternative to steel girder bridges and segmental concrete box girder construction. The tested splice connections performed well under service level loads. However, the lack of continuity of the pretensioning through the splice connection region had a significant impact on the behavior at higher loads approaching ultimate conditions. Improved connection behavior at ultimate conditions is expected through enhanced connection details. Recommendations for design of continuous spliced precast girders, along with several detailing suggestions are discussed in the report.

The spans of precast prestressed concrete bridge girders have become longer to provide more economical and safer transportation structures. As the spans have increased, so has the depth of the girders which in turn have increased the slenderness of the girders. Slenderness in a beam or girder would increase the likelihood that a stability failure would occur. Stability failures could pose a danger to construction personnel due to the sudden nature in which a stability failure would occur. Furthermore, stability failures of prestressed concrete girders during construction would cause a detrimental economic impact due to the costs associated with the failure of the girder, the ensuing construction delays, damage to construction equipment and potential closures to highways over which the bridge was being constructed.

This book was written with a dual purpose, as a reference book for practicing engineers and as a textbook for students of prestressed concrete. It represents the fifth generation of books on this subject written by its author. Significant additions and revisions have been made in this edition. Chapters 2 and 3 contain new material intended to assist the engineer in understanding factors affecting the time-dependent properties of the reinforcement and concrete used in prestressing concrete, as well as to facilitate the evaluation of their effects on prestress loss and deflection. Flexural strength, shear strength, and bond of prestressed concrete members were treated in a single chapter in the of flexural strength has third edition. Now, in the fourth edition, the treatment been expanded, with more emphasis on strain compatibility, and placed in Chapter 5 which is devoted to this subject alone. Chapter 6 of this edition, on flexural-shear strength, torsional strength, and bond of prestressed reinforce ment, was expanded to include discussions of Compression Field Theory and torsion that were not treated in the earlier editions. In similar fashion, expanded discussions of loss of prestress, deflection, and partial prestressing now are presented separately, in Chapter 7. Minor additions and revisions have been made to the material contained in the remaining chapters with the exception of xv xvi I PREFACE Chapter 17. This chapter, which is devoted to construction considerations, has important new material on constructibility and tolerances as related to prestressed concrete.

Methods and practices for constructing sophisticated prestressedconcrete structures. Construction of Prestressed Concrete Structures, Second Edition,provides the engineer or construction contractor with a completeguide to the design and construction of modern, high-qualityconcrete structures. This highly practicable new edition of Ben C.Gerwick's classic guide is expanded and almost entirely rewrittento reflect the dramatic developments in materials and techniquesthat have occurred over the past two decades. The first of the book's two sections deals with materials andtechniques for prestressed concrete, including the latest recipesfor high-strength and durable concrete mixes, new reinforcingmaterials and their placement patterns, modern prestressingsystems, and special techniques such as lightweight concrete andcomposite construction. The second section covers application tobuildings; bridges; pilings; and marine structures, includingoffshore platforms, floating structures, tanks, and containments.Special subjects such as cracking and corrosion, repair andstrengthening of existing structures, and construction in remoteareas are presented in the final chapters. For engineers and construction contractors involved in any type ofprestressed concrete construction, this book enables the effectiveimplementation of advanced structural concepts and their economicaland reliable translation into practice. Precast prestressed concrete panels have been used as subdecks in bridge construction in Iowa and other states. To investigate the performance of these types of composite slabs at locations adjacent to abutment and pier diaphragms in skewed bridges, a research project which involved surveys of design agencies and precast producers, field inspections of existing bridges, analytical studies, and experimental testing was conducted. The survey results from the design agencies and panel producers showed that standardization of precast panel construction would be desirable, that additional inspections at the precast plant and at the bridge site would be beneficial, and that some form of economical study should be undertaken to determine actual cost savings associated with composite slab construction. Three bridges in Hardin County, Iowa were inspected to observe general geometric relationships, construction details, and to note the visual condition of the bridges. Hairline cracks beneath several of the prestressing strands in many of the precast panels were observed, and a slight discoloration of the concrete was seen beneath most of the strands. Also, some rust staining was visible at isolated locations on several panels. Based on the findings of these inspections, future inspections are recommended to monitor the condition of these and other bridges constructed with precast panel subdecks. Five full-scale composite slab specimens were constructed in the Structural Engineering Laboratory at Iowa State University. One specimen modeled bridge deck conditions which are not adjacent to abutment or pier diaphragms, and the other four specimens represented the geometric conditions which occur for skewed diaphragms of 0, 15, 30, and 40 degrees. The specimens were subjected to wheel loads of service and factored level magnitudes at many locations on the slab surface and to concentrated loads which produced failure of the composite slab. The measured slab deflections and bending strains at both service and factored load levels compared reasonably well with the results predicted by simplified Finite element analyses of the specimens. To analytically evaluate the nominal strength for a composite slab specimen, yield-line and punching shear theories were applied. Yield-line limit loads were computed using the crack patterns generated during an ultimate strength test. In most cases, these analyses indicated that the failure mode was not flexural. Since the punching shear limit loads in most instances were close to the failure loads, and since the failure surfaces immediately adjacent to the wheel load footprint appeared to be a truncated prism shape, the probable failure mode for all of the specimens was punching shear. The development lengths for the prestressing strands in the rectangular and trapezoidal shaped panels was qualitatively investigated by monitoring strand slippage at the ends of selected prestressing strands. The initial strand transfer length was established experimentally by monitoring concrete strains during strand detensioning, and this length was verified analytically by a finite element analysis. Even though the computed strand embedment lengths in the panels were not sufficient to fully develop the ultimate strand stress, sufficient stab strength existed. Composite behavior for the slab specimens was evaluated by monitoring slippage between a panel and the topping slab and by computation of the difference in the flexural strains between the top of the precast panel and the underside of the topping slab at various locations. Prior to the failure of a composite slab specimen, a localized loss of composite behavior was detected. The static load strength performance of the composite slab specimens significantly exceeded the design load requirements. Even with skew angles of up to 40 degrees, the nominal strength of the slabs did not appear to be affected when the ultimate strength test load was positioned on the portion of each slab containing the trapezoidal-shaped panel. At service and factored level loads, the joint between precast panels did not appear to influence the load distribution along the length of the specimens. Based on the static load strength of the composite slab specimens, the continued use of precast panels as subdecks in bridge deck construction is recommended.

Right from the inception of the implementation of prestressed concrete in the bridge construction field, it has been very popular. Even though this type of bridges has big advantages, cracking is a major problem. The cracking event, due to its detrimental effects on the structure is the most objectionable problem. In cracking shrinkage plays a very significant role. This implies that the study of shrinkage is essential to study the phenomenon of cracking. Due to many variables responsible for deck cracking, it is very difficult to study the overall effect of these variegated factors taken in the consideration at a time. This thesis aims to confluence as many such aspects as possible in a single plane of consideration with the help of Finite Element software namely ABAQUS. The goal of this research is to study shrinkage, shrinkage effects, and factors affecting the shrinkage and ultimately to incorporate the shrinkage effects in Finite Element Modeling. Here the study is constrained to Prestressed Concrete Bridge. Thus, the research is carried to incorporate the shrinkage effects in FE Modeling of

Prestressed Concrete Bridge. This is a difficult task as many finite element programs do not have pre-programmed methods for simulating the time dependent properties of concrete. Therefore, it is necessary to develop these methods. This study concentrates on trying to simulate the behavior of a simple span bridge as a means of developing the basic analytical method. In the research Abaqus has been selected and the selection has been justified for the purpose of analyzing time dependent effects in bridges. A parametric study has been carried out with a view to identifying the effects of various parameters of shrinkage in a structure. The effects of the parameters such as length of the span, girder spacing, deck thickness and modulus of elasticity of girder have been analyzed with the help of bridges modeled in Abaqus. The parametric study concludes that shrinkage strain increases with increase in length and spacing of girder. The shrinkage strain decreases with increase in compressive strength of girder and deck thickness.

An effective, viable design solution for the elevated viaduct guideway for Universal Freight Shuttle (UFS) system championed by Texas Transportation Institute (TTI) is presented. The proposed precast elevated UFS bridge system is analyzed for the operational vehicular loading as provided by TTI and a number of design alternatives for the various bridge components are provided. These includes: the design of the fully precast deck panels for long continuous spans, design of the shear connectors resisting interface shear at bridge deck-girder interface, design of structurally efficient and cost-effective trough girders and its design alternative with I-girders, and economic and long-term serviceable design of bridge piers. A literature review and study of the existing precast bridges is presented for the state-of-the-art and practice, design specifications and publications by AASHTO, State Department of Transportation and other agencies. These existing systems are refined to determine the most appropriate specification for the proposed bridge components by integrating the planning, design, fabrication and construction techniques to ensure high precision freight shuttle movement, construction feasibility, safety, life-cycle cost, durability and serviceability requirements. The design concept presented is a deviation from the conventional railways and highways design. The best practices and specifications of AASHTO and AREMA are combined suitably in this research to suit the major requirements of the project. A combination of the design philosophy with appropriate construction techniques has been blended to devise a system which is efficient for offsite manufacture of components for construction of the bridge and adaptable to the different bridge configurations. Based on the design results, it is found that precast concrete deck panels in combination with precast, prestressed concrete trough girders provides the most efficient superstructure solution for this project. The Damage Avoidance Design for the precast bridge piers along with the precast superstructure provides a system with comparable structural performance along with other benefits such as long term serviceability, economical sections, practically transportable units, modular simplicity for relocation as desired and ability to

offer space for commercial usage. The steps for construction of the bridge is schematically presented and sequentially explained. The electronic version of this dissertation is accessible from http://hdl.handle.net/1969.1/150928
An extensively illustrated handbook summarizing the current state of the art of design and construction methods for all types of segmental bridges. Covers construction methodology, design techniques, economics, and erection of girder type bridges; arch, rigid frame, and truss bridges; cable-stayed bridges; and railroad bridges.