PRACTICAL GUIDANCE FOR DESIGNING LIGHTWEIGHT CONCRETE BRIDGES – THE FHWA *LIGHTWEIGHT CONCRETE DESIGN PRIMER*

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INTRODUCTION

Lightweight concrete has the obvious benefit of reducing the weight of large precast elements often used for ABC projects. This can save project costs by reducing the equipment requirements for handling, transporting and erecting the elements. Lightweight concrete has also been used to allow the use of fewer, larger elements to avoid joints in a structure, to allow reuse of existing substructure elements, to avoid driving additional piling, to allow widening of bridges without modification of the substructure or superstructure, and to reduce the mass of a bridge on a seismic site. It has also been demonstrated both in laboratories and through field experience that lightweight concrete has durability equal to or greater than conventional concrete of the same quality. While some engineers are not familiar with lightweight concrete, it is not a new material – it has been available commercially in the US since 1920, and has been used in bridges such as the upper deck of the San Francisco Oakland Bay Bridge, which was constructed in 1936 using 95 pcf lightweight concrete, that is still in service today.

However, many engineers are reluctant to use lightweight concrete in their bridge designs because they are not familiar with the material and how to use it. Others have attempted to use lightweight concrete in past projects but had found that the requirements for lightweight concrete in the *AASHTO LRFD Bridge Design Specifications* made the use of the material more costly and less efficient. Therefore, they gave up trying to consider it in their projects.

This paper introduces a *Lightweight Concrete Design Primer* that is being developed for FHWA to address these issues by gathering the information needed for design of lightweight concrete bridges into a single concise document.

DOCUMENT BACKGROUND

A process to produce structural lightweight aggregate by expanding slate, clay, and shale at high temperatures using a rotary kiln was patented in 1918. Use of the material began immediately but increased significantly when the patent expired in the 1950s. At that time, the Expanded Shale, Clay and Slate Institute (ESCSI) was formed, which pursued the development and marketing of lightweight aggregate in the US. Rapid growth in the use of lightweight concrete continued until the mid-1970s when the cost to produce lightweight aggregate increased because of increased fuel prices caused by the fuel crisis and increased production costs due to the introduction of pollution controls. With increased costs, the industry contracted, resulting in the curtailing of development and promotional efforts.

In the early 2000s, FHWA recognized that lightweight concrete had potential for improving the economy and performance of bridges but was being under-utilized. Additional information needed in marketplace to encourage its use, including research to answer several questions, such as the performance of “specified density” concrete in range between lightweight and normal weight concrete.

In 2005, the Federal SAFETEA-LU legislation included funds for FHWA to use for research on high performance concrete (HPC). These funds were directed to studying lightweight concrete at FHWA’s Turner Fairbank Highway Research Center. These efforts were coordinated with NCHRP Project 18-15 titled “High-Performance/High-Strength Lightweight Concrete for Bridge Girders and Decks” which resulted in Report 733 (2013).

Using the results of the two research efforts and earlier work, FHWA spearheaded development of revisions to the LRFD Specifications that were adopted by AASHTO. In 2014, a new equation for the modulus of elasticity was adopted by AASHTO that provided better results for lightweight and high strength concretes. This change was followed by a much broader revision of the specifications that was adopted in 2015, which included a new definition for lightweight concrete, introduction of the concrete density modification factor, λ, and insertion of λ into equations where appropriate.

However, it still appeared that the marketplace needed more information about design of lightweight concrete bridges to encourage wider use of the material. Designers and owners did not seem comfortable with using lightweight concrete, and some misconceptions about lightweight concrete existed.

Therefore, a lightweight concrete design primer was identified as a product that would be useful to advance the use of lightweight for bridge design. It was envisioned that the document would provide a concise summary of the full range of information needed to design a lightweight concrete bridge. The document would also highlight benefits of lightweight concrete in various applications and cover primary design and construction subject areas needed to design lightweight concrete highway structures. It would also identify and describe recent changes in the *AASHTO LRFD Bridge Design Specifications* related to lightweight concrete as well as providing guidance on using lightweight aggregate for internal curing. A webinar and seminar based on the completed primer would also be developed and presented.

DOCUMENT DEVELOPMENT AND CONTENTS

Development of the primer has begun. A preliminary draft was completed and reviewed by FHWA. A final draft is currently in review. It had been hoped that the work would have progressed farther by the time of the conference. Therefore, this presentation is based on the unreviewed draft, so the information presented is still preliminary. Since the primer is intended to be a “concise” document, it will not be comprehensive, but will cover necessary topics.

The current table of contents is:

1. Introduction
2. Properties of Lightweight Aggregate and Lightweight Concrete
3. Initial Design Considerations
4. Design for Lightweight Concrete using LRFD Specifications
5. Construction Considerations
6. Specifying Lightweight Concrete
7. Project Examples
8. Cited References

Chapter 1 provides a definition of lightweight concrete and points out that it is not a new material. Lightweight concrete has been mentioned in the AASHTO design specifications since at least 1969. A detailed FHWA report on lightweight concrete for bridges was developed by TY Lin International and was published in 1985 that pointed out that the material had a “sufficient record of successful applications to make it a suitable construction material … for bridges” and that “sufficient information is available on all aspects of its performance for design and construction purposes.” This chapter discusses briefly some advantages and perceived disadvantages of lightweight concrete, followed by three examples of projects that have used lightweight concrete.

Chapter 2 provides data on material and durability properties of both lightweight aggregate and lightweight concrete, along with properties used for seismic applications and service life estimation. The concept of internal curing, which uses the increased absorption of lightweight aggregate to deliver curing water to the interior of concrete elements, is introduced.

Chapter 3 discusses in greater detail the reasons for which the use of lightweight concrete in bridges should be considered, such as reduced weight and enhanced durability. The types of elements for which lightweight concrete is typically used is also discussed. The chapter provides guidance on the selection of material properties for lightweight concrete for use in design, considerations for estimating the cost of

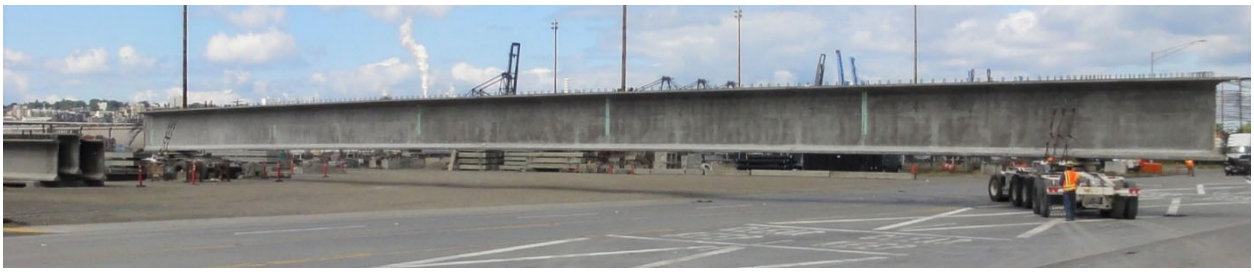
lightweight concrete, and design considerations for different elements and structure types. Much of this guidance has not been readily available in the past.

Chapter 4 presents the major recent changes in the LRFD Specifications related to lightweight concrete. The document then provides discussion of each article in the design specifications that address the use of lightweight concrete, or where it is significant that lightweight is not mentioned. During development of the primer, items were identified that may need to be considered for future revisions. These items are noted as they are presented in the chapter.

Chapter 5 discusses a wide range of construction topics that should be considered, or that the designer should be aware of, when using lightweight concrete in the design of a bridge. These topics include quality control, proportioning of mixtures, prewetting lightweight aggregate, batching, placing, finishing, curing, grinding and grooving, and heat of hydration.

Chapter 6 provides guidance in topics that should be considered when specifying lightweight concrete for a structure, such as concrete density, material properties, test methods, construction specifications, and topics particular to Internal curing.

Chapter 7 gives information for a limited list of bridges for which lightweight concrete has been successfully used. Many more bridges could have been included; references are mentioned which given further examples. Examples are included to give designers ideas about the range of potential types of applications in brides, and to give examples where lightweight concrete provided an economical solution. The list provided includes a wide range of bridge projects that are large and small, new and old, and include decks to pretensioned girders, and segmental box girders to suspension bridges. It is noted that the longest single-piece pretensioned girder fabricated in the US (223 ft plus skews) required lightweight concrete for shipping, and the three longest-span concrete segmental box girder bridges erected using balanced-cantilever construction in the world all use lightweight concrete in their main spans to achieve the record span lengths, the longest of which is 987 ft.



Longest single-piece pretensioned precast concrete girder in the US, which required lightweight concrete to reduce the girder weight for transportation to the project site. The girder is 223 ft long at the centerline, but is heavily skewed so it is 230 ft long from end to end. Photo: Concrete Technology Corp.

Chapter 8 provides over 160 references that allow readers to obtain more information on material properties, projects, and other topics related to lightweight concrete and internal curing if needed.

It is anticipated that the primer will be published in 2020, followed by a webinar and seminar that will summarize the content of the primer.