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16. Abstract

This report presents to TxDOT a proposed manual that outlines a comprehensive approach to bridge superstructure and substructure design to improve both aesthetics and efficiency of short- and medium-span bridges

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AESTHETICS AND EFFICIENCY GUIDELINES FOR SHORT AND MODERATE SPAN BRIDGES

BY

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JOHN E. BREEN AND D. ANDREW VERNOOY

Research Report No. 1410-1

Research Project 0-1410

"Aesthetics and Efficient New Substructure Designs for Standard Bridge Systems"

conducted for the

Texas Department of Transportation

IN COOPERATION WITH THE

U.S. Department of Transportation

Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH

BUREAU OF ENGINEERING RESEARCH

THE UNIVERSITY OF TEXAS AT AUSTIN

October 1997

This report was prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

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John E. Breen, P.E. (Texas No. 18479)
Research Supervisor

ACKNOWLEDGEMENTS

The aesthetic guideline development phase of this project had many important contributors. Special recognition must be given to Scot Listavich who developed a first draft of the guidelines that was extremely important as a foundation for the overall direction. Similarly, Scot and Robbie Barnes through wide-ranging photo trips across Texas, provided many of the illustrations used. Carl Holliday added a great deal with sketches and models. More than with most projects, the TxDOT project directors from the Design Division worked very closely and contributed much information, ideas, advise and encouragement. Norman Friedman's input and enthusiasm for this project contributed greatly. His successor, Dean Van Landuyt, brought extremely helpful outlook and experience which helped shape the final form.

TxDOT engineers from the Austin, Corpus Christi, Dallas, El Paso, Houston, Pharr, San Angelo and Wichita Falls districts provided important inputs and constructive criticism. Representatives from design, precasting, forming, and construction industries provided invaluable practical guidance. Finally, a special acknowledgment is in order for Theresa Augsburger of University Publications who designed and typeset the layout for the Guidelines. She performed a highly professional role under tight time constraints.

The senior author of this report, Dr. Sarah L. Billington, deserves special recognition. Most of the report is taken fairly directly from her doctoral dissertation. She is an able and gifted engineer, steeped in bridge history and an appreciation and deep understanding of bridge aesthetics.

IMPLEMENTATION

This report presents to TxDOT a proposed manual which outlines a comprehensive approach to bridge superstructure and substructure to improve both aesthetics and efficiency of short- and medium-span bridges.

It is envisioned by the authors that dissemination of the basic report (without Appendix C) would be in typical black-and-white format and to the more traditional limited report distribution list with copies available on request from interested parties. On the other hand, the Aesthetic Guidelines (Appendix C) are designed to be an attractive color print manual, distributed widely through TxDOT and available for public purchase by transportation agencies, consultants and others.

The TxDOT Aesthetics & Efficiency Guidelines should be distributed to highway planners and bridge engineers throughout the State. In addition to the Design Division and the District Design Offices, it is essential that highway planners in the area offices around the State receive copies of the Guidelines. Many of the decisions affecting bridge aesthetics and in particular the geometric layout, are made at the preliminary stages of design by highway planners. The Guidelines point to the importance of these decisions on the development of attractive and efficient bridges. With all parties involved in bridge design aware of the aesthetic consequences of their decisions, there can be more understanding and communication between the parties.

The successful use of Guidelines in both Maryland and Minnesota have been initiated by short courses led by the developers of their Guidelines. Short courses give engineers an opportunity to focus on how to use the manual. Typically such a short course ends with a design competition between groups of engineers working on an existing standard bridge project. These short courses have been well received and a valuable learning tool. A strong introduction in the use of Guidelines will make future use of the Guidelines easier.

The Aesthetics & Efficiency Guidelines may also be conveniently implemented during Value Engineering meetings. Value Engineering meetings are typically held for bridge projects in highly visible or highly controversial sites. Focusing on aesthetics and efficiency while striving for an economical solution will be useful for Value Engineering sessions.

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SUMMARY

Designed for economy and function alone, standard highway bridges of short and moderate spans often detract from rather than enhance the environment in which they are built. Such an unimaginative display of structural engineering does little to express the rapid growth and exciting advancement of this profession.

Aesthetics & Efficiency Guidelines have been developed that are primarily intended for use by bridge and highway engineers designing standard short and moderate span bridges with an emphasis on bridges using precast concrete superstructures. Four example applications of the Guidelines to standard bridge projects in Texas show general approaches and varied economic benefits and/or costs.

An outline of the Guidelines is given in Figure 3.71. The entire Guidelines are presented in Appendix C of this report. The Guidelines are organized in the order of the design process. They contain suggestions of what to consider at each phase of design to lead to efficient and aesthetically pleasing structures. Typical decisions which can enhance aesthetics are illustrated and are related directly to other considerations such as function, safety, serviceability and economics. Possible aesthetic improvements are pointed out while still utilizing the most suitable and economical structural shapes and standard bridge components.

In each of the chapters covering the design process (Chapters 2-5), the many design options in terms of structural systems are presented. Potential aesthetic results or improvements are discussed. Each topic is presented along with illustrations of its relevance and effect on aesthetic results as well as implications for efficiency. Suggestions are given for the best implementation of proposed ideas. Case studies are made at each design step to outline aesthetic improvements and potential economic impacts of the suggestions offered.

At the conclusion of the guidelines, a chapter entitled "Particular Settings" addresses the most important considerations for given scenarios and site conditions. These scenarios include urban expressways, causeways, urban interchanges, overcrossings in both urban and rural settings, and bridges in environmentally sensitive areas. An additional small chapter is included that covers issues to consider when widening existing bridges.

Appendix A to the Guidelines presents different aesthetic "techniques" that may be employed throughout the design such as proportioning systems or optical corrections. These are techniques typically taught in architecture schools but rarely introduced in engineering education. These are helpful tools that are simple to use and easy to learn. Appendix B to the Guidelines presents information on surface treatments for concrete. Surface treatments discussed include exposed aggregate, formliners, color through staining or painting, and concrete pavers. These surface treatments are discussed in terms of aesthetic options, typical uses, maintenance concerns and relative costs. Appendix C to the Guidelines presents an alternative substructure system that is made up of primarily precast (match cast) column and cap elements. This system is presented more fully in Report 1410-2F.

Important background concerning literature review, photographic surveys, surveys of the public and interviews with TxDOT personnel are included as well as the history and philosophy behind the aesthetic guidelines.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Bridges are an essential part of any infrastructure. They span countless obstacles to connect the roads of our highway systems. Bridges can be found in a variety of settings from congested urban areas to under-populated rural locations to beloved park environments. Many bridges are in highly visible and dramatic settings. As a result, these structures have caught the imagination of the public, in particular of many writers and artists, in the past (Figures 1.1-1.2).

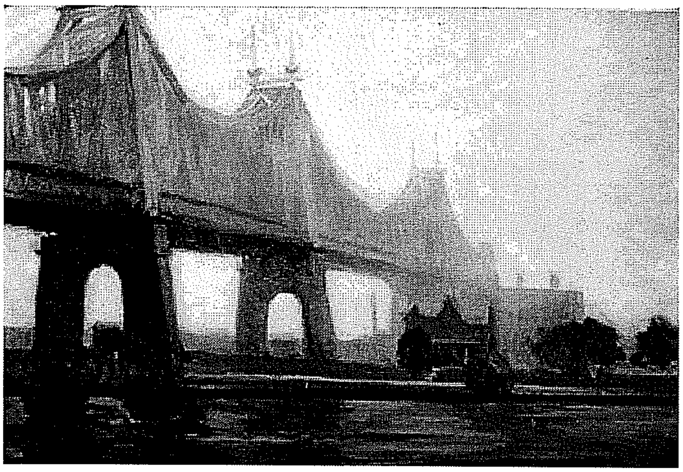


Figure 1. 1 "Queensborough Bridge," Edward Hopper, 1913

The vast majority of the world's bridges are of short and moderate spans. Yet it is not these most common bridges but rather the monumental long-span bridges that are the most noticeable and striking due to their size and often scenic settings. Many long-span monumental bridges are considered works of structural art[1]. The much more prevalent short and moderate span bridges simply remain functional and non-descript (Figure 1.3). It is these more moderate-sized bridges which dominate our highway landscape yet typically fail to catch even the imagination of the engineers who design them.

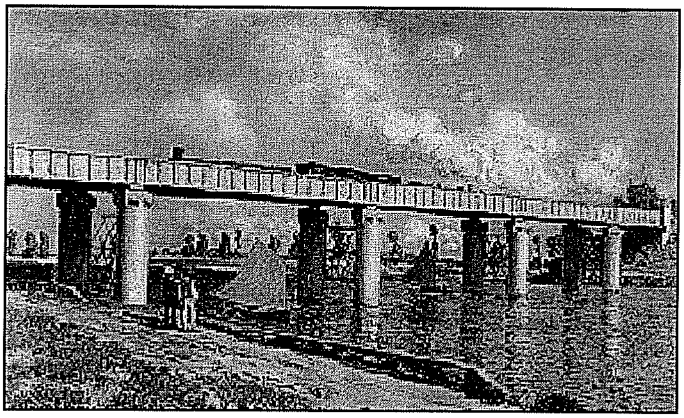


Figure 1. 2 "The Railroad Bridge at Argenteuil," Claude Monet, 1873

Designed for economy and function alone, standard highway bridges of short and moderate spans often detract from rather than enhance the environment in which they are built. Such an unimaginative display of structural engineering does little to express the rapid growth and exciting developments in this profession. Rapid advances in the state-of-the-art of engineering design, materials and construction provide engineers with countless new options for short and moderate span bridge design. High performance materials, advanced methods of fabrication and innovative construction techniques may now be combined in new ways to result in different forms and original solutions for bridge design. Engineers must

Figure 1. 3 A typical standard overpass in Texas

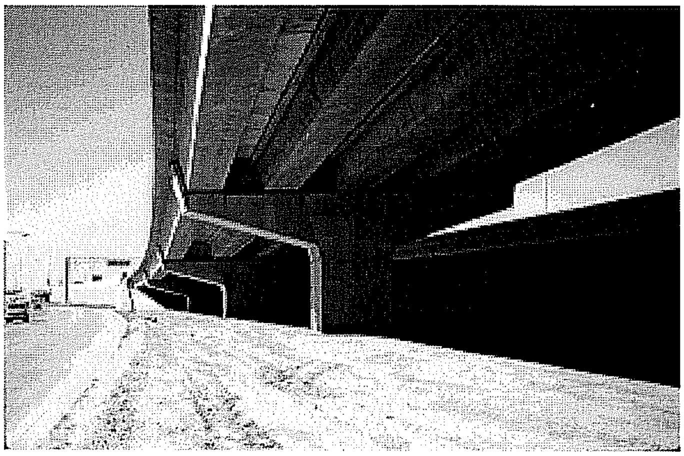


Figure 1. 4 The Texas U-beams were developed with aesthetics in mind

now take on the challenge to design bridges that are not only functional and economical, but attractive additions to their landscape.

The call for more attractive bridges has been made throughout the world. Top structural engineers from many countries are eager to share their design ideas and their collective belief that it is the duty of all structural engineers to design efficient *and* attractive structures[2,3]. Much of the attention on bridge aesthetics has been paid to long-span bridges, while short and moderate span bridges have largely been overlooked. Designers are just beginning to address the appearance of shorter span bridges. While there is certainly a large amount of literature calling for better bridge aesthetics (Appendix A), it is now timely that more attractive bridges *be built*, not just "called for."

Many State DOT's have made important steps resulting in the construction of more attractive bridges. State DOT's in particular are now more concerned with maintaining a positive image with the tax-paying public and are therefore taking steps toward the development of a more attractive infrastructure. Many States have developed Aesthetics Guidelines for the design of more attractive bridges.[4,5] The Texas DOT (TxDOT) has made great strides towards improving the appearance of their bridges through the development of U-beams and trapezoidal box beams particularly for urban areas (Figure 1.4). An increased use of attractive retaining wall patterns (Figure 1.5) and new railing types (Figure 1.6) has also added to the recent improvement of highway bridge aesthetics. TxDOT is now expanding the State's Roadway Beautification program to include the bridges of their highway system (Figure 1.7).

Many more significant improvements can be made to the standard bridges of Texas. An increased awareness by highway planners and bridge designers of the visual effect of their engineering decisions is necessary for the design and construction of more attractive structures. As every element of a bridge will affect its appearance, it is time for engineers to look at the appearance of every element. In particular, attractive substructure designs that provide an alternate to the current common practice of cast-in-place circular columns with prismatic bent caps and more attention given to the planning and layout stage of design will greatly improve the aesthetics of standard highway bridges. Attention to non-structural details such as drainage, joint types and materials, color and texture of concrete, and how these details may enhance or detract from a well thought-out project will also make considerable improvements to the appearance of these bridges (Figures 1.8-1.9).

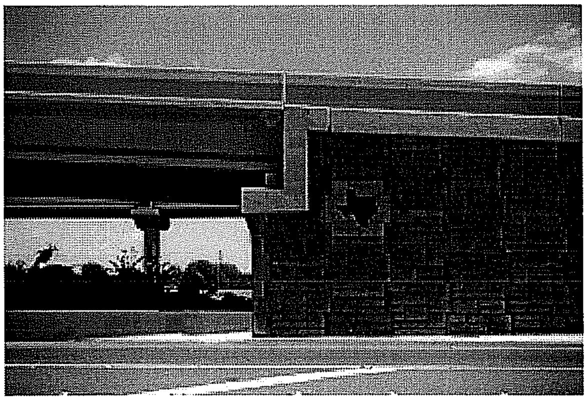


Figure 1. 5 *A variety of attractive retaining wall patterns are available today*

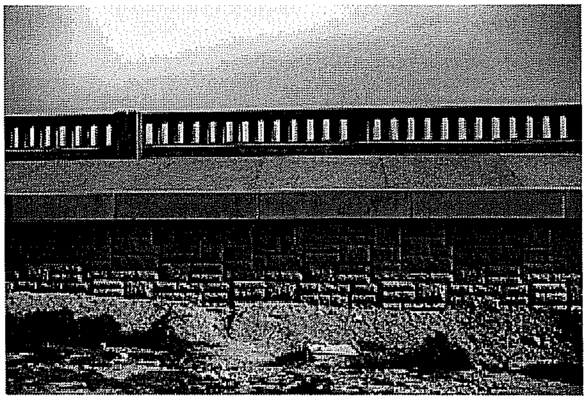


Figure 1. 6 *The recently developed C411 rail series used in Texas*

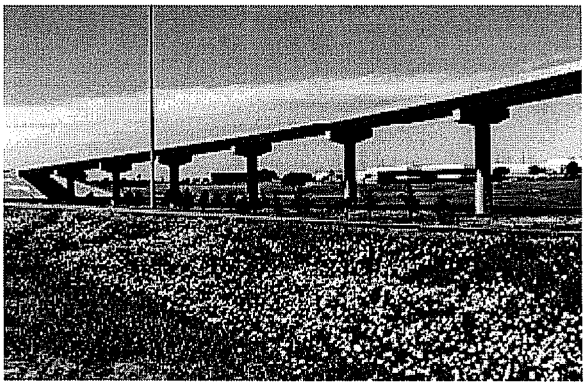


Figure 1. 7 *Wildflowers bloom along many Texas highways each Spring*

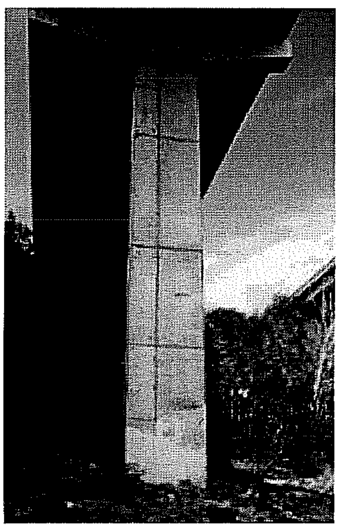


Figure 1. 8 *Lack of attention to concrete finish results in an unattractive pier*

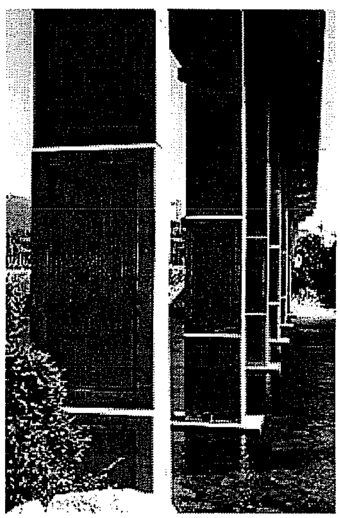


Figure 1. 9 *Simple use of formliners provide an attractive finish*

More attention must be given to the environment in which a new bridge will be built. It is wrong to assume that the same standard bridge will be appropriate to cross I-10 through Houston, a stream in the Hill Country, the Rio Grande in El Paso and a highway overpass in East Texas. Economics currently dictate a few standard bridge types for such a variety of settings. As a result, designers are remaining "prisoners of the familiar," designing the same bridge for sites with a variety of constraints and characters. In particular, substructures are a major visual disturbance for these standard bridges. Additionally, current cast-in-place substructure construction leads to extensive traffic delays and rerouting headaches. Little effort has been made to investigate new substructure shapes, designs and construction methods.

Short and moderate span bridge design in Texas has been dominated in the past 20 years by precast pretensioned concrete superstructure bridges (Figure 1.10). This began in the 1950's when precast prestressed concrete was first introduced in the United States. Soon after, with the introduction of high strength steel for prestressing, prestressed concrete became a very economical and durable alternative for bridge construction. The development of highly efficient plant production methods for precasting has kept this form of construction economical. State-owned bridges in particular (Figure 1.10b) are

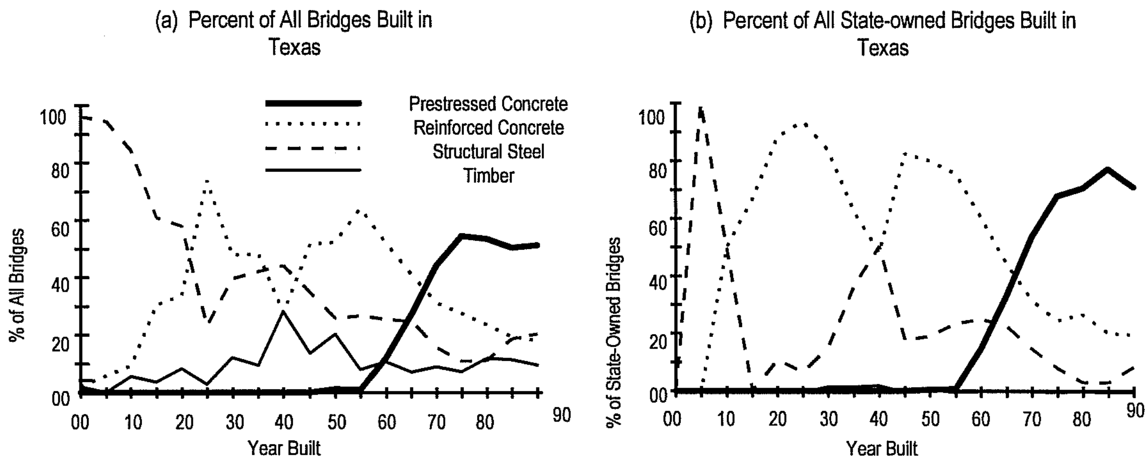


Figure 1. 10   Bridge types built in Texas since 1900

predominantly prestressed concrete because they are durable and economically most competitive. In 1996, these bridges typically cost $310 per square meter ($29 per square foot). Precast concrete superstructure systems were used for 75-80% of new highway construction let in Texas between September 1994 and August 1995. (During this time, all new construction in Texas averaged $345/m^2 ($32/ft^2). In 1994, only 5 other States had averages below $430/m^2 ($40/ft^2) while the national average was $710/m^2 ($66/ft^2).)

The high repetition of precast superstructure elements, low cost of labor and availability of concrete all contribute to this very economical bridge type. The superstructure girders are slim, efficient and often attractive. However, many problems have been identified with the substructures of these bridges. The predominantly cast-in-place substructures are typically the least durable element of these bridges, particularly in aggressive environments.[6] On-site labor and construction of the substructure often leads to excessive and undesirable traffic delays (Figure 1.11). The unattractive forest of columns created by the multi-column bent substructures is an unfortunate addition to any environment. For these many reasons, alternative substructure designs and construction methods are being investigated.

Figure 1. 11 *Extensive on-site equipment for cast-in-place multi-column bents*

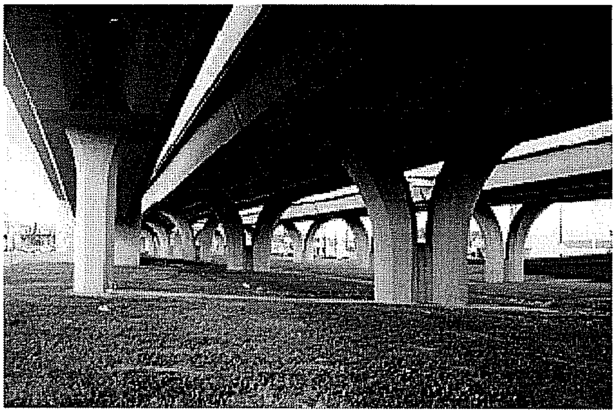


Figure 1. 12 *An attractive cast-in-place substructure*

Precasting offers an alternative for substructure design that can move much of substructure fabrication off-site and into the precasting plant. The efficiency of mass production and the high quality control of fabrication in a precasting plant has made precast superstructure elements an extremely economical form of construction. These same techniques may certainly be applied to substructure elements. On-site labor and construction time will be shortened thus substantially reducing traffic delays and rerouting during construction. High performance concrete may be used more consistently with higher quality control in a precast plant. This should result in more durable substructures with a higher quality and more attractive finish. The higher strength of high performance concrete allows for hollow sections. Hollow sections result in material savings, keep hauling and erection weights low and decrease foundation costs. The use of post-tensioning with precast substructures can further improve durability by eliminating cracking under service loads and providing stiffer vertical elements to keep lateral deflections low.

The repetitive use of cast-in-place formwork for a few standard column shapes has proven economical in the past. New problems now call for new solutions using state-of-the-art technology. In particular, problems such as durability, quality control, construction time, the impact construction has on the environment, and bridge aesthetics must be addressed. Precasting is one option for improved substructure design. Repetition of forms is essential to keep the bridges economical. Any proposed precast systems for standardization must be applicable to a wide range of problems. As precasting will not be advantageous for every bridge site, new cast-in-place shapes should be investigated - ones that use a higher quality of concrete, and have careful attention paid to their details to improve durability and prevent unwanted staining (Figure 1.12).

Recognizing that the creative imagination of engineers is often stifled rather than cultivated in many engineering offices and in typical engineering curricula, a research project was proposed to the Texas Department of Transportation (TxDOT) by the University of Texas at Austin Center for Transportation Research (CTR) to address the problem of the efficiency and aesthetics of Texas' short and moderate span bridges and their substructure systems. By addressing efficiency, or the minimization of wasted material and construction time, the function and construction of the bridge is tied more closely to the economy of the bridge. The precast superstructure systems so commonly used throughout Texas have been proven successful through their efficiency, elegance and economy. Through CTR Project 0-1410, attention is now being turned towards improved substructure design, to advance the proud Texas tradition of building functional, economical and attractive bridges for their highway system.

1.2 Objectives

1.2.1 Objectives of the Project

The objectives of CTR Project 0-1410 as proposed to TxDOT are[7]:

1. To develop conceptual plans and visual guidelines for improving the aesthetics and efficiency of widely used moderate-span bridge systems;
2. To introduce more attractive structural forms and textures in substructures though increased use of precasting or, where appropriate, in-situ casting utilizing improved form systems similar to those used in precasting;
3. To reduce construction time, cost of traffic delay and rerouting during construction, and field concreting problems by increased precasting of bridge substructures;
4. To develop conceptual plans for several demonstration projects and to refine those plans based on field experience and observations; and
5. To provide useful design guidelines and examples for improving the aesthetics and efficiency of substructures for Standard Bridge Systems.

The objectives of this project have been carried out in detail by four Graduate Research Assistants associated with this project. Preliminary design guidelines were developed by Scot Listavich (M.S.E., 1995) and are presented in his Thesis entitled *The Development of Aesthetic Guidelines for Short and Medium Span Texas Bridge Systems*[8]. The background was largely completed and an initial precast single column substructure system developed for Objectives 2 and 3 by Robert Barnes (M.S.E., 1996). This work is presented in Barnes' Thesis entitled *Development of a High Performance Substructure System for Prestressed Concrete Girder Highway Bridges*[9]. Work towards Objectives 4 and 5 was carried out by Steve Ratchye (M.Arch, M.S.E. 1997). Ratchye's Report[10] includes a series of case studies applying the principles developed in the design guidelines to four existing and varied sites in Texas. Ratchye's research work was further developed by the author and research team for inclusion in the final design guidelines.

Further development and restructuring of the guidelines for Objectives 1 and 5 were completed by the senior author resulting in a manual which is Appendix C of this report entitled *TxDOT Aesthetics & Efficiency Guidelines*. This work was used by Ratchye to complete Objective 4. These examples are included in Appendix C. Development of a precast substructure system for Objectives 2 and 3 begun by Barnes has been analyzed and continued by the authors with extensive contributions from the research team, designers, precasters, form manufacturers and contractors. The original concept has been substantially modified and expanded to cover a wide range of substructure types generally found in Texas. Descriptions of the process and the results of the development of the precast substructure system will be included in Report 1410-2F.

1.2.2 Objectives of this Report

There are three major objectives of this report. The first objective is to present the background and development of the final *TxDOT Aesthetics & Efficiency Guidelines* (TxDOT Guidelines). The second is to illustrate their appropriateness and applicability to problems TxDOT faces in standard highway bridge design. The third objective is to document the possible benefits of applying this research to practice. Benefits as well as drawbacks in terms of aesthetic consequences, safety, serviceability and economy considering both initial and life-cycle costs are demonstrated through case studies using the TxDOT Guidelines.

1.3 Scope

The scope of this report is to document the completion of the objectives described above in Section 1.2.2.

Chapter 2 is a literature review of several of the most important documents concerning broad design and construction issues for improved efficiency and aesthetics of short and moderate span bridges. Additional literature reviews pertaining more closely to the development and use of design guidelines are presented in Chapter 3.

Chapter 3 outlines the development and refinement of the TxDOT Guidelines. This work includes a review of existing design guidelines for improving bridge aesthetics, an informal survey of the public's opinion of the bridges of Texas, a photographic survey of the short and moderate-span bridges of Texas and interviews with District and Area Engineers throughout the State. The focus and goals of the TxDOT Guidelines and an outline of that document are presented.

Chapter 4 provides a summary and conclusions of this work.

There are three appendices in this report. Appendix A is a bibliography of numerous articles and books identified by the researchers that pertain to the aesthetics of bridges as well as precast substructure design. Appendix B is a brief summary of the informal survey of the public conducted in Texas and presented in Chapter 3. The weighting of the survey results and limitations of interpreting the results are discussed. The third appendix (Appendix C) is the *TxDOT Aesthetics & Efficiency Guidelines*. It is envisioned that after review and approval, this document will be printed and distributed separately.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

An extensive literature review has been carried out through the course of the research project. Literature was collected on a variety of topics providing background and insight for both the *TxDOT Aesthetics & Efficiency Guidelines* (Guidelines) and the design, fabrication and erection of substructures for short and moderate span (10m-45m, (35'-150')) bridge systems. Literature most pertinent to the development of the Guidelines covered the topics of,

1. *General bridge aesthetics,*
2. *Existing guidelines for aesthetic bridge design,*
3. *Aesthetics for short and moderate-span bridges,*
4. *Aesthetic evaluation of bridges.*

A bibliography containing much of the literature review separated into the above categories is presented in Appendix A. Section 3.3 contains a review of the existing bridge aesthetics guidelines that were instrumental in developing the Guidelines (Item 2 above).

The remainder of this chapter will focus on seven of the most important articles and collections of articles, as determined by the authors, from the literature review concerning bridge aesthetics.[11-20] Most aesthetics-related writing in the past has focused on monumental long-span bridges. While some of the key references outlined are directed principally towards long-span bridges, much of the literature is applicable in different ways to the problems that face State transportation engineers for short and moderate span bridge design. For example, the economy of construction is an important aspect of aesthetic considerations when designing with public funds. Therefore emphasis on economy tends to be a recurring theme in the key references. Lessons drawn from large projects may also provide useful guidance for smaller bridges.

Specific articles among these seven key references can provide an interested "beginner" a concise and thorough description of the value and necessity of aesthetic considerations for bridge design. The depth and applicability of the subject for all bridge forms can be quickly understood. A discussion of the applicability of this literature review to the research presented in this report follows in Section 2.3.

2.2 LITERATURE REVIEW

2.2.1 "The Aesthetics of Bridge Design", Christian Menn[11]

Published in 1985 by the Bulletin of the International Association for Shell and Spatial Structures (IASS), "The Aesthetics of Bridge Design" is an excellent introduction to the application and role of aesthetics in good bridge design. Recognizing that a large amount of significant material covering philosophical aspects of bridge aesthetics as well as careful analyses of existing bridges already exists, Menn focuses his paper instead on guidance for designers on how to develop good design concepts for bridges that include attention to aesthetics.

The article focuses primarily on fundamentals of aesthetics in bridge design. The fundamentals fall into two categories; integration of a bridge into its surroundings and the design of a bridge as a structure in itself. Under the latter focus, Menn covers topics of:

Transparency - visibility through a bridge,

Slenderness - the ratio of the span length to girder depth,

Regularity and Simplicity - a call for symmetry, and regularity in span lengths and element sizes, and

Artistic Shaping - designing structural elements to conform to stress conditions.

Concerning artistic shaping, Menn discusses the place for artistic decoration or embellishments in bridge design. He strongly emphasizes that such embellishments should be carried out only by "real" artists and that the "normal" engineer should rather focus on shaping elements to comply with the static flow of forces.

Menn concludes the article with a discussion of the relationship between aesthetics and economy. He suggests that in most cases where the guidelines he has laid out are followed, the additional costs for typical moderate span bridges should amount to no more than 1-2% of the construction costs. Recognizing the dramatic artistic impression that longer spans can have on the viewer, Menn suggests allowance of up to 5-7% additional costs to increase span lengths of projects designed originally with more moderate spans.

2.2.2 Bridge Aesthetics Around the World - Transportation Research Board, National Research Council[2]

This extensive compilation of articles concerning bridge aesthetics was published in 1991 and represents opinions from authors in 16 countries around the world. In addition to the articles, this compilation contains an annotated bibliography with references to over 250 articles, books and papers on the subject of bridge aesthetics. Topics range from general guidelines for bridge aesthetics and evaluation techniques to specific issues of aesthetics for short and moderate span pedestrian and/or highway bridges to cultural influences on bridge design. A wide variety of bridge systems, span lengths and material types for bridges are addressed.

2.2.3 Esthetics in Concrete Bridge Design - American Concrete Institute (ACI), MP-1[3]

Published in 1990, this collection of papers is a record of the proceedings of four ACI convention sessions on aesthetics in concrete bridge design. Two of the sessions were held at the Fall 1987 ACI convention in Seattle, WA and two were held at the Spring 1988 ACI convention in Orlando, FL. The authors of the papers are predominantly bridge engineers as well as some "bridge architects" from around the world. The many authors discuss topics ranging from personal experience, aesthetic vision and recent designs to philosophical discussions of aesthetics, aesthetic principles and aesthetic rules. A number of papers specifically address State (US) highway bridges, the interrelation of economy and aesthetics or the aesthetics of pier design.

2.2.4 The California Tradition

The California Department of Transportation (Caltrans) has had a long standing tradition of addressing aesthetics in their bridge designs. The goals and approach taken by the department have been well documented. Arthur Elliot, former Bridge Engineer of Caltrans, is the author of *"Esthetic Development of California's Bridges"*[12] presented at the 1980 ASCE Convention in Portland, Oregon. Elliot argues that engineers must not ask "how to make a bridge beautiful" but rather, how does one make a beautiful bridge. Aesthetics along with safety and function are related to a three-legged stool - each leg is essential. Elliot then traces the history of striving for beauty in the design of bridges in California through descriptions of the different bridge types and forms which have been experimented with by Caltrans over the years.

A more recent Chief of the Office of Structure Design at Caltrans, James Roberts, writes as well on the California tradition of designing attractive bridges. In *"Aesthetic Design Philosophy Utilized for California State Bridges,"*[13] Roberts discusses the important collaboration between bridge structural engineers, maintenance engineers, construction engineers, bridge architects, and geological engineers in order to determine the most appropriate bridge form for a given site. Through extensive discussions of the cost impact of Caltrans' consideration of aesthetics as an integral part of design, Roberts shows that designing attractive structures does not add a significant cost to their bridges. The attractive and economical results are achieved through encouragement by all levels of management that designers should strive for beautiful bridges as well as use a variety of bridge forms repetitively. A similar and also important article by Roberts entitled *"Aesthetics and Economy in Complete Concrete Bridge Design"*[14] appears in the ACI MP-1 publication described above.

John Ritner, Chief Bridge Architect at Caltrans is the author of *"Bridges Produced by an Architectural Engineering Team"*[15] which describes the actual methods and principles used by the designers at Caltrans to produce attractive bridges. Ritner discusses the "team approach" taken by Caltrans and the importance of collaboration between bridge engineers and bridge architects at the earliest possible stages of design. As well, architectural treatments are presented as changes in form or surface texture that do not compromise the structural function and purpose of the bridge. This concise and thorough paper gives several very clear examples of how significant improvements to visual appearance can very easily be made considering all elements of a bridge; abutments, columns, superstructure, etc. Several award-winning structures are presented and discussed as well.

2.2.5 IABSE Congress, 1980

The Eleventh Congress of the International Association of Bridge and Structural Engineers (IABSE) held in Vienna in 1980 had one of eleven themes devoted to "Aesthetics in Structural Engineering". Of the fifteen papers presented,[16] five articles are specifically related to structural bridge design. These include,

> Bridge Aesthetics: 1925-1933 (Billington), A review of active discussions during this time period on the role of engineers working with or without architects to achieve aesthetic design excellence,
>
> The Engineer and Bridge Aesthetics (Bagon, in French), An analysis of the causes of problems in bridge aesthetics, suggestions for what not to do and brief guidelines for the design of attractive bridges,
>
> On the Manual for Aesthetic Design of Bridges (Tahara, Nakamura), A presentation of a design manual to raise the aesthetic awareness of bridge designers in Japan and to improve even to a small extent the attractiveness of their bridges,

Bridge Aesthetics (Slater), A paper arguing that the character of a bridge is more often determined by spatial proportions, in particular void shapes, and layout. Suggestions are given for bridges as relating to their landscape, bridges with multiple approach spans, bridges on highways and arch rib bridge forms,

Research in Aesthetics of Standard Bridges (Grelu et. al., in French), A three-step methodology for designing attractive moderate span bridges as a whole rather than addressing aesthetics separately. A detailed example is given of the methodology applied to a moderate span highway bridge.

2.2.6 Concrete International, July 1995[17]

A special collection of six articles was gathered and printed together in the July 1995 Concrete International magazine of ACI. Of particular interest to designers of standard highway bridges is Antonio Garcia's article *"Treasures or Trash?"*[18] The everyday issues of short and moderate span design are very well-addressed in this article. Emphasis is placed on showing that aesthetics is not something added or appended to a bridge at the end of the design process, but rather an integral part of good bridge design. Issues of alignment, drainage and joint details, and rehabilitation are discussed. Consideration of the location of a bridge, consistency among the bridge elements and effects of standardization are addressed as well.

Another article particularly germane to the topic of this report is *"Aesthetics in the Design of Precast Prestressed Bridges"* by Maestro et. al.[19] In this article, the authors discuss aesthetic ideas such as the logic of the structural form, harmony, elevation vs. cross section, and slenderness ratios. Specific precast prestressed bridge elements are addressed as well.

2.2.7 Structural Engineering International, April 1996[20]

A series of seven articles was devoted to the subject of "Aesthetics in Structural Engineering" in the April 1996 issue of Structural Engineering International (SEI). The articles are written by seven leading structural engineers from Europe and one from the United States (one paper is co-authored). Five of the articles focus specifically on bridge aesthetics. Some of the common themes are the collaboration of architects and engineers with both positive and negative effects and the examination of the design process as leading to attractive bridge design. While many of the articles focus on long span bridges, many of the ideas, principles and methods are applicable to short and moderate span bridges.

While this issue of SEI devotes a specific section solely to aesthetics in structural engineering, the magazine in general very often has articles pertaining to state-of-the-art bridge design. Study of recent and past bridge projects that emphasize aesthetics with state-of-the-art design such as are found in SEI, is important for the continuing education of all engineers.

2.3 SUMMARY - RELEVANCE AND USE OF THE LITERATURE REVIEW

The seven articles and groups of articles described in Section 2.2 give a thorough overview of the many issues faced and solutions achieved by designers in the past, present and future when addressing aesthetics in their bridge designs. Despite the wealth of information on general bridge aesthetics that does exist, there are only a handful of significant papers that really address issues of aesthetics of short and moderate span bridges within the economic bounds often set by State Departments of Transportation (DOT's). Even the few articles that do address the issue of economy with aesthetic bridge design cannot be applied to all DOT's. Different structural systems, structural materials and construction methods are more economical in different regions of the country. As these aspects of bridge design have a considerable impact on the visual impression of a bridge, guidelines or successful project prototypes in one State very often cannot be economically extended to another State.

An extensive literature review of available material on bridge aesthetics is certainly educational however, and can provide a wealth of ideas. To be of any use, the ideas and experiences of past designers must be viewed within their context - their setting, their time, their local political, social, and economic conditions. It is most important to understand how designers achieved attractive structures within the constraints of their projects. It is this analysis of the design process and the many factors that affect the process that must be studied and modeled for future bridge designs. Such analysis and understanding can then supply a framework for designing attractive structures. A thorough understanding of design processes rather than specific aesthetic rules, *is* transferable across time, and across political, social and economic climates. Design processes may vary according to bridge type but the understanding of how a certain bridge type is formed will give designers insight into where they can better influence the appearance of *their* bridges; where changes can be made within their own design constraints, and what solutions are feasible that will result in elegant structures.

This literature review has provided an introduction to methods of design that have been successful in the past and a review of state-of-the-art bridge design. Such information provides a base as well as inspiration to apply the knowledge gained to develop more attractive solutions for the standard short and moderate span highway bridges that dominate our landscape.

CHAPTER 3

DEVELOPMENT OF AESTHETICS & EFFICIENCY GUIDELINES

3.1 INTRODUCTION

State Departments of Transportation have traditionally taken pride in their job of providing the public with safe, functional and economical highways and bridges. The Federal and State highway systems continue to be expanded and rebuilt in this tradition. The majority of the new bridges constructed are of short and moderate spans (10m-45m, 35-100'). Much construction and reconstruction is now occurring through heavily populated areas thus having considerable lasting aesthetic and environmental effect on local users and neighbors. Likewise, even with bridges in under-populated areas, there is often considerable public concern about any negative effects highways and bridges might have on the local environment. As a result, the job of State transportation engineers has become much more challenging. Highway planners and bridge engineers must now not only provide safe, functional and economical designs, but they must also address the visual and environmental impact of their designs. Focusing on bridge design, the *aesthetics* and the *efficiency of both material use and construction methods* are two key areas needing attention so that engineers can better address the impact of their designs on the users and the environment.

3.1.1 Aesthetics and Efficiency of Long Span Bridges

There are many successful examples of elegant and efficient monumental, long span bridges (spans greater than 45m). With large projects, efficient use of materials and efficient construction methods are tied very closely with the economy of the project. The minimization of wasted material very often leads to highly economical designs and, with added consideration, designs that are slender and attractive as well (Figure 3.1). Engineers can benefit greatly through careful study of successful long-span bridges of the past. An appreciation for, and better understanding of bridge aesthetics can be gained. Then, similar or refined ideas can be applied to other long span projects.

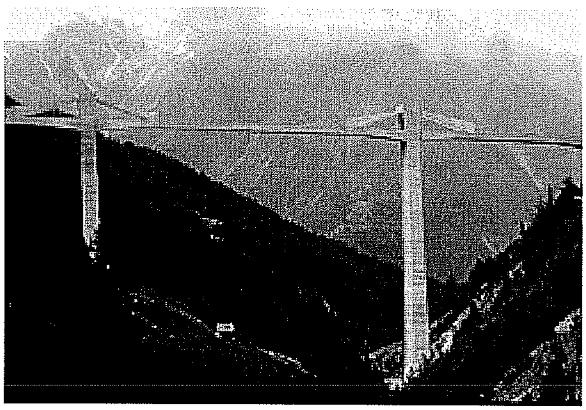


Figure 3. 1 The Ganter Bridge, Switzerland

3.1.2 Aesthetics and Efficiency of Short and Moderate Span Bridges

With short and moderate span bridges, it is much less likely that the efficient use of materials and efficient construction methods traditional for economical structures will result in attractive designs. Due to the economics of standardization, minimizing wasted material (which often leads to attractive and elegant designs) has in many cases proven to be uneconomical for short and moderate span bridge design.

For example, modern techniques like pretensioning call for uniform depth girders. Tailoring the depth to match the moment diagram and hence save material is not practical on the long pretension lines utilized. Thus the extremely rigorous standardization often necessary for the sake of economy tends to stifle the creativity of engineers designing short and moderate span bridges. This trend is not present in substructure design where less standardization is used and where most construction is cast-in-place. Yet designers tend to pay relatively little attention to aesthetics and economy for these bridge elements. The interaction between aesthetics, efficiency, economy and the effects of standardization on the design of short and moderate span bridges must now be addressed. New attractive solutions that will be economical, simple to construct and not wasteful of materials must be the goal of engineers designing standard bridges of moderate spans.

3.1.3 The Need for Aesthetics and Efficiency Guidelines

During formal education, engineers may be exposed to issues of efficiency in design but they are rarely expected to address the aesthetics of their designs. In the workplace as well, there is very little guidance for engineers wishing to address both aesthetics and efficiency more closely in design. In particular, the aesthetics and efficiency of short and moderate span bridges has been sorely neglected.

A number of State DOT's have recognized that addressing aesthetics adds an important new dimension to bridge design. Many DOT's have begun to address aesthetics more formally though the development of guidelines for aesthetic bridge design with encouraging results (see Section 3.2).

Currently, the Texas Department of Transportation (TxDOT) has only a brief half-page statement concerning aesthetics in their Bridge Design Guidelines.[21] The recent 1996 LRFD AASHTO Specification for Highway Bridges has a slightly more expanded section addressing aesthetics but it remains cursory and generalized.[22] Engineers at TxDOT however, have been making a strong effort recently to address the aesthetics of their highway projects and in particular, the bridges they design for the State. A few results of their efforts are depicted in Figures 1.4-1.6, and Figure 1.9. The public has recognized and been receptive to these efforts (see Sections 3.3.2-3.3.3) and TxDOT has now decided to go forward with developing their own set of guidelines for improving the aesthetics and efficiency of the bridges of Texas. Work towards the development of a set of guidelines titled the *TxDOT Aesthetics and Efficiency Guidelines* (referred to as the Guidelines) is presented in this chapter.

3.2 LITERATURE REVIEW

There are a number of existing manuals of aesthetics guidelines for bridge design. A few are written for State DOT engineers and focus on improving short and moderate span bridges. The guidelines of other DOT's are particularly useful in terms of providing a basis from which to develop the TxDOT Guidelines. Existing guidelines for State engineers address many issues specific to short and moderate span bridges. In particular, economics is an important concern, as the engineers are designing State-owned bridges that are paid for by tax-dollars.

There are other aesthetics guidelines in existence that are more general and are meant to apply to all types of bridges; long and short spans, masonry, timber, concrete or steel bridges, and arches, beams, or cable bridges. Still other sets of guidelines may address the aesthetics of just one specific type of bridge such as railroad bridges. Examination of both broad and specific (i.e. not necessarily State DOT) guidelines is useful and informative. Although not focused on bridge types most often constructed in Texas, such guidelines supply engineers with important principles inherent to good bridge design that can apply to all types of bridges.

Many of the ideas from existing sets of aesthetic guidelines have been helpful in developing the Guidelines. Brief descriptions of some of the existing guidelines examined are presented herein. A discussion of the most influential ideas gained from this literature review concludes this section.

3.2.1 Existing Guidelines

Bridges, Fritz Leonhardt23. German engineer Fritz Leonhardt developed a set of guidelines in his book *Bridges*. These guidelines are organized by categories of bridges; arch bridges, beam bridges, cable-stayed bridges, and suspension bridges. Throughout his guidelines, Leonhardt emphasizes nine principles of aesthetics. They are:

- *Clarity of function* - Efficient appearance, clear form and imparting a feeling of stability
- *Proportion* - Balance and harmonious relationships between elements
- *Order* - Symmetry, repetition and limited number of lines, directions and edges
- *Refinement of form* - Optical corrections, light and shadow and skew angle views
- *Integration into the environment*
- *Color* - Harmonious coloring
- *Texture* - Break in monotony of large expanses of concrete
- *Character* - Deliberate effect on user and positive user-friendly impressions
- *Complexity* - Limited variety to evoke interest while maintaining order

Leonhardt also emphasizes the importance of layout, planning and roadway alignment on overall bridge aesthetics.

Aesthetic Bridges, Maryland Department of Transportation[4]. The Maryland Department of Transportation has developed guidelines titled *Aesthetic Bridges*. specifically for State DOT engineers. Their guidelines are organized in the order of the design process. They address issues involving the geometry and layout of the bridge, superstructure design, substructure design, color & texture and signs, lighting & landscaping. Site-specific considerations are addressed in separate sections and cover such topics as bridges in urban vs. rural areas or bridges spanning water vs. a highway. The Maryland Guidelines emphasize the importance of six ideas referred to as the keys to success. These are:

- *Strength through form* - Shape elements to respond to their structural function
- *Clear display of structure* - Display role of each element and show how forces act
- *Unity* - All elements should contribute to a single whole
- *Economy* - The bridge should serve its function with a minimum amount of material
- *Proportion* - Each element size should relate clearly to the overall structure

- *Appropriateness* - The bridge should have a clear and consistent relationship to the area around it

The goal of the Maryland guidelines is to aid designers in making explicit decisions concerning aesthetics just as they would make decisions for structural members, safety or cost.

Aesthetic Guidelines for Bridge Design, The Minnesota Department of Transportation[5]. The Minnesota Department of Transportation has developed a set of guidelines very similar to those of the Maryland DOT. Minnesota's guidelines begin with a section on fundamentals of aesthetic design and a section on the aesthetic design process. The fundamentals of aesthetic design presented include:

- Visual Design Elements - Line, shape, form, color, texture
- Aesthetic Qualities - Proportion, rhythm, order, harmony, balance, contrast, scale, unity
- Aesthetic Design Objectives - Functional clarity, Scale and Proportion, Order and Balance, Simplicity and Continuity, Site/Environment Integration
- Aesthetic Design Hierarchy
    - Principle Aesthetic Design Factors - superstructure type and shape, geometry and relationship to site, pier location and shape, abutment location and shape, interaction between bridge and its surroundings
    - Secondary Aesthetic Design Factors - railing details, surface colors and textures, architectural embellishments, lighting

More detailed discussions including design examples are given for superstructure design, substructure design, bridge related components (railings, drainage, signs, etc.) and bridge categories (interchanges, grade separations, long-span bridges, etc.).

"Bridge Design Aesthetics," California Department of Transportation. As discussed in Section 2.2, the California Department of Transportation (CALTRANS) has had a long-standing tradition of emphasizing the importance of aesthetics in their bridge designs. Section 7 of their Bridge Design Practice Manual is titled "Bridge Design Aesthetics." [24]

This Section begins by defining a beautiful bridge,

> Beautiful Bridge - *A beautiful bridge makes a minimal impression on the environment, has good proportions both in its integral parts and in the space outlined by its parts. It is composed of one dominant structural system using a minimum number of bents with a minimum number of columns per bent. Size, shape, color and texture on superstructure, columns, and abutments are utilized to either call attention to or play down, the role of these structural parts.*[24]

The design philosophy at CALTRANS of encouraging beautiful structural design is emphasized from the top management down. A section of the department titled Aesthetics and Models keeps this emphasis alive by coordinating with engineers from the very beginning of each project.

Another key element to designing beautiful bridges at CALTRANS that is emphasized in their Bridge Design Practice Manual is the choice of structural type resulting from a "type selection meeting." The type selection meeting involves input from professionals representing all disciplines involved with bridge design. Professionals include representatives from the divisions of Specifications, Design, Aesthetics and Models, Construction, Estimating, and Maintenance.

More detailed discussion is provided concerning railings, girders and decks, and column shapes, in particular column cross sections and the use of tapered and flared columns. There is also a section devoted to aesthetic considerations for seismic retrofits.

"Development of Aesthetic Guidelines for Short and Medium Span Texas Bridge Systems". A preliminary set of aesthetic guidelines was developed for the Texas Department of Transportation by Scot Listavich under the same research project as this report. Listavich's preliminary Aesthetic Guidelines cover 40 topics representing ideas to be applied to the short and medium span bridge systems of Texas.[8] These 40 topics are divided into three main groups; Form, Composition and Entity (Figure 3.2). These three groups represent an approach to aesthetics in bridge design that involves consideration of individual forms of a bridge and how they come together in the whole composition (Form), consideration of ideas that are applied to the whole composition rather than individual parts (Composition), and consideration of the bridge's role in its environment and how the bridge interacts with its setting (Entity). Each of these groups and their related topics is presented in six steps. These steps are:

1. Title
2. Introduction Statements including definition of the title.
3. Initial Figures illustrating the principle subject.
4. Additional or Diagrammed Figure further illustrating idea.
5. Discussion/Transition statement leading to following topics.
6. List of following Topics

These Guidelines are thorough and present an extensive amount of useful information for application to short and medium span Texas bridge systems.

Miscellaneous Guidelines. The Wisconsin DOT has a small chapter on aesthetics in their bridge manual.[25] Key ideas briefly discussed include unity through form, simplicity of design, focal points, feature of relief, and proportion of elements. The Wisconsin DOT is in the process of developing a more comprehensive set of guidelines similar to those of the Maryland and Minnesota DOTs.

The Illinois DOT developed a set of guidelines specifically for use on bridge projects for one highway,[26] Highway I-255. One emphasis was on streamlining the bridges - using single spans for highway over- and underpasses to avoid the need for piers where possible. Surface treatment was carefully planned to harmonize with the natural environment. Different treatments were used for bridges of different functions - one texture was used for bridges crossing the interstate and a different texture was used for interstate bridges crossing local roads. Careful planning from the outset of design resulted in a very attractive set of bridges with the attention to aesthetics costing less than 3% of the project cost.

The Swiss National Railway (SBB) has a set of guidelines for their railway structures.[27] Issues briefly discussed include the engineering work's relationship to the environment, form, structural system, texture, color, environmental impact and protection and landscaping. After these issues are presented, numerous examples, both good and bad are pictured and discussed. The examples include railway

AESTHETIC GUIDELINES

Form-

Refinement of Form-

Form Related Idea:	Shape Elevation Section Footprint
Form Related Strategy:	Accentuation (Highlighting Form) Continuity Optical Corrections Light and Shadow Structural Expression

Proportion-

Proportional Idea:	Proportioning System Scale
Proportional Strategies:	Functional Layout: Elevation and Section Relative Sizes of Components Application to Composition as a Whole

Composition-

Order-
- Symmetry
- Repetition
- Hierarchy
- Transformation
- Rhythm

Texture-
- Fine-Scale
- Medium-Scale
- Large-Scale

Color-
- Thematic
- Entropic

Entity-

Integration into the Environment-
- Texture
- Color
- Proportions
- Transitions
- Order

Clarity of Function-
- Clear Form
- Clear Circulation
- Safety and Stability
- User-Friendly

Character-
- Complexity
- Economy of Means
- Social Implications

Aging-
- Graffiti
- Drainage Staining
- Wear Staining
- Paint Chipping and Peeling

Figure 3. 2 Outline for TxDOT Aesthetics Guidelines by Listavich[8]

bridges, underpasses (under railways), overpasses (crossing railways), tunnel portals, retaining walls and noise barriers.

3.2.2 Summary

The numerous ideas and organizational methods displayed in many of the existing guidelines have been carefully studied and analyzed to provide a background for the Guidelines. Some of the previously used strategies are important and appropriate for guidelines for Texas while others are not.

In Leonhardt's book, *Bridges*, the nine principles of aesthetics presented are well explained. These principles are ideas that are often taught to students in architecture school but rarely are discussed among engineers. While the principles certainly have applications to engineering works, these applications are less clear to an engineer who has never considered aesthetics in bridge design. The principles are presented and many photographs of different bridges are shown but the connection between the two is weak. There are very many principles and very many ways to carry them out. However, no guidance is given as to how to put them together in one project. The extensive use of photographs of actual bridges and the effectiveness of comparative photographs is a very positive feature of the book and was adopted for the Guidelines.

Maryland's Aesthetic Bridges is more specifically aimed at helping a State engineer develop an awareness of bridge aesthetics. The organization of these guidelines in the order of the design process is highly effective. This order is logical for DOT engineers and it is easy to follow. This organization inherently shows the importance of addressing aesthetics at all stages of the design process, not just at the end with add-on details. Another important feature of these guidelines is the ability to read the document at different "levels" (Figure 3.3). Main ideas are in bold type with further explanations underneath. As well, all photographs have captions to further illustrate the ideas presented. Such organization allows a reader to browse casually or study in depth and yet always receive useful information from the document.

The organization of Minnesota's guidelines (following the order of the design process) is similar to Maryland's and is a positive feature for any DOT guidelines. Minnesota's mention of the hierarchy of design is a key point that should be stressed more emphatically - the importance of the overall form and the structural components, not simply the details. This idea of looking at where aesthetics belongs within the whole bridge design process is one that should continue to be stressed in future guidelines.

While California generally uses very different structural systems for their highway bridges than does Texas (cast-in-place concrete continuous box girders vs. simply supported precast pretensioned concrete girders, respectively), their approach to aesthetics is excellent and can be applied to any type of structure. Their overriding design philosophy which emphasizes the importance of addressing aesthetics is stressed from their top management down. As a result, aesthetics is considered in the beginning of every bridge project. The existence of an entire section of the department (Aesthetics and Models) devoted to visual analysis of potential bridge types for a project is a clear indication of the pride CALTRANS takes in designing beautiful bridges. While these organizational features at CALTRANS cannot be directly transferred through guidelines alone, small steps can be taken to reach such a high level of aesthetic awareness. An emphasis on considering aesthetics from the beginning and the importance of visual aids including both physical and computer-generated models was made in the Guidelines.

Listavich's Guidelines were very useful in laying the groundwork for the final version of the Guidelines. The ideas and principles presented specifically address Texas bridge systems. They pinpoint areas where more thoughtful consideration should be given in design. Most of these principles and ideas have been

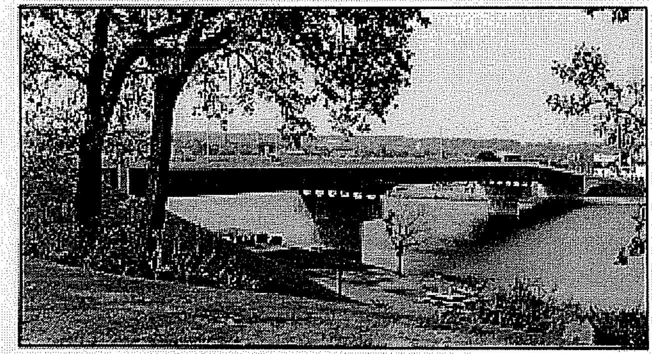


Fig. 2.01
The short vertical curve at the second pier "kinks" the bridge.

B. LAYOUT

Layout is a matter of placing the substructure units so as to minimize disruption to the continuation of whatever the bridge crosses.

Once the span to vertical clearance ratio is established (S/G) for the main span, it should be held constant, when possible, so that the spans decrease proportionally as the height decreases.

Throughout the bridge the proportions of the major elements are the strongest single determinant of the visual impact. For pier placement the key proportion is span versus vertical clearance; or, a better way to look at it, span versus the overall shape of the space beneath the bridge. Generally, the bridge will look better the more the horizontal dimension of this space (the span) exceeds the vertical dimension (See Figs. 2.02 and 2.03).

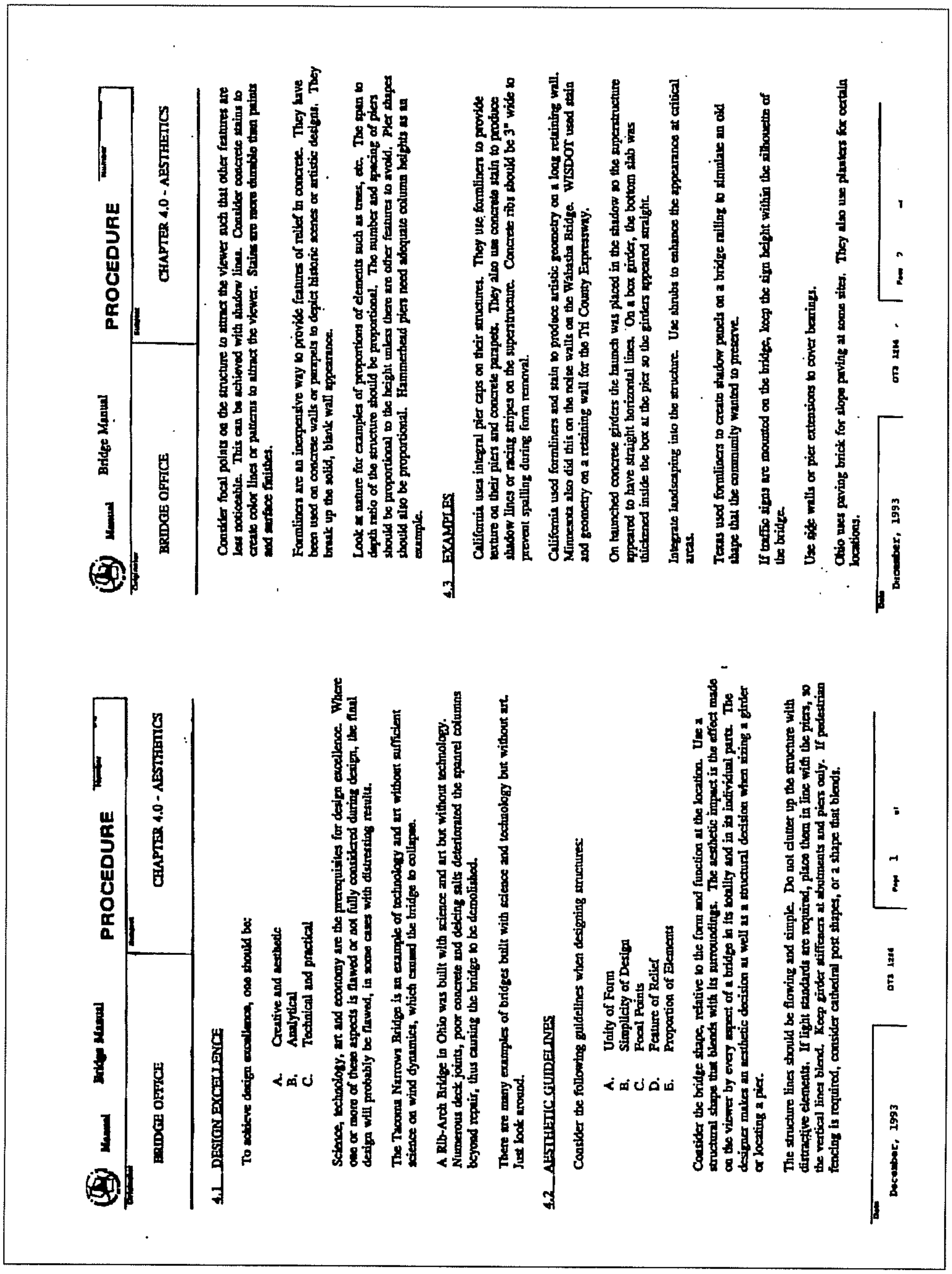
Fig. 2.02 Emphasizing horizontal proportions in pier placement and keeping the S/G ratio constant

II-2

Figure 3. 3 *A page from the Maryland DOT's Aesthetic Bridges*[4]

incorporated into the new version. The clear presentation of ideas with illustrations was recognized to be essential for a useful and "user-friendly" document to result.

In looking at other guidelines such as those from Wisconsin and the SBB, it is clear that the use of visual aids is one of the most effective ways to develop a reader's awareness of bridge aesthetics. Words and principles alone as presented in Wisconsin's brief guidelines are important but yet are not convincing without photographs (Figure 3.4). The SBB guidelines show clearly that a good photograph with a brief



Manual Bridge Manual PROCEDURE

BRIDGE OFFICE — CHAPTER 4.0 - AESTHETICS

4.1 DESIGN EXCELLENCE

To achieve design excellence, one should be:

A. Creative and aesthetic
B. Analytical
C. Technical and practical

Science, technology, art and economy are the prerequisites for design excellence. Where one or more of these aspects is flawed or not fully considered during design, the final design will probably be flawed, in some cases with distressing results.

The Tacoma Narrows Bridge is an example of technology and art without sufficient science on wind dynamics, which caused the bridge to collapse.

A Rib-Arch Bridge in Ohio was built with science and art but without technology. Numerous deck joints, poor concrete and deicing salts deteriorated the spandrel columns beyond repair, thus causing the bridge to be demolished.

There are many examples of bridges built with science and technology but without art. Just look around.

4.2 AESTHETIC GUIDELINES

Consider the following guidelines when designing structures:

A. Unity of Form
B. Simplicity of Design
C. Focal Points
D. Feature of Relief
E. Proportion of Elements

Consider the bridge shape, relative to the form and function at the location. Use a structural shape that blends with its surroundings. The aesthetic impact is the effect made on the viewer by every aspect of a bridge in its totality and in its individual parts. The designer makes an aesthetic decision as well as a structural decision when sizing a girder or locating a pier.

The structure lines should be flowing and simple. Do not clutter up the structure with distractive elements. If light standards are required, place them in line with the piers, so the vertical lines blend. Keep girder stiffeners at abutments and piers only. If pedestrian fencing is required, consider cathedral post shapes, or a shape that blends.

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Manual Bridge Manual PROCEDURE

BRIDGE OFFICE — CHAPTER 4.0 - AESTHETICS

Consider focal points on the structure to attract the viewer such that other features are less noticeable. This can be achieved with shadow lines. Consider concrete stains to create color lines or patterns to attract the viewer. Stains are more durable than paints and surface finishes.

Formliners are an inexpensive way to provide features of relief in concrete. They have been used on concrete walls or parapets to depict historic scenes or artistic designs. They break up the solid, blank wall appearance.

Look at nature for examples of proportions of elements such as trees, etc. The span to depth ratio of the structure should be proportional. The number and spacing of piers should be proportional to the height unless there are other features to avoid. Pier shapes should also be proportional. Hammerhead piers need adequate column heights as an example.

4.3 EXAMPLES

California uses integral pier caps on their structures. They use formliners to provide texture on their piers and concrete parapets. They also use concrete stain to produce shadow lines or racing stripes on the superstructure. Concrete ribs should be 3" wide to prevent spalling during form removal.

California used formliners and stain to produce artistic geometry on a long retaining wall. Minnesota also did this on the noise walls on the Wabasha Bridge. WISDOT used stain and geometry on a retaining wall for the Tri County Expressway.

On haunched concrete girders the haunch was placed in the shadow so the superstructure appeared to have straight horizontal lines. On a box girder, the bottom slab was thickened inside the box at the pier so the girders appeared straight.

Integrate landscaping into the structure. Use shrubs to enhance the appearance at critical areas.

Texas used formliners to create shadow panels on a bridge railing to simulate an old shape that the community wanted to preserve.

If traffic signs are mounted on the bridge, keep the sign height within the silhouette of the bridge.

Use side walls or pier extensions to cover bearings.

Ohio uses paving brick for slope paving at some sites. They also use planters for certain locations.

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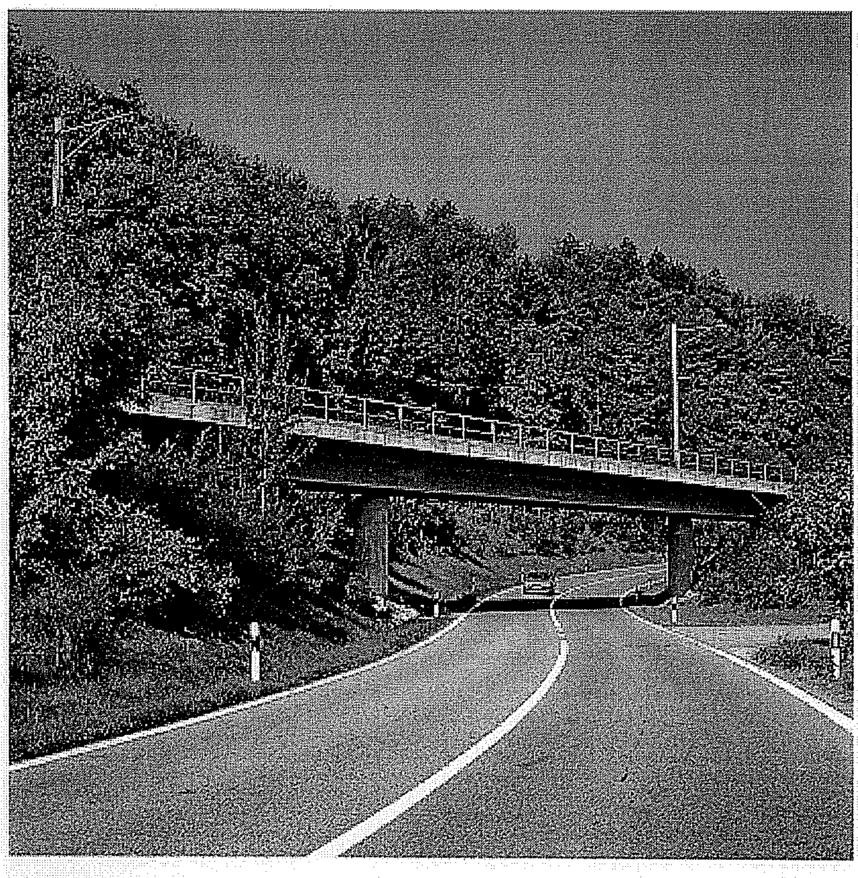
Figure 3. 4 *An excerpt from the Wisconsin DOT's Bridge Manual[25] chapter on Aesthetics (shown for visual impression only)*

statement explaining the connection between a principle and the built form is far more valuable than pages of poorly illustrated written explanation (Figure 3.5).

3.3 Background for TxDOT Guidelines

To best serve the engineers of TxDOT it was necessary to gain an understanding and appreciation of the challenges that the engineers of TxDOT face. The types of bridges these engineers most often design were studied as well as the most common detailing problems that concern them - specifically details that effect aesthetics and efficiency. Interviews with highway planning engineers, bridge engineers, and landscape architects throughout the State were conducted to better understand the concerns of the local



Sehr gutes Beispiel einer Dreifeldbrücke, hervorragend ausgeführt. Die Disposition ermöglicht eine gute Verkehrsführung (Sichtverhältnisse). Die Transparenz erleichtert die Einpassung in die Landschaft. Die Bepflanzung der Böschung entspricht derjenigen der weiteren Umgebung. Besonders günstig wirken sich die kurzen Wege zu Unterschlupfmöglichkeiten für Tiere aus.

Un excellent exemple de pont à trois travées d'une réalisation impeccable. La visibilité est parfaite, ce qui garantit la fluidité du trafic. La transparence de l'ensemble facilite son intégration dans le paysage. La végétation choisie correspond à celle des zones environnantes. A noter tout particulièrement l'attention portée à la faune: les animaux n'ont qu'une distance minimale à parcourir pour pouvoir se cacher.

Caption translation: An excellent example of a three-span bridge designed impeccably. The layout allows for good visibility through the bridge for traffic passing through. The transparency of the bridge facilitates integration with the landscape. The vegetation chosen for the sloping abutments corresponds to local vegetation. Particularly favorable is the minimal distance required for animals to cross and be able to hide.

Figure 3. 5 A page from the SBB guidelines[27]

DOT offices and the challenges that their specific geographical and cultural climates create. An informal survey of the public (the tax-payers and essential owners of the State bridges) was conducted to get a feel for the public perception of their highway system.

All of this information was gathered as background information for developing the Guidelines. As the Guidelines are to be primarily for the engineers of TxDOT, the background information gathered in Texas and presented in this section was essential so that the Guidelines would best serve their primary users.

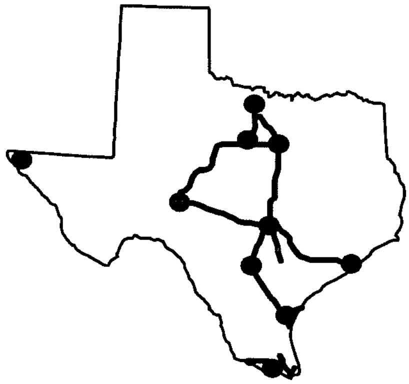


Figure 3. 6 General sites and routes taken for the photo survey of Texas bridges and non-structural details of Texas bridges

3.3.1 Photo Surveys

An extensive photographic survey of roughly 2500 slides (~700 different bridges) was conducted to identify the characteristics of short and moderate span bridge types used in Texas. Examples of both attractive and unattractive short and moderate span bridges were photographed. A photographic survey was also made recording successes and failures of non-structural details (such as railings, drainage and textured surfaces) and how such details can enhance or detract from a project. The general routes taken for gathering the majority of the photographs are shown in Figure 3.6.

3.3.1.1 Short and Moderate Span Bridge Types

The short and moderate span bridges of Texas fall loosely into five major bridge categories. Each bridge type has a different setting and very often a different set of users. Identifying such differences is important when addressing the aesthetics and efficiency of these bridges. The different bridge categories are;

- Highway grade separations - urban and rural locations
- Urban elevated highways and interchanges
- Stream crossings
- Low water crossings along the Gulf Coast
- Bridges in park settings or "environmentally sensitive" locations

Highway Grade Separations. Grade separations include both overpasses and underpasses. Grade separations in rural locations will typically be viewed only by quickly moving traffic. In addressing aesthetics, the overall form, or the appearance of the bridge as a whole from a distance will have the most visual impact on the viewers (Figures 3.7-3.8). Attention to small scale details such as texture or relief will go virtually unnoticed. In addressing construction efficiency, construction time may or may not be of concern for grade separations in rural areas. For example, if the required separation is for a school bus route, construction may need to proceed rapidly. If the highway that is crossing or being crossed is not

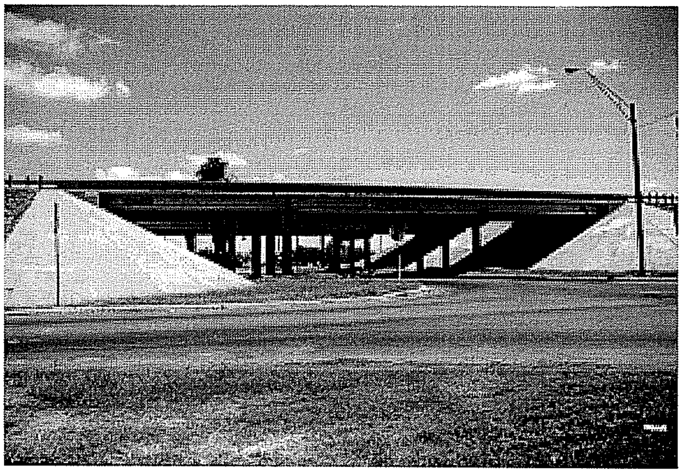


Figure 3. 7 A heavy, cluttered overall appearance

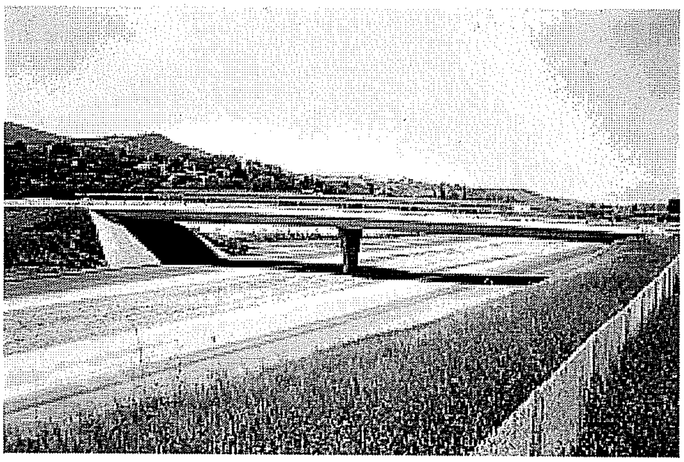


Figure 3. 8 A light elegant overall appearance

heavily used, construction time and methods may not be so critical as traffic delays will most likely not be a problem. Availability of materials is a concern for particularly remote sites.

Grade separations in urban locations will often be viewed both by quickly moving traffic and slower moving pedestrians, or people in neighboring buildings. Here, both the visual impression of the overall structure *and* smaller scale details that will be seen by the "slower" users and viewers are important (Figures 3.9-3.10). Particular care for long-term appearance is essential where distinct signs of aging (such as staining) will have negative psychological effects on neighbors and users. Construction efficiency may be essential to avoid unwanted traffic delays. Construction methods that speed up construction time in heavily congested areas will be desirable for both the contractors and the public.

Urban Elevated Highways and Interchanges. Urban elevated highways are usually heavily viewed from directly underneath by pedestrians and crossing traffic and obliquely underneath by frontage road traffic and pedestrians. Urban elevated highways often cut through existing neighborhoods or commercial districts thus having a profound effect on the highway's "neighbors" (Figures 3.11-3.12). Interchanges directly in an urban area have an impact on the surroundings similar to that of urban elevated highways. Interchanges outside of an urban area on the other hand give the strongest visual impression when viewed from a distance as a whole (Figures 3.13-3.14). Attention to small-scale details viewed only by slow moving traffic or pedestrians is generally not important for remote interchanges.

Construction efficiency is often essential for urban elevated highways and interchanges in populated areas. Traffic delays can be costly and construction methods should be explored that will speed up on-site construction. While it is desirable to use the most economical construction method for a project, engineers, planners and contractors also recognize the hidden costs (as opposed to up-front design and construction costs) associated with excessive traffic delays and traffic re-routing. In certain situations direct construction cost increases may be justified to avoid the cost of undesirable traffic problems. Some interchanges outside of cities will not produce extensive traffic problems and thus may not be heavily influenced by rapid construction procedures.

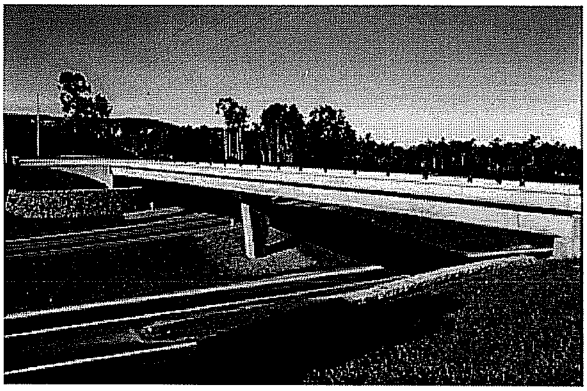


Figure 3. 9 *Attractive overall form and details of abutment, rail and substructure*

Figure 3. 10 *Attractive overall form and details of abutments and substructure*

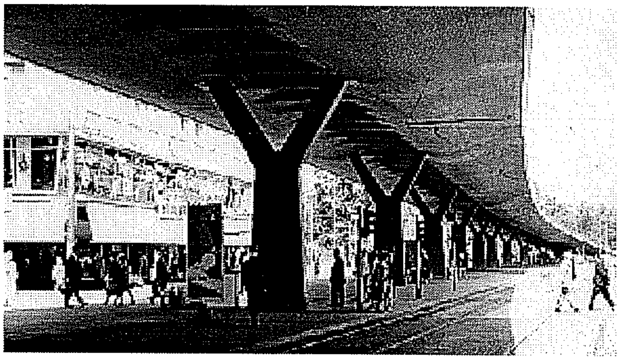


Figure 3. 11 *Heavy pedestrian use under an attractive urban elevated highway*

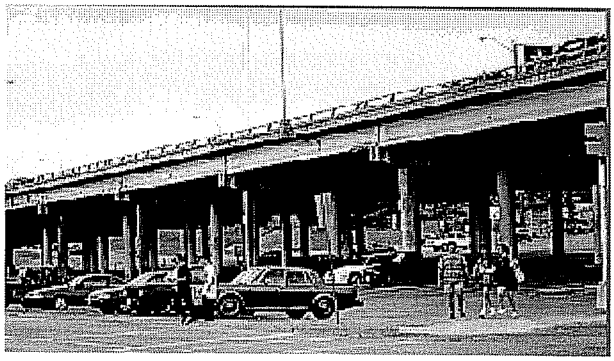


Figure 3. 12 *Heavy pedestrian use under an ugly urban elevated highway*

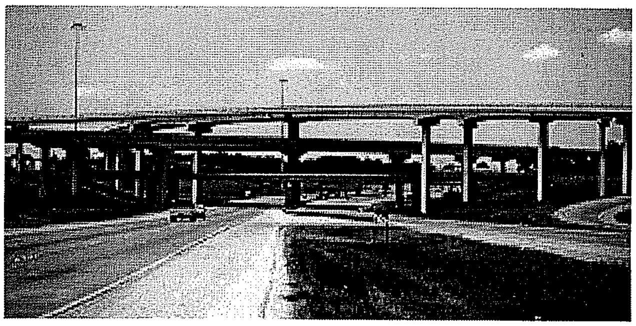


Figure 3. 13 *Interchange with a clean, simple appearance*

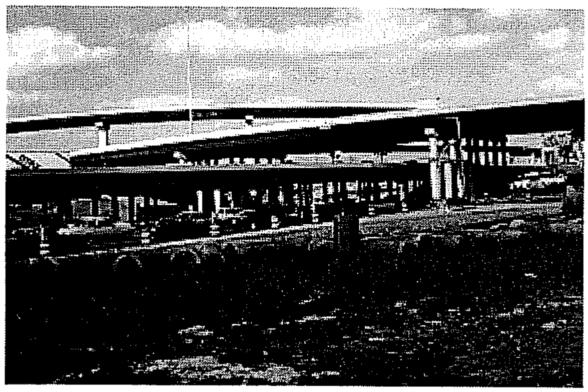


Figure 3. 14 *Interchange with a confusing, heavy appearance*

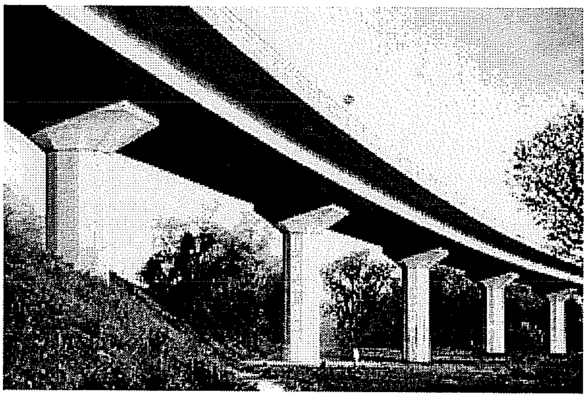


Figure 3. 15 A "clean" addition to a natural setting

Figure 3. 16 A cluttered forest of columns

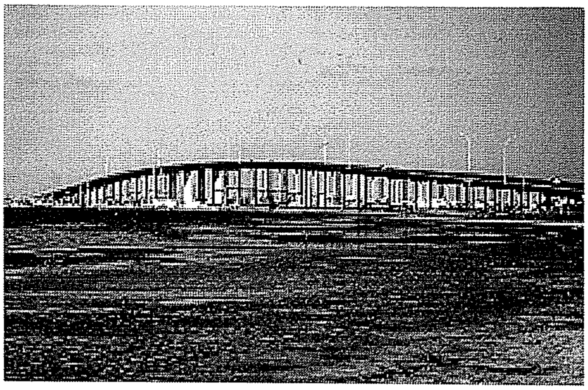
Stream Crossings. In some districts around the State, stream crossings make up the majority of the bridges built by TxDOT. Stream crossings are very often hidden from view and many motorists would not know they are crossing a bridge if not for the presence of a rail along the side of the road. Many engineers feel that the aesthetics of such bridges is irrelevant. However in the case of stream crossings that are visible from roadside parks or curved approaches, attention to the aesthetics of the structure can provide an attractive addition to a natural setting rather than a thoughtless jumble scarring the landscape Fiures 3.5-3.16).

Efficient use of materials and efficient construction methods will depend on the remoteness of the stream crossing site. Structural elements, material use and construction techniques for these crossings are most often chosen based on availability and local contractor experience.

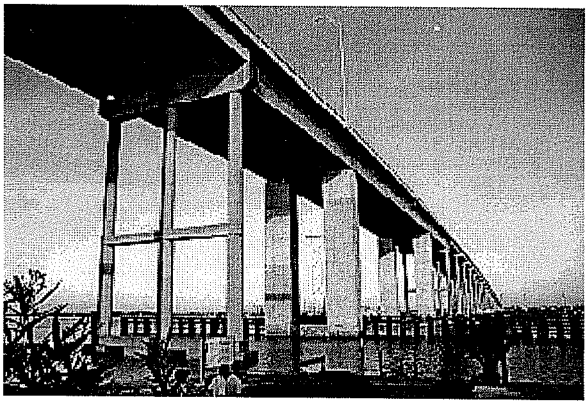
Causeways. Causeways are low water crossings along the coastal regions that often have a raised portion to allow passage for water traffic. These highly visible structures are often on curved alignments and can be viewed not only by boat traffic but also by motorists approaching and using the causeway. These long structures often have a very dramatic visual impact from great distances as well as an effect the experience of local water traffic at a close range (Figures 3.17-3.18).

Efficient use of materials and efficient construction methods will be very closely tied with accessibility to the site. Cast-in-place concrete placement from barges could be replaced with the use of precast driven piles and precast pile caps.[28] The effect that materials and construction methods chosen will have on durability is vital. The salt water environment of causeways is one of the most aggressive environments that can lead to corrosion of reinforcement in concrete members.

Bridges in Park Settings and Environmentally Sensitive Areas. Numerous short and moderate span bridges are built in environmentally sensitive areas. Examples of environmentally sensitive areas include parks that are highly valued by their users as well as habitats for wildlife or endangered species. Bridges built in these environments are often unwanted by the public. Thus, it is essential that they be designed to blend in and enhance their setting. They should never be an eyesore and detract from a site's natural beauty. Attention to designing an elegant overall form and careful detailing for final appearance and attractive aging are very important considerations for bridges in these sensitive areas (Figures 3.19-3.20).



(a) Distant view



(b) Close-up view

Figure 3. 17 *The JFK Causeway in Corpus Christi, Texas*

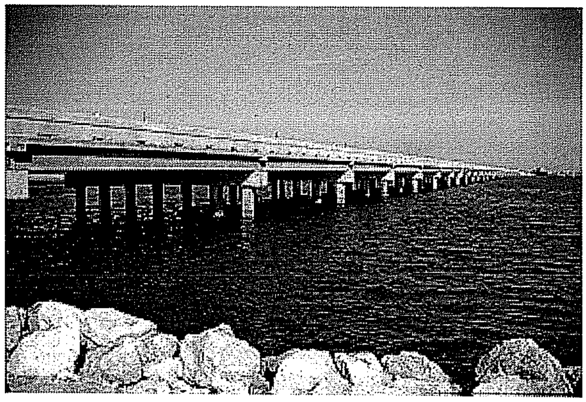


Figure 3. 18 *A low-water crossing on the Gulf Coast near Corpus Christi, Texas*

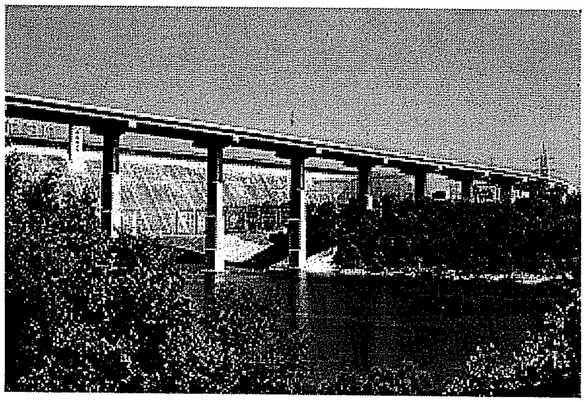
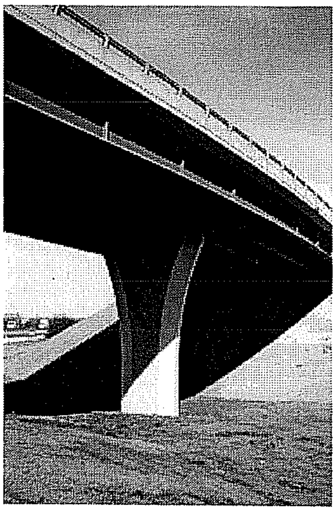
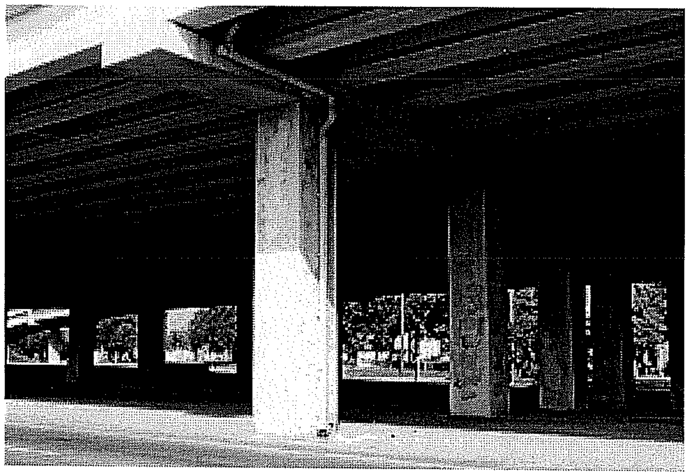


Figure 3. 19 *An attractive addition to an environmentally sensitive site*

Figure 3. 20 *An eyesore in a popular park area in Austin, Texas*



(a) Texture accents this elegantly tapered pier



(b) Tacked on drain pipes and peeling paint creat a feeling of decay

Figure 3. 21 Examples of non-structural details

Efficient construction methods are advantageous to minimize the impact that construction might have on the site. Innovative use of "top-down" construction (in particular with precast construction) should be examined. Top-down construction refers to constructing the substructure and/or superstructure from above - typically from the abutment and then moving out along the previously constructed portion of the bridge. This method of construction eliminates the need for extensive formwork or scaffolding to be set up on the ground (in the environmentally sensitive area) and also moves construction equipment and its impact on the surroundings up off the ground. Some examples of successful use of this method of construction are the Linn Cove Viaduct in North Carolina,[29] the Vail Pass and Glenwood Canyon structures in Colorado[30,32] and the Loop 1 bridge over the Barton Creek Greenbelt in Austin, TX.[31]

3.3.1.2 Non-structural Details

A photographic survey of non-structural details on the short and moderate span bridges of Texas was conducted. Examples of attractive non-structural details as well as highly unfortunate non-structural details were recorded (Figures 3.21a&b).

A certain amount of non-structural detail is required for almost every bridge project. These details include edge barriers and railings, pedestrian access, drainage provisions, joint types, and sign and lighting supports and locations. Other details which must be addressed and allow for considerable freedom in choice are overhangs, surface texture and/or color.

It is apparent in surveying a wide range of bridges in Texas that thoughtful attention to non-structural details is essential for the design of attractive bridges. For instance, slenderness is a very attractive attribute for bridges. When looking at non-structural details, the choice of edge barrier and rail and how this effects the apparent slenderness of the bridge will be important. As shown in Figure 3.22, apparent slenderness is defined as the clear span length divided by the apparent depth of the structure. The apparent depth includes the beam depth, the depth of the slab and the depth of the solid portion of the rail and/or edge barrier above the slab.

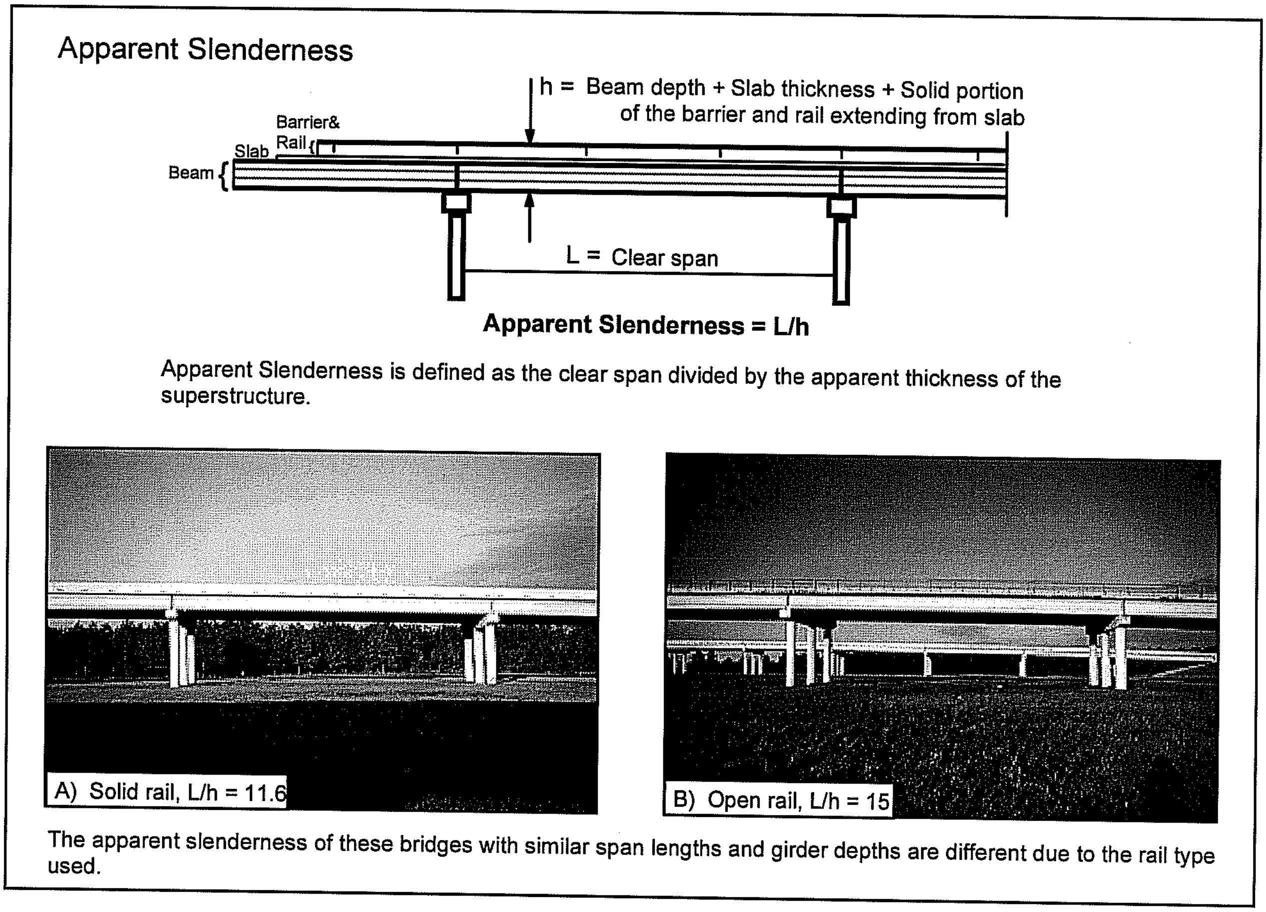
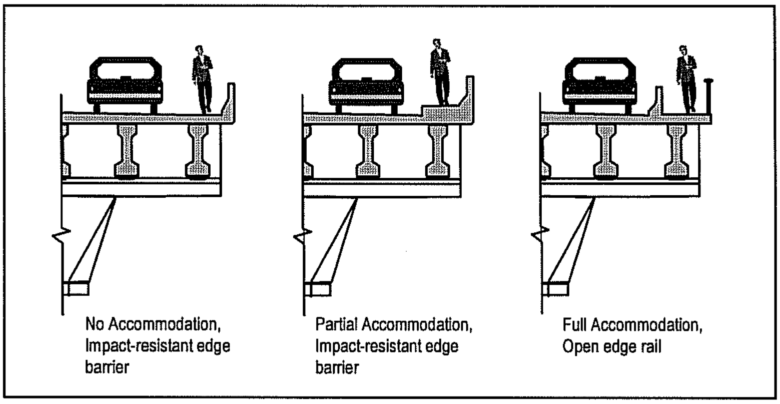


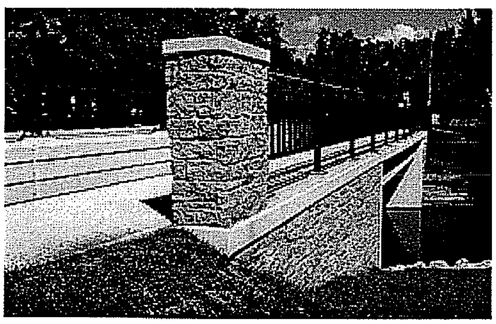
Figure 3. 22 Definition of apparent slenderness

Another important non-structural detail effecting apparent slenderness is pedestrian access on a bridge. Attention to the level of accommodation provided for pedestrians can effect edge barrier and rail requirements (Figure 3.23a). This in turn will effect the apparent slenderness of the bridge (Figure 3.23b). The choice of overhang length will effect apparent slenderness through shadows cast on the depth of the superstructure. Larger overhangs will cast larger shadows which mask the depth of the span and give the bridge a more slender appearance (Figure 3.24).

With careful planning, the service life and durability of the structure may be improved through attention to non-structural details. Attention to drainage details and joint types can prevent or limit unwanted staining. Drain pipes may be tacked on as afterthought appendages (Figure 3.25a) or may be more attractively hidden within the structure (Figure 3.25b). Small raised edges, or berms, may be incorporated into designs to direct water to drain pipes and avoid unwanted dripping down the outside of the substructure. Attention to the types of joints used for the roadway will also effect the apparent aging of the structure. Open joints allow for the passage of water from the roadway above carrying with it dirt, debris, broken down jointing material, and in some areas of Texas, de-icing salts, all of which cause staining and may lead to corrosion problems in the substructure (Figure 3.26).



(a)



(b)

Figure 3. 23 *(a) Three levels of pedestrian accommodation; (b) An open edge rail accommodating pedestrians puts the impact barrier on the "inside." Thus the apparent depth of the superstructure is kept low.*

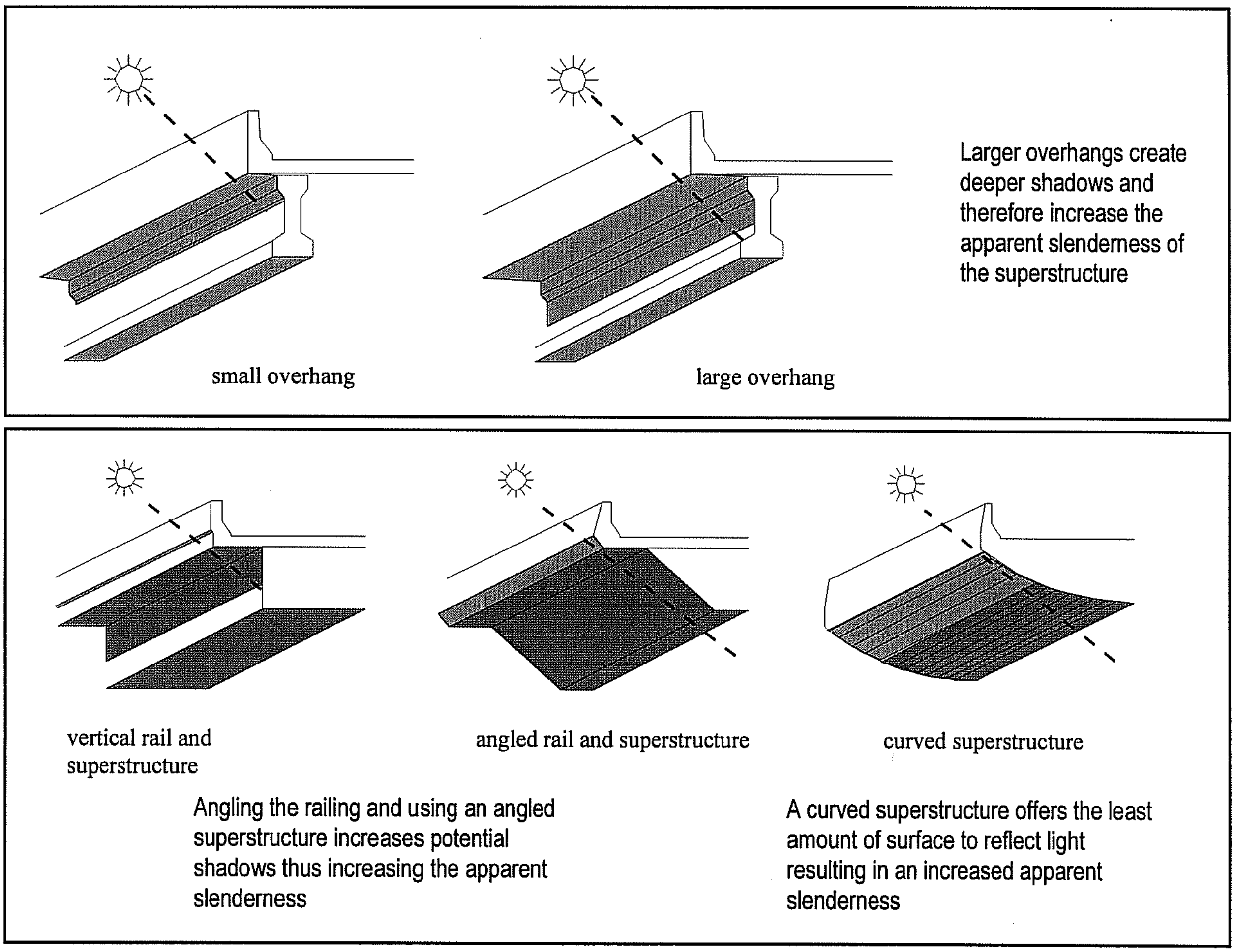
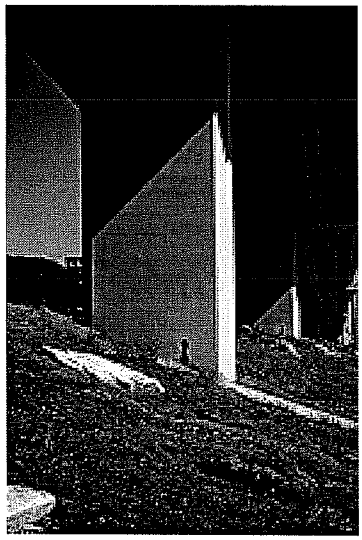


Figure 3. 24 Effect of overhangs on superstructure apparent slenderness

(a) Drain pipes tacked onto the substructure



(b) Outlet of an internal drain pipe

Figure 3. 25 Drainage details

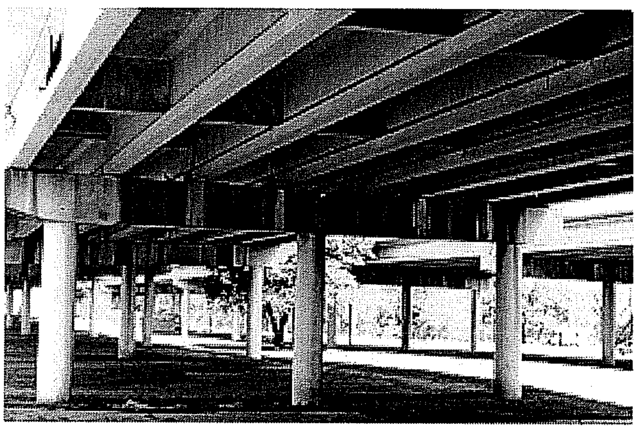


Figure 3. 26 Substructure staining due to the open joint above

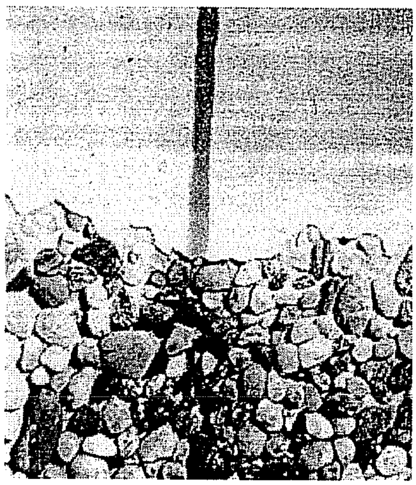


Figure 3. 27 Exposed aggregate (below) masks staining well[87]

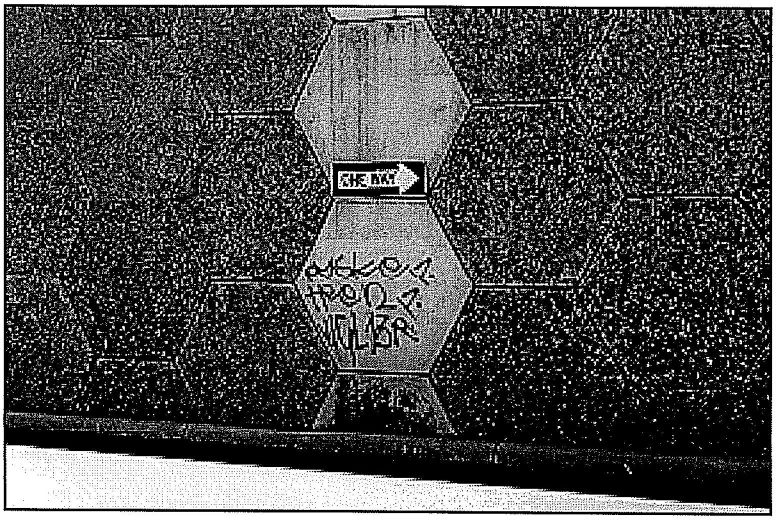


Figure 3. 28 Graffiti "artists" typically prefer a plain canvas to a textured one

Staining is a maintenance problem that can be handled in many other creative ways through attention to details of surface texture. Certain textures such as exposed aggregate and some formliner patterns can essentially mask staining (Figure 3.27). Relief can be designed into columns to direct water flowing down the substructure to run in a groove. The groove would be dark due to shadows and will therefore not appear significantly different if the groove is exposed to dark staining. The choice of surface textures has also been seen to deter graffiti "artists" (Figure 3.28).

Attention to surface texture may also eliminate the need to paint the concrete bridges and in particular the substructures. Painting concrete essentially turns a maintenance free material into a maintenance intensive material as the paint typically peels and chips within a few years of a fresh coat (Figure 3.21b). With more careful attention to surface treatments and drainage up front, painting can be avoided and the life-cycle costs of maintaining the bridge can be reduced (Figure 3.29).

Clearly, attention to non-structural details will be an important part of bridge design. Not only will good non-structural detailing enhance the aesthetic qualities of the bridge but they may lead to more durable structures that require less maintenance and will have a more lasting value for its users.

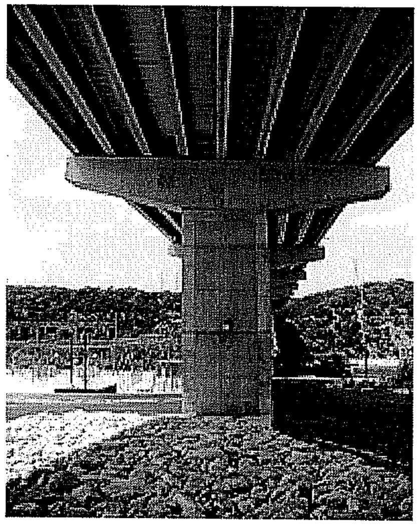


Figure 3. 29 A formlined surface and internal drain reduce maintenance needs

3.3.2 Interviews with TxDOT Personnel

The senior author conducted a number of interviews with TxDOT engineers, planners and landscape architects throughout the State. These interviews were conducted in July and August of 1995 as well as in January, 1996. The titles and positions of the people at the time they were interviewed are listed below:

Corpus Christi District:	Tom Bell, Bridge Engineer
San Angelo District:	John Dewitt, Bridge Engineer
	Mark Tomlinson, Bridge Engineer
	Joseph Morales, Area Engineer, San Angelo
	Jerry Fields, BRINSAP Engineer
Dallas District:	Van McElroy, Bridge Engineer
Pharr District:	Steve Walker, Landscape Architect
	Jody Ellington, Area Engineer, Raymondville
El Paso District:	Mary May, District Engineer
	Ray Lopez, Bridge Engineer
	Charles Berry, Bridge Engineer
	Richard Mason, Landscape Architect
Houston District:	J.C.Liu, Bridge Engineer

To better understand the relationship between the various positions held by the interviewees, Figure 3.30 shows the organization of TxDOT. The Design Division in Austin generally acts as a consultant to the district and area offices, doing design work for the smaller offices when they have too much work for their office or they do not have the in-house capabilities for a certain project.

Some of the questions raised and the responses given included:

What is the perception of the engineers as to what their role is?

The most common theme in response to this question was that engineers feel their job is to get the public on the roads quickly, safely and economically. The biggest thrust is on economics - producing cost effective designs, working within the budget.

Many interviewees felt that TxDOT engineers took pride in their work and would like to consider aesthetics more. However there was a strong consensus among the less senior personnel that without the approval or consent of upper management, they would not be permitted to carry out new ideas for more attractive solutions. Among the more senior personnel there was a mix of reactions to the consideration of aesthetics. Some felt that aesthetics always meant increased costs and were therefore resistant to discussing the topic, while others were interested in finding economical and attractive solutions to better serve the public and their cities.

How much in-house bridge design is done in your office?

The larger district offices (Dallas, Houston, El Paso) do a considerable amount of in-house bridge design but much work is also sent to the Design Division in Austin. The smaller district offices concentrate mostly on roadway layout and alignments. In the past, bridge design often dictated roadway alignments but the opposite is true today. The general trend now is for highway planners to design the highway and tell the bridge designers where the bridge will start and stop.

While much of the design work is carried out in the larger district offices and the Design Division in Austin, the district offices as well as the area offices do make suggestions and requests as to what type of superstructure and slab they would prefer for their projects.

How much communication is there between highway planners and bridge design engineers?

Communication between the highway planners and bridge designers generally equates to communication among the area offices, the district offices and the Design Division in Austin. The general consensus is

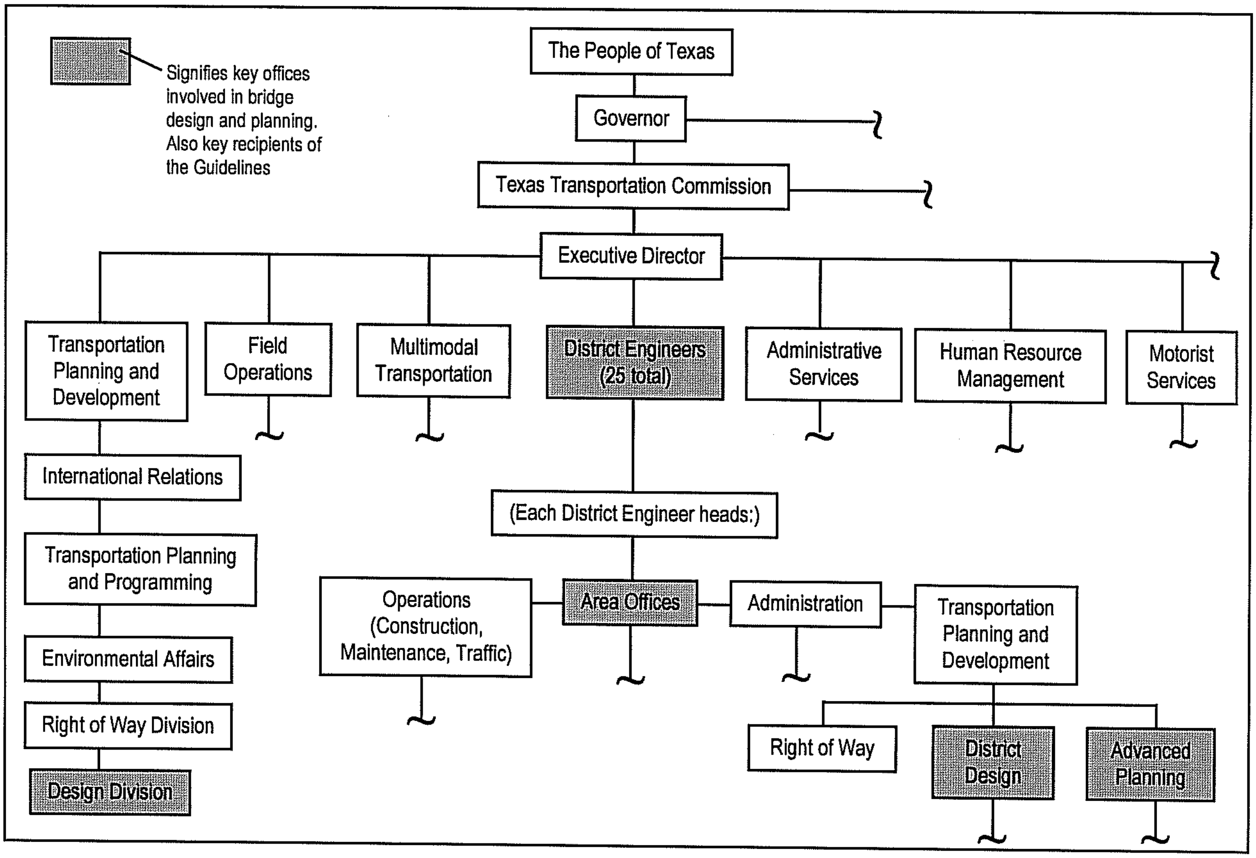


Figure 3. 30 Simplified breakdown of the Texas Department of Transportation

that communication is very good between the parties. There is some concern however, about knowing which office should be responsible for which part of a design. This results from in-house capabilities being limited in smaller offices. While some work can be done in-house, often it must be sent either from the area office to the district office or from the district office to the Design Division. As a result, there is often not much continuity from one project to the next or even within a single project as so many different engineers in different offices may complete a separate part of the project.

How receptive are local contractors to new design ideas?

In most districts, the engineers have a good working relationship with local contractors. Many engineers are comfortable with and do call contractors for advice concerning design and construction issues. There is a general feeling that contractors are receptive to new ideas but that it is important to have the contractors attend meetings and discussions with TxDOT about new ideas right from the beginning.

How much do local engineers get out on the site? Who does?

Responses to this question varied considerably. In a few districts bridge engineers almost always visit the site before beginning the design. In others, bridge designers do not. Rarely do highway planners visit the sites. Often, the Advanced Planning personnel are the only engineers to visit the site (they are required to) and this may occur up to 5 years before design work begins. Photogrammetry, or aerial photographs for surveying are always taken but these black and white photographs do not give designers a feel for the site as seen by future users.

Many engineers in the districts felt it would be easy to visit the sites, take pictures and send copies to Austin if the Design Division would be doing the bridge design.

How does the politics of right-of-ways (ROW's) and businesses affect planning? When ROW's are settled are they essentially "set in stone"?

Most engineers agreed that once a public hearing had been held concerning the location of a new project, the layout could not be changed. If changes were proposed that would improve the efficiency of the structure or result in cost savings, there might be an opportunity to make the changes. Rarely would any alignment changes be made strictly for improved appearance. If changes are made after a public hearing, compensation may need to be paid to businesses who feel they will be adversely affected by new changes.

What sort of computer graphics are available and used?

All of the offices are equipped with computer facilities that have good computer graphics packages. However, very few of the offices use these packages. The engineers feel it takes too much time to learn the software, new versions are released too quickly and there is little then justification for spending the time to learn them. Some engineers dislike the use of three-dimensional computer modeling as it is not representative of what the public will actually see (signs, light posts and other visual"obstacles" are often omitted). As a result, the public having initially seen"clean" or "simplified" computer images, may be unhappy about the final built form.

How do you feel about painting concrete?

Generally, everyone was opposed to painting concrete due to the maintenance problems of needing to continually repaint. Some engineers did like the way painted structures looked but felt the maintenance problems out-weighed the appearance benefits. In El Paso however, painting has been considered essential due to the heavy graffiti problem in their city. Other surface treatment options for their bridges such as staining or exposed aggregate would need to be sand blasted continually to remove graffiti. The surface would be ruined within a few years because of the extensive and constant graffiti problems in El Paso.

Each district seemed to face different problems in terms of the obvious signs of aging on their bridges that they typically cover with paint. The Corpus Christi District has a considerable amount of mold collecting as dark gray patches on their bridges while in El Paso it is dry dirt that accumulates on their bridges. In most other districts, dirty run-off water from the deck heavily stains substructures and in urban areas there is the added problem of exhaust pollution accumulating on the bridges.

What are the rough figures for what types of structures are built?

The majority of bridge projects in the Corpus Christi and San Angelo Districts are for stream crossings (~80%) and overpasses (~20%). The Corpus Christi District uses precast T-beams most often with precast I-girders and box beams used as well. The projects in the El Paso District are about 80% overpasses and 20% stream crossings. Much of the work in El Paso is in widening and repair of existing structures. The Dallas and Pharr Districts have roughly equal numbers of stream crossings and grade separations with Dallas also having a considerable square footage of interchange work in their district (Interchange designs generally get sent to the Design Division). Most of the projects in Houston are new construction for interchanges. Trapezoidal concrete box girders are popular in Houston and steel plate girders and steel box girders are often used for the large curved spans on interchanges in the city.

What is the typical cost per sq. ft. of bridges in this district?

The cost of precast I-girder bridges in most Districts was comparable to the State average of $310/m^2 ($29/ ft.^{2}). The El Paso District was the exception with precast concrete bridges costing roughly $590/m^2 ($55/ft.^{2}) apparently due to there being only one concrete supplier in the area.

3.3.2.1 Summary

Meeting with the many different engineers and landscape architects across the State provided important background for the development of the Guidelines. Understanding the duties and concerns of the local engineers was essential in developing guidelines that would be most useful to them. There was a strong interest for the Guidelines on the part of almost all of the engineers and landscape architects interviewed.

3.3.3 Informal Survey of the Public

An informal survey of the public in Texas was conducted. The goal of this survey was to determine the public's interest and feelings about a part of their infrastructure that is paid for by their tax dollars. What do they think of their highway bridges? Do they notice them? Do they care about them? Should the State bother to address the aesthetics of these structures? A copy of the survey questions asked is found in Appendix B. A large amount of information was gathered from the responses to these questions. However, only the questions particularly important to the development of the Guidelines are presented here. These include questions that display the interest or disinterest of the public in having their State engineers address aesthetics when designing State highways.

Face to face interviews were conducted with approximately 400 people at various locations across Texas. The interviews generally lasted from three to five minutes. The locations of these interviews are shown in Figure 3.31. As seen in Figure 3.32a, the number of interviews conducted in Austin were much greater than any other location. The effect of the Austin pool did not significantly skew the data except in the response to a few questions. Where the responses in Austin did skew the data, the Austin pool was

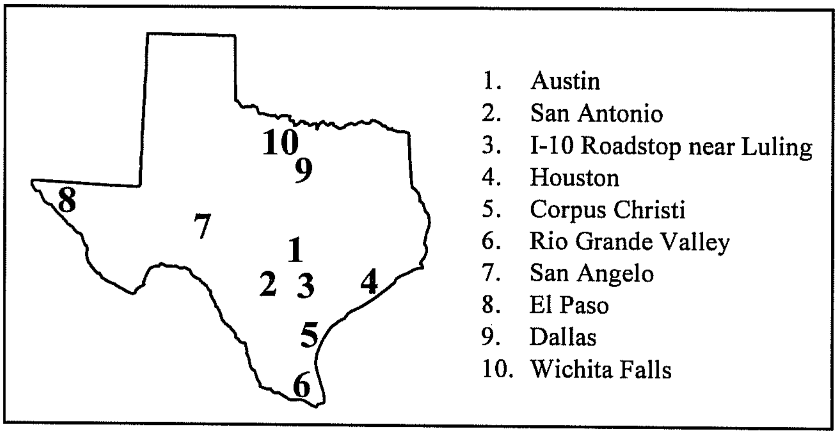


Figure 3. 31 *Locations in Texas where the "Survey of the Public" interviews were conducted*

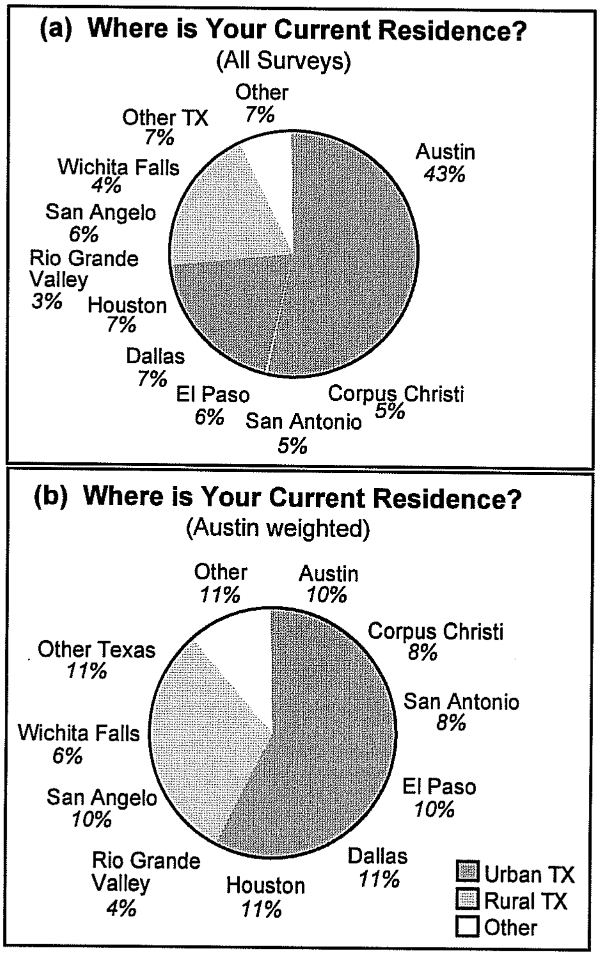


Figure 3. 32 *Survey of the Public*

reduced to a percentage more equal to the percentages of the other nine survey locations. With Austin "weighted," each location represents between 4-11% of the responses (Figure 3.32b). (See Appendix B for further explanation). For the figures in this section, if the Austin pool was weighted, it is indicated beneath the question as "(Austin weighted)."

The responses to the survey represent a wide geographical and cultural mix of people surveyed. The occupations of those surveyed (Figure 3.33) also show that opinions were gathered from a realistic cross-section of workers, students and retirees throughout Texas.

The surveys from Austin were conducted by approximately 45 different students as an assignment for their Concrete Bridge Design class at the University of Texas at Austin. One result of such a wide variety of surveyors was that the amount of information recorded for each survey varied. To display clearly the amount of information gathered, two separate numbers appear at the bottom of each figure. The first number represents the percentage of people who responded to the question. As some questions asked for more than one answer, the second number represents the total number of responses given. Another important aspect of the large number of different surveyors is the assumptions made by the authors in interpreting the responses. These assumptions and their limitations are discussed in Appendix B.

Some background questions were asked at first to determine how much the public feels affected by their built environment. As seen in Figure 3.34, the appearance of buildings is important to the vast majority (over 90%). While bridges are typically a less frequent site than buildings in most locations, the appearance of a bridge had at least some effect on over 85% of those surveyed.

When asked about favorite bridges (Figure 3.35) the majority of the public's favorites were out of State bridges with the Golden Gate bridge amounting to 35% of the out of State favorites. Close to one third of the favorite bridges were in Texas. Some responses mentioned only a certain type of bridge such as suspension bridges, arch bridges or covered bridges. These are represented on Figure 3.35 as "Specific Type." Of those who named one specific bridge, only 10-15% of these bridges were of short or moderate spans (an exact percent was not possible to determine as some of the names of the bridges were unfamiliar to the authors).

The series of questions asked that were particular to Texas and to Texas Bridges are shown in Figures 3.36-3.38. The majority of the public surveyed is on the highways almost every day. A surprising 80% of the people surveyed notice at least some of the standard bridges in the State. Of those on the highways almost every day, a similar 82% said they notice at least some of the bridges.

While 30% of the responses shown in Figure 3.38a were positive towards Texas bridges, the majority of comments were negative. The bridge comments were particularly negative by respondents from urban areas of Texas. Respondents from the international border towns felt more favorably towards Texas bridges (Figure 3.38b).

While the public had certain opinions about the bridges in Texas, they also were aware of bridges in other states. By far, the public felt that California had the nicest looking bridges (Figure 3.39a). Geographically, the Northeast and the West Coast seemed to have the most attractive bridges in the minds of those surveyed (Figure 3.39b).

Many of these responses might be representative of the States having nicer monumental bridges so it should not necessarily reflect negatively on Texas's short and moderate span bridges. However, clearly bridges can make an impression and are identified with their State. The image of a State can be enhanced or diminished through it's infrastructure.

What is Your Occupation?

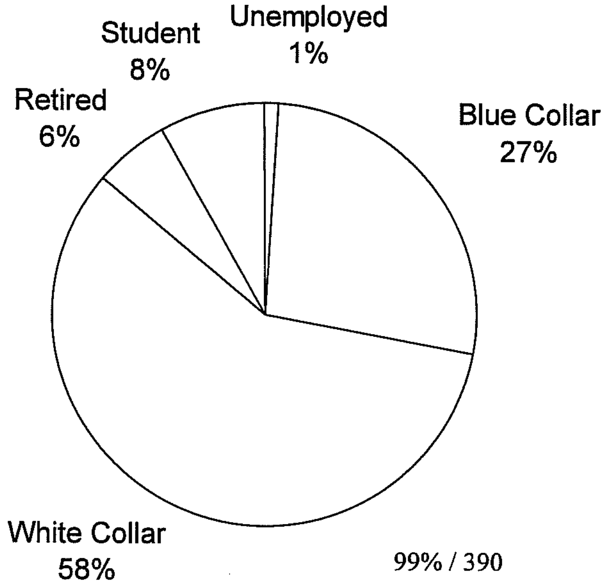


Figure 3. 33 Survey of the public

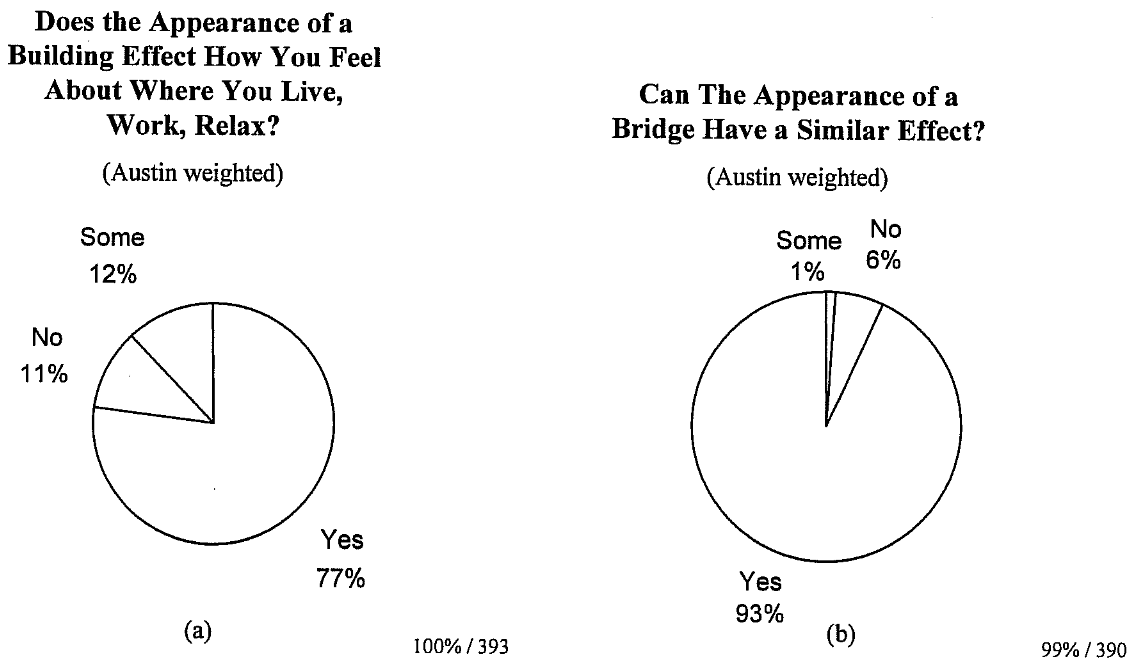


Figure 3. 34 Survey of the public

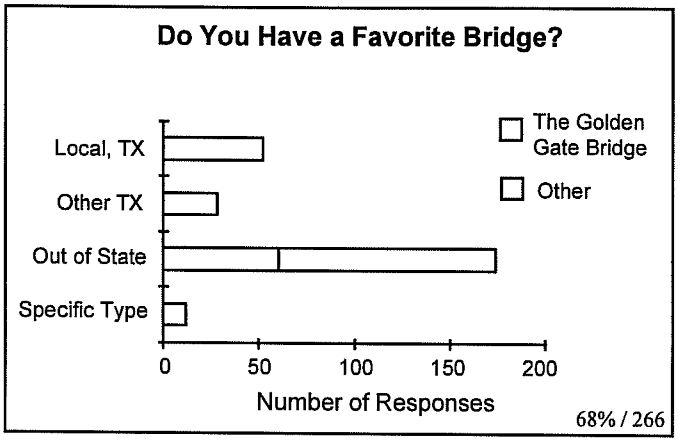
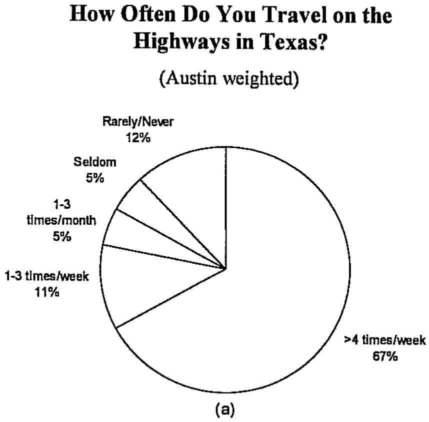


Figure 3. 35   Survey of the public



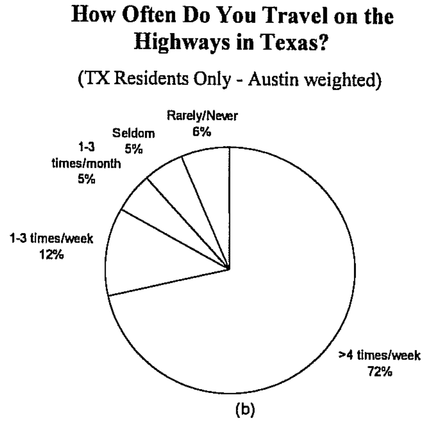


Figure 3. 36   Survey of the Public

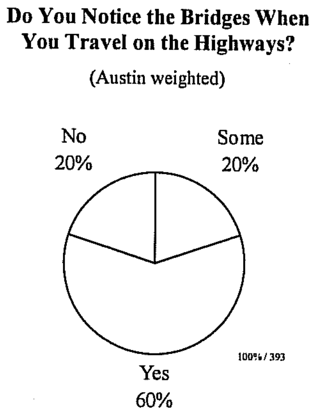
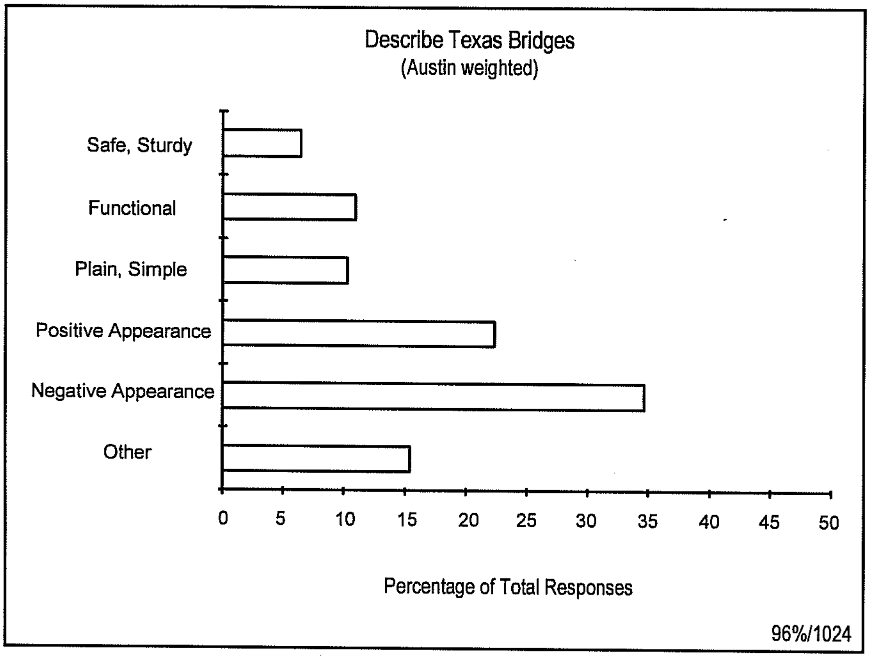
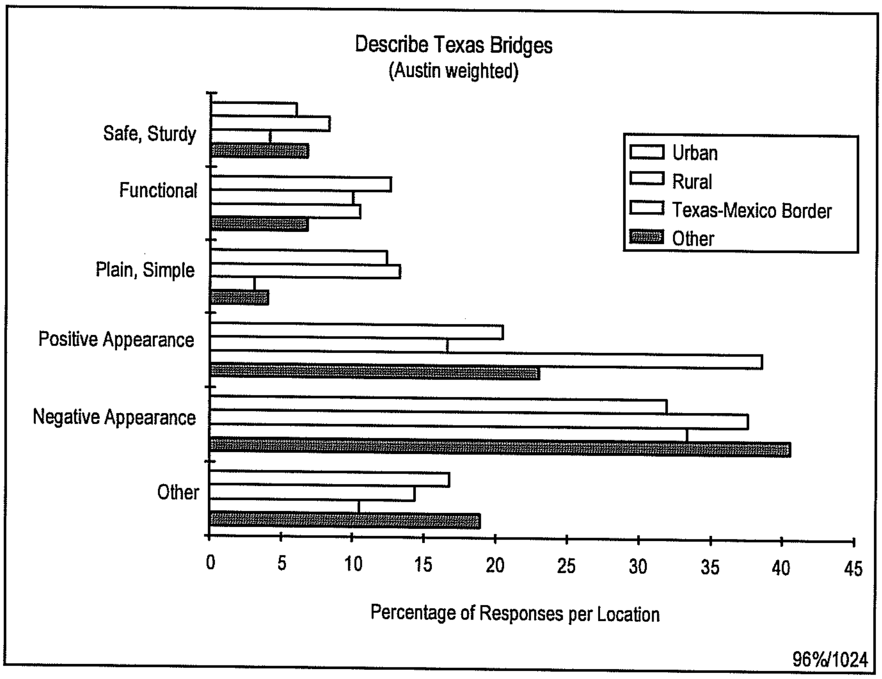


Figure 3. 37   Survey of the public



(a)



(b)

Figure 3. 38 Survey of the public

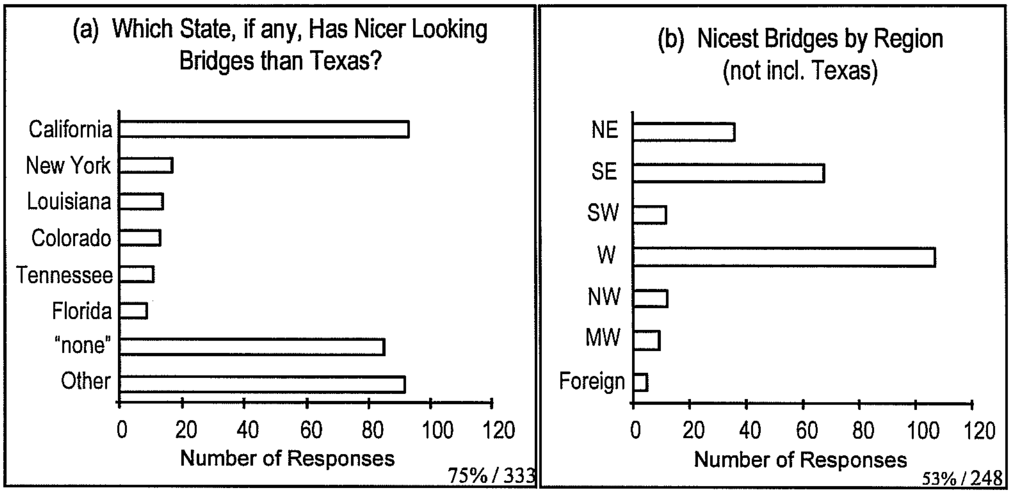


Figure 3. 39 Survey of the public

Describe Texas Culture		**Describe Texas Bridges**	
Friendly	199	**Ugly, Dull**	**206**
Diverse	*140*	*Plain*	*127*
Laid Back	73	Functional	118
Unique, Colorful	**59**	Attractive	111
Western/Cowboys	56	Unsafe, Dangerous	88
Energetic, Lively	55	Safe, Sturdy	72
Proud	44	*Same everywhere*	*46*
	97% / 1068		96% / 1024

Figure 3. 40 Survey of the public

The public was also asked to describe the culture in Texas. The responses varied but, interestingly, showed a very positive, friendly and diverse culture. When compared to the appearance of their bridges, there is little consistency between what the State represents to the people and what a considerable part of their infrastructure represents to them (Figure 3.40).

Finally, the public was asked if they felt the State would be justified in spending their tax dollars on improving the appearance of the standard bridges of Texas. The response is quantified in Figure 3.41. While the majority of those interviewed did approve of tax dollars being spent on building more attractive bridges, almost 40% were against such spending. Looking only at the responses of those who notice the bridges, there was no significant difference in the percentage of people for or against tax money going towards improved bridge aesthetics.

Many other comments and concerns of the public regarding highway bridges were recorded. Safety was a big concern as well as avoiding traffic delays during construction. When asked to make suggestions for improvements, a majority of the responses referred to surface treatments such as painting, using more color and "decorating" the bridges.

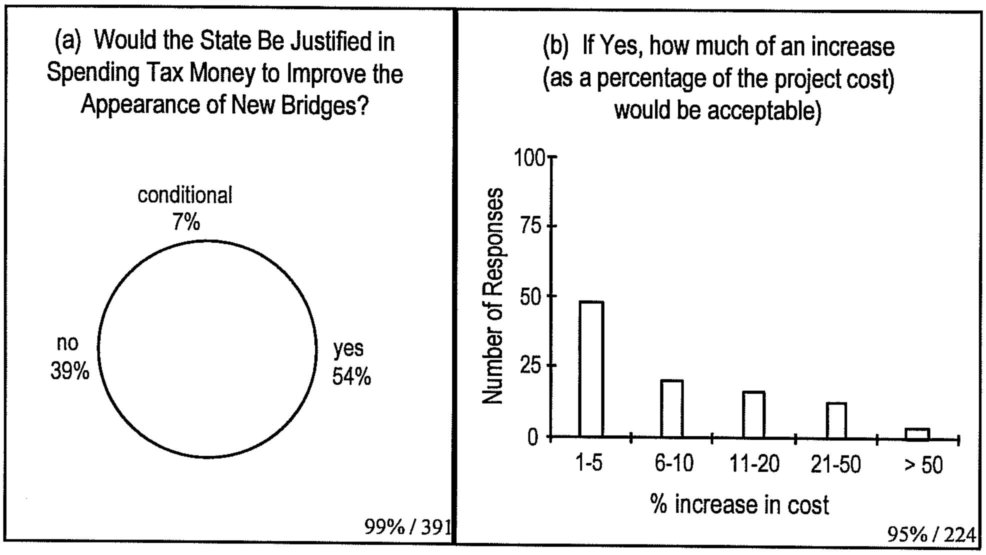


Figure 3. 41 Survey of the public

3.3.3.1 Summary

Surveying the public on their impressions and concerns about the short and moderate span highway bridges in Texas was a valuable exercise. At least some of the standard bridges in the State are noticed by 85% of the people surveyed. People do notice their local bridges and do identify with them. The appearance of these bridges therefore can reflect the quality of life of the area. Attention to bridge aesthetics is also an opportunity for the State to display its care for the public when spending their tax dollars on an important part of their infrastructure.

When questioned about their favorite bridges, over 85% of the people surveyed named bridges that were long-span and often monumental bridges such as the Golden Gate Bridge in San Francisco. Short and medium span bridges are not attracting their attention. This may or may not be a reflection on the aesthetic qualities of the bridges. Perhaps short and moderate span bridges will never be "favorites". However, these short and moderate span bridges are a recognizable and impressive part of their built environment. The predominance of negative comments concerning these bridges of Texas shows considerable dissatisfaction with their appearance. There is a call for more attractive standard highway bridges.

There is an interesting challenge involved with recognizing the public's suggestions for improvements and their feelings towards spending tax money to improve bridge aesthetics. Most of the comments for improvements dealt with surface treatments, in particular color and decorations. Although many surface treatments do not require excessive costs, in general added color or decoration will increase costs. While 60% of the public felt the State is justified in spending tax dollars to improving bridge aesthetics, the 40% who are opposed is a significantly strong voice. What is important for engineers to recognize is that improvements must be made and searched for that will remain economical. Surface treatments are attractive and can and should be used in highly visible locations to enhance a good project. However, good engineering design with attention to improved layouts, choice of structural systems, and overall form will have more of an impact with very little if any increase in cost.

The public seems generally unaware of state-of-the-art bridge design. Engineers however, are aware of and have a better understanding of the elegant possibilities in engineering design. The strong tradition within the field of structural engineering of designing elegant *and* economical structures must be carried on. Elegant structures in the past generally have minimized unnecessary detail. The popularity of California's bridges shows what an important and good visual impression can be made with elegant structures that are simple and not "decorated". Attention to the appearance resulting from each engineering decision in the past has and in the future should continue to result in attractive structures.

As State engineers are well aware, safety and economics are typically the overriding concerns for everyone. However, the positive interest in bridge aesthetics by the public should be seen as a call for more innovative and attractive designs that will still remain economical. Knowing that the public is in support of having more attractive bridges should act as an inspiration for State engineers to strive for engineering elegance in their work.

3.4 Themes for the TxDOT Aesthetics & Efficiency Guidelines

A number of different principles, ideas and "keys for success" have been identified in previous aesthetics guidelines for bridges (see Section 3.2). Emphasizing such ideas in a set of guidelines is important and such emphasis should be found throughout the entire document. For the Guidelines, effort has been made to synthesize into three simple themes, many of the key principles that are inherent to good bridge design (including many of those addressed in previous guidelines). By minimizing the number of themes, the ideas they encompass can be more effectively understood and implemented. Rather than having up to 10 separate topics to address and apply to one project, the TxDOT engineers will be asked in the Guidelines to consider how their designs will hold up to the ideals of three main themes.

The three themes are listed here and are discussed in depth in the following sections:

(1) **Aesthetics, Efficiency and Economics** - the interrelationship of these disciplines in engineering design.

(2) **Vision** - the importance of having an overall design concept for a project.

(3) **Coherence** - the integration of the engineered design and the design concept with each decision to form a coherent, attractive structure.

3.4.1 Aesthetics, Efficiency, and Economy

The first theme in the Guidelines is that there is a strong interrelationship between aesthetics, efficiency and economics in every good bridge design. **Aesthetics** in bridge design is defined in the Guidelines as the visual appearance or impression given by the structure. Considering the visual impact of a bridge to be important, all engineering design decisions should be sensitive to bridge aesthetics. **Economics** plays a key role in bridge design particularly for public works. Engineering design decisions must always be related to their economic impact on a project. The **efficiency** of a design is directly connected to and joins together both aesthetics and economy.

Efficiency may be thought of in terms of material efficiency or construction efficiency. Material efficiency refers to optimizing material use - or minimizing wasted material. Construction efficiency refers to minimizing the time and simplifying the process of fabrication and erection. For short and moderate span bridges in particular, optimizing the construction method will often override optimizing material use for efficient design. In relation to economics, efficiency in design may for instance lead to decreasing material amounts or increasing the rate of construction, thus directly effecting the cost of the project. In relation to aesthetics, material efficiency or, minimizing wasted material, may allow the pure structural form to shine forth, thus dictating the bridge's appearance. Efficiency therefore affects and is affected by both economics and aesthetics. For a successful result, efficiency must balance the two. It is an assumption and "prejudice" of the author and research team that efficient structural forms are a key component to the design of attractive structures. This partiality is maintained throughout the Guidelines.

Ideally, an efficient design will be one that is both attractive and economical. Different projects however, will certainly have different constraints and perhaps different demands of the public. Certain projects may demand special attention to the visual impact while others may be more controlled by a tight budget. While the emphasis of certain designs may focus more on the appearance than on the economy or vice versa, neither discipline may be entirely neglected. Efficient design will strive for economy and attractiveness no matter what the constraints are and in a balance that satisfies both the owners and the users.

To display the interconnectedness of the disciplines of aesthetics, efficiency and economics, consider three examples where the project focus is function, construction and maintenance, respectively.

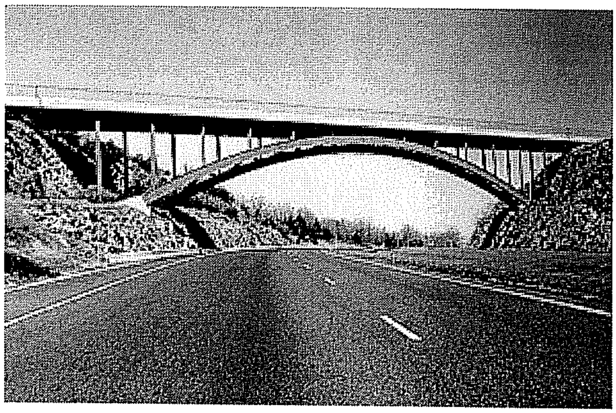


Figure 3. 42 *An arch bridge taking advantage of the natural abutments*

Function - A balance of aesthetics, efficiency and economics can be achieved by focusing on the function of the bridge and its elements. If the bridge is to span a valley, an efficient form might be an arch - the valley walls are natural abutments therefore eliminating the need for man-made abutments (Figure 3.42). If the bridge is to span a highway (grade separation) a slender beam system might be chosen to satisfy clearances and minimize the height of the built up approaches. Angled piers may be chosen to provide more horizontal clearance without increasing the central span, and to minimize foundation requirements by taking advantage of required retained earth or abutments (Figure 3.43). Focusing on the function, efficient forms are chosen to take advantage of natural conditions (valley) or project constraints (need for abutments or certain vertical clearances). Searching for an efficient form in these examples has a direct effect on economics - foundation costs could be minimized. Such decisions also have a direct effect on the aesthetics of the structure. The visual impression of the structure results directly from the choice of overall form. Clearly this choice of form at the outset has more aesthetic effect than any embellishments or additional color or texture that could be added at the completion of the project.

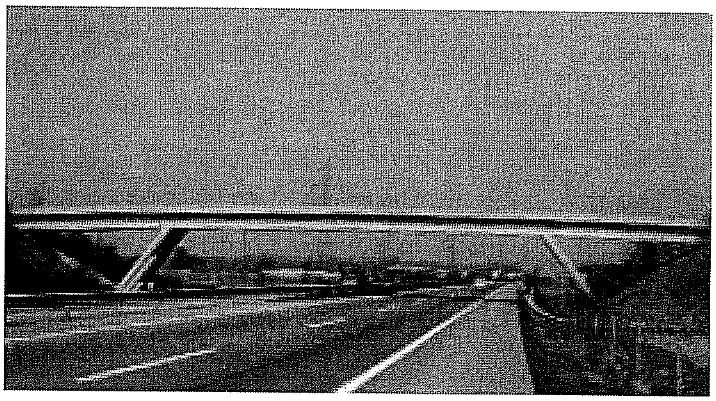


Figure 3. 43 *Angled strut piers decrease the clear span and superstructure depth while increasing clearance for traffic passing through (photo, Reference 23)*

Construction - Aesthetics, efficiency and economics may be driven by construction methods. For the use of highly repetitive bridge elements, precasting is cost effective. In congested areas, this method of construction may be much faster than cast-in-place construction thus reducing traffic delays and on-site labor. This has been conclusively shown in the development of highly efficient, slender precast pretensioned I, U and box beams. The slender and efficient use of concrete for these superstructures has had a direct positive effect on bridge aesthetics. However, in the case of substructure design, most short and moderate span bridges use standardized but less attractive and inefficient cast-in-place systems. Often large amounts of highly repetitive form assembly, bar placement and field concreting are carried out at hazardous and inefficient elevations over long time periods which can substantially disrupt or constrict traffic (Figures 3.44-3.45). A more artistic and efficient substructure shape could be precast economically for repetitive use (Figure 3.46). Quality control and material characteristics would be improved with precasting and lead to more attractive finishes and more durable substructures. The attractive finishes and improved durability will decrease future maintenance costs as well by no longer requiring painting. On site construction time could be considerably reduced leading to lessened traffic disruption and traffic control costs.

Figure 3. 44 *Highly repetitive substructures requiring extremely tall and strong forms*

Maintenance - Aesthetics, efficiency and economics may be combined while concentrating on maintenance issues for a project. Many nagging and expensive maintenance issues result from problems with "surface" aesthetics, such as unwanted staining of concrete, or peeling of paint. Bridges in highly visible locations may be designed with a focus on avoiding such maintenance problems. For instance, with attention to issues of proper drainage considered at the outset as part of the plans, aesthetics will be improved with negligible cost (Figure 3.47). An efficient design will incorporate problem-solving details in an attractive and economical way. Drain pipes may be hidden inside hollow columns or drip lines may be incorporated into the structure to avoid or control unwanted staining. Attention to surface treatments such as exposed aggregate or use of texture and formliners can replace the need for painting thus ensuring an attractive appearance while decreasing maintenance and life span costs (Figure 3.48).

3.4.2 Vision - Developing a Design Concept

The second major theme in the Guidelines is that a designer must have a vision or, develop a design concept for each project. It is important for the designers to have an *initial vision* of how the bridge will function and appear in it's *final form*. The basis of a vision or design concept may vary widely. It may be a result of the geography or the local culture. It may result from the support conditions expressing structural function or local construction practices. Vision has always been a necessary element of successful engineering works.

Figure 3. 45 *Repetitive cast-in-place columns requiring considerable on-site labor and space*

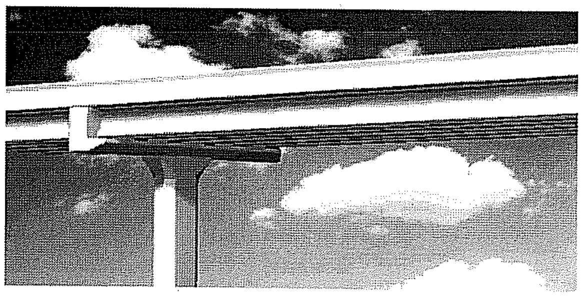


Figure 3. 46 *Precast concrete substructure systems can be efficiently fabricated and erected with attractive and durable results*

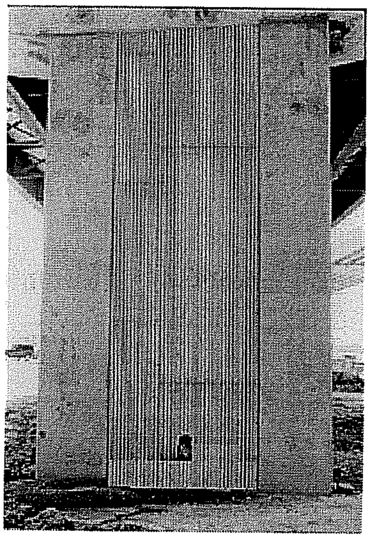


Figure 3. 47 *Use of internal drain pipes*

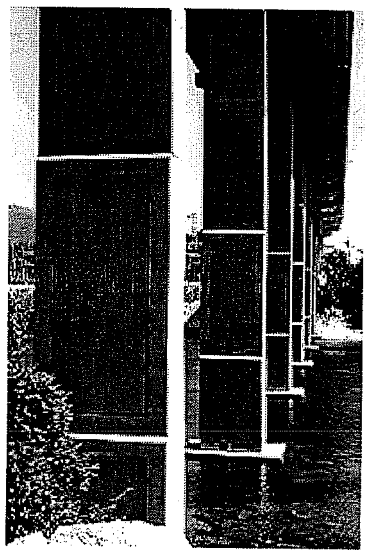
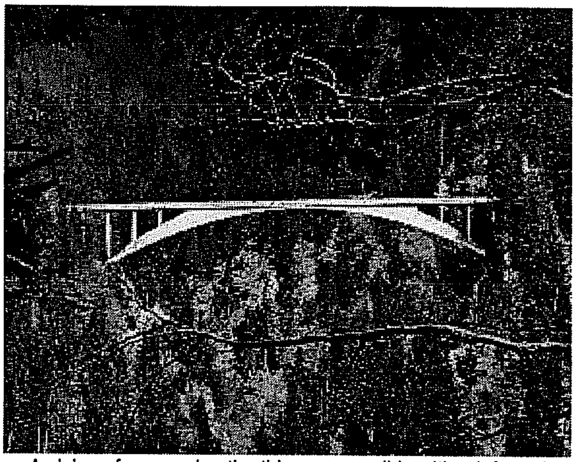
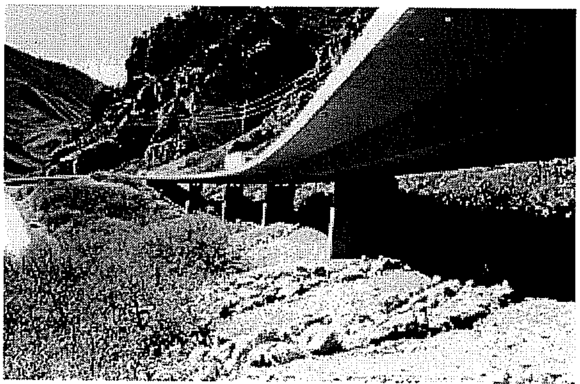


Figure 3. 48 *A formlined surface eliminates the need for painting*



A vision of expressing the thinness possible with reinforced concrete in an arch form.

Figure 3. 49 *Maillart's Salginatobel bridge in Switzerland*



A vision of harmonizing with the striking beauty of the environment

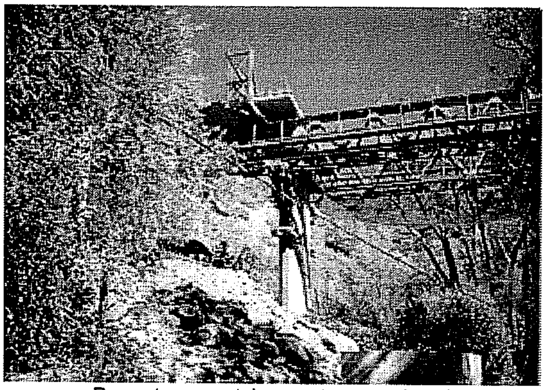
Figure 3. 50 *One of five segmental bridges along I-70 through Glenwood Canyon*

Great engineers of the past conceived and carried out their vision of what an appropriate and attractive structure would be for a particular site. Swiss engineer Robert Maillart was driven by the desire to build very light elegant structures that were simple to construct. His structures were often designed as entries in design competitions where the low price solution was usually the winner. Efficiency, constructibility and low cost were driving forces behind his vision for winning bridges (Figure 3.49). The elegance of Maillart's designs clearly show that beauty does not have to equate with costly.

The former Figg & Muller Engineers Inc., had a tradition of developing and carrying out visions for their designs. They were the designers of five segmental concrete bridges along I-70 through Glenwood Canyon in Colorado (Figure 3.50). The breathtaking beauty of the canyon was well appreciated as it was the site of the most frequently hiked trail in Colorado at the time the project began in 1981.[32] Figg & Muller's vision for this bridge was sensitive to the natural beauty of the site and focused on the design of structures that would harmonize with the environment. Post-tensioned segments were chosen as the structural system for both the piers and the superstructure and a major portion of the work was carried out from the already placed superstructure (Figure 3.51). This method of construction minimized site impact by reducing the large amount of temporary bracing built from the ground below, typical of cast-in-place construction. Segments were cast indoors using the short-line method allowing fabrication to occur indoors year round - an important feature in Colorado's typically harsh climate where the construction season is short.[32] All of these techniques were efficient and economical solutions that the engineers chose in order to comply with their vision of harmonizing with the environment. The success and attractiveness of the project is clear and was recognized in a project description; "...the roadway blends into the scenery so smoothly that it seems a natural part of the canyon. ....as is so often the case, this natural appearance was gained only through careful planning and painstaking attention to details."[32]

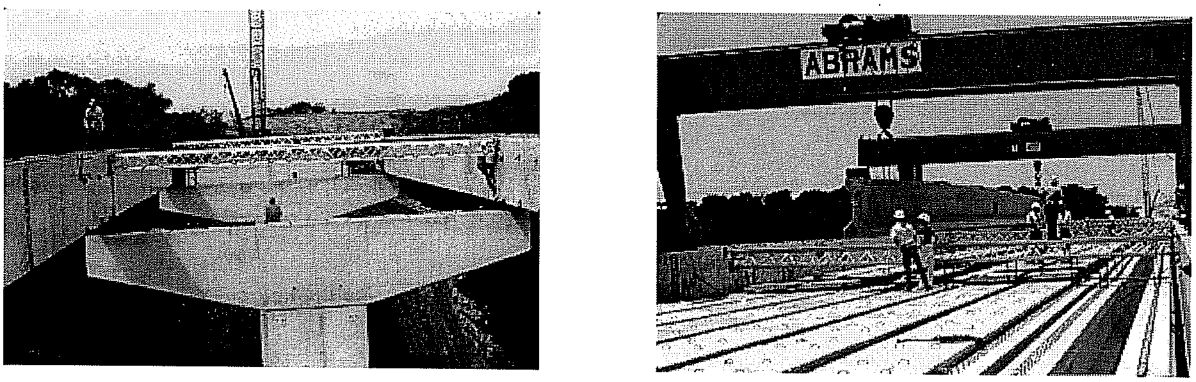
TxDOT as well has built bridges with a vision of minimizing environmental impact on the surroundings. The Loop 1 ("Mo-Pac") extension over Barton Creek in Austin is a standard precast I-girder bridge with attractive single column hammerhead bents. The precast beam superstructure was placed from above to minimize disturbance to the site below (Figures 3.52a&b).

There was a consistent vision behind the US183 elevated highway in Austin (Figure 3.53). Attention was paid to the environment as human scale was introduced through relief in the tall columns. At the same



Precast segmental superstructure placed
on erection trusses using a launching gantry
from the already built deck

Figure 3. 51 Minimizing site disruptions



(a) (b)

Figure 3. 52 (a) Steel girders positioned for straddle cranes;
(b) Placement of recast girders using straddle cranes

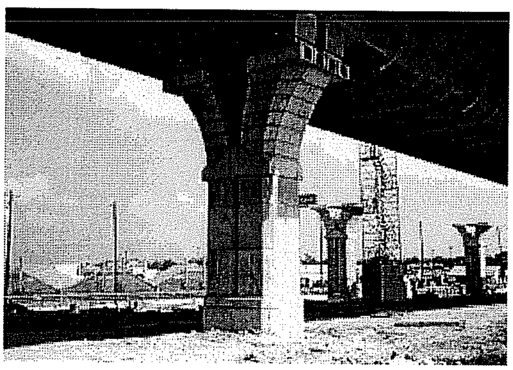
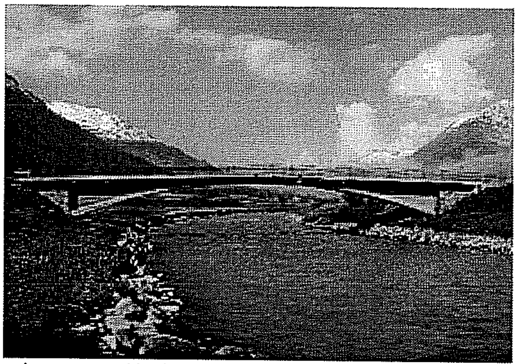
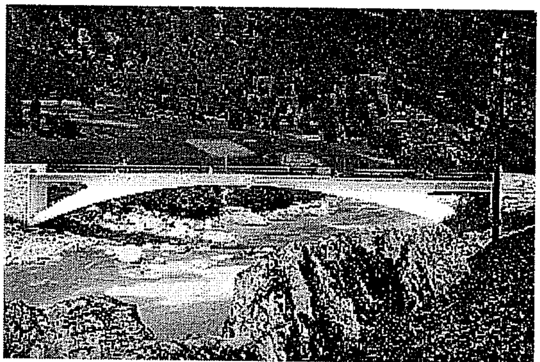


Figure 3. 53 US183 in Austin, Texas, during construction



Cracks appeared in the side walls of this three-hinged box-arch when the bridge was put in service.

Figure 3. 54 Robert Maillart's Inn River Bridge at Zuoz, Switzerland



The side wall material not required structurally was removed from this three-hinged arch resulting in a new, elegant, and more efficient form.

Figure 3. 55 Maillart's Rhine River Bridge at Tavanasa, Switzerland

time the progressive and technological environment of Austin was expressed in the state-of-the-art technology of the precast segmental box girder. The interesting new column shape is an innovative solution to expressing both the construction and structural function of the bridge. The notch in the "Y"-shaped piers provided a support for the erection truss used to erect the superstructure. The need for temporary supports or attachments to the piers was minimized. The function of the piers to carry the bridge loads down to the foundations is expressed in the unique "Y" shape. The exposed steel pipes carry tension and the concrete is primarily in compression.

In all of these examples, the vision and design concepts were developed through experience over time. Vision is not a sudden inspiration attained only by a chosen few artists. Rather, vision is the product of long and careful consideration throughout one's career. Some examples follow.

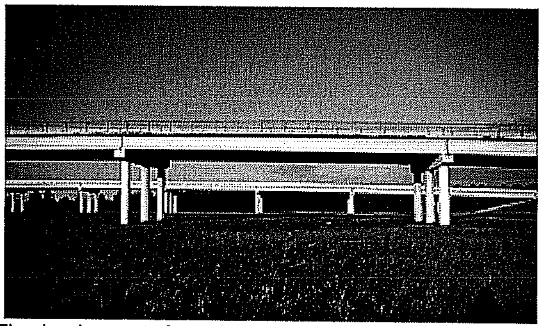
Maillart began many of his projects by imitating previous designs. Examining his work, one can see the development and evolution of his design concepts. The Inn River Bridge at Zuoz, Switzerland completed in 1901 was a 3-hinged box arch with solid side walls. When the bridge was in service, Maillart noticed cracks appearing in the walls. Upon investigation, he realized that the cracks were due to shrinkage and temperature problems and that in fact the solid wall of concrete was not needed structurally. In a later design of a three-hinged arch for the Rhine River Bridge at Tavanasa, Switzerland completed in 1905, Maillart removed the unnecessary material resulting in a new and elegant form that was more efficient than that of the Zuoz - the amount of unnecessary material was reduced. With each new design, new challenges were faced and new structures, ones that were further refined, were the result (Figures 3.54-3.55).[33]

In Texas, the continuous development of design concepts can be seen as well. In the past, many short span slab bridges with trestle bent substructures were built. These were simple to construct as well as economical. Over the years, TxDOT has developed the use of the highly efficient and economical precast, prestressed I-girder for bridge superstructures. TxDOT carried out their vision for efficient economical design in pursuing this new form. Aesthetics were improved as well. Longer and more slender spans were achieved, allowing for less substructure and therefore increasing the visibility through the bridge (Figures 3.56-3.57).

The development and construction of segmental box girder bridges is another example of refining design concepts in Texas. Segmental concrete bridge construction has been developed and advanced over time

A common bridge system used in Texas up to the 1960s

Figure 3. 56 Short-span slab bridges with trestle bent substructures



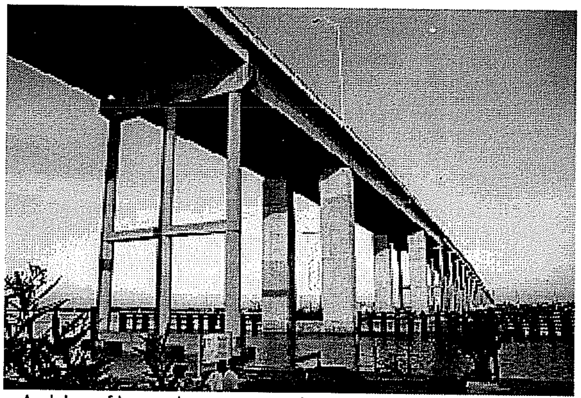
The development of standard precast prestressed I-girders has economically increased span lengths and reduced the number of required substructure units

Figure 3. 57 Prestressed I-girder bridge

in Europe and more recently in the US. Economic savings through the ease of construction has been the guiding vision for the development of segmental bridge construction.[34] Both the economy and flexibility of construction techniques for building precast segmental box girder bridges led to the design of the first of these bridges in the US - the JFK Causeway in Corpus Christi, Texas (Figure 3.58). A later segmental box girder water crossing was the Long Key Bridge in Florida designed by Figg & Muller. Here the basic ideals from the JFK Causeway of economy and flexibility in construction were incorporated and refined to form a different and very attractive structure (Figure 3.59). Figg and Muller then brought their experience and ideas back to Texas where the choice of a segmental box girder bridge fit the vision for their design of the San Antonio "Y" project. The "Y" project bridges were to be built in congested urban areas where speed of construction was essential, high visibility required particular attention to aesthetics and the use of public funds demanded an economical solution (Figure 3.60). A number of years later, TxDOT saw the vision of the "Y" project fitting well with the US183 project in Austin and also chose to design and construct segmental concrete box girder bridges for their elevated highway. The vision for economy, attractiveness and speed of construction was carried further through the design of segmental piers to speed construction and improve the piers' surface texture (Figure 3.61). Each project's vision incorporated a basic ideal of segmental bridge design - economy of construction. And each project can be seen as development or refinement from the previous one, all with efficient and quite different aesthetic results.

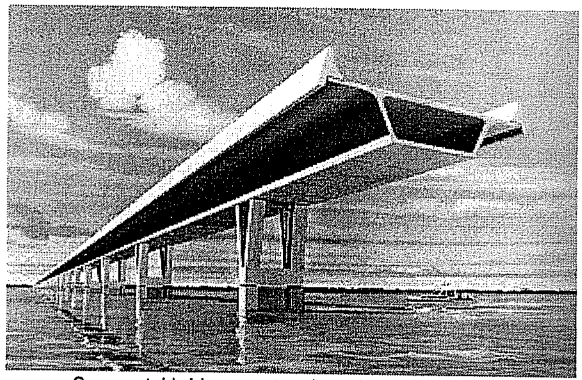
The study of past works to understand what the key visions were for various projects in different contexts helps guide the design process. It is also important for engineers to write or speak about their own projects to share ideas and experiences. Communication furthers collaboration between designers and builders. Familiarity with previous works of other engineers provides a foundation from which engineers may develop new forms or ideas for the bridges that they design.

Regardless of how vision and design concepts develop, the TxDOT Guidelines urge that the concept must be considered at *all* stages of the design process - from planning and layout to super- and substructure design to non-structural details such as choice of railings or surface texture. With design intentions formulated at the outset, guidelines will then be useful in aiding designers to carry out their vision for a bridge. Guidelines are simply a set of tools to be accessed and referred to when needed. Designers must hold true to their ideas and vision for a design in order to produce well-integrated and attractive structures.



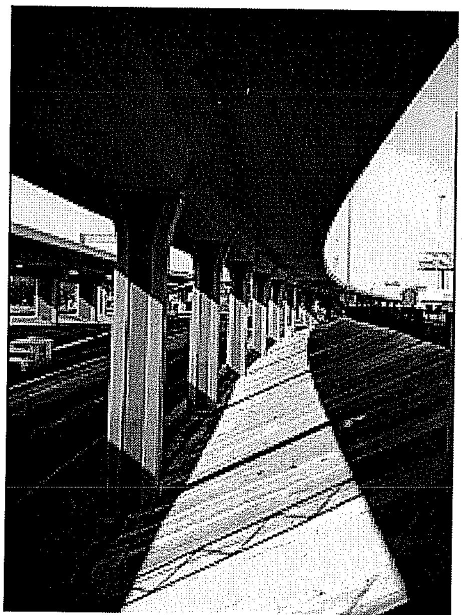
A vision of improving economy through a flexible construction technique

Figure 3. 58 The JFK Causeway in Corpus Christi, Texas



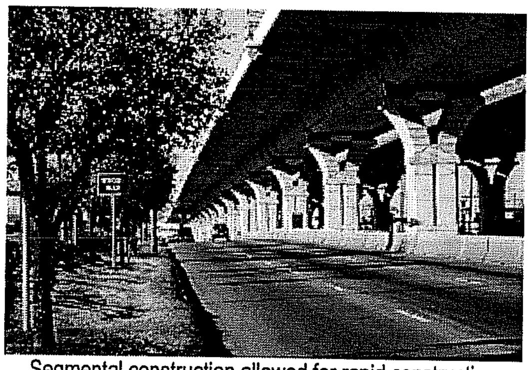
Segmental bridge construction with a different and very attractive result.

Figure 3. 59 The Long Key bridge



Segmental construction provided attractive and rapid construction for the highly visible and congested urban site

Figure 3. 60 The San Antonio "Y"



Segmental construction allowed for rapid construction and improved surface finish

Figure 3. 61 US 183 in Austin, Texas

3.4.3 Coherence

The third major theme of the Guidelines is that all projects must be coherent. Coherence for the Guidelines is defined in two ways, as an intellectual objective and as an objective for the final design form. As an intellectual objective, coherence for bridge design in accordance with the Guidelines refers to the integration of the engineered design and the design concept with each decision. As an objective for the design form, coherence is achieved when a structure is seen as one united composition rather than the sum of unrelated parts. The relation of each bridge element to another should have an apparent logic. A coherent form will have well-integrated parts. Standardized bridges in particular are made up of many individual elements. The successful integration of the elements together*and* in accordance with a design concept or vision for the bridge will lead to an attractive, coherent design.

Coherence may be striven for with every step and every decision made during design. Coherence also requires attention to how the many different parts of a design will come together. The principles of efficient and economic design applied in accordance with an aesthetic vision for a bridge must guide each step. All decisions made with the same set of goals in mind will lead to a well-integrated structure. Decisions which are as basic as the support layout or as detailed as drainage pipe locations all have an important effect on the coherence of a structure. (Detail decisions are particularly important for life span and maintenance considerations.) There are many examples of bridges which have attractive layouts and overall form (Figure 3.62) yet which have little attention to non-structural details (Figure 3.63). While the objective of relating the bridge elements to one another may be achieved, the objective of adhering to the design concept at every step of the design process was not. The result is a non-coherent, unattractive structure when seen up close. Another common example of non-coherence occurs when bridges with poor layouts or dull forms are simply painted differently or covered with a textured facade (Figure 3.64). The objective of relating bridge elements to one another for coherent design is ignored. Instead, an attempt is made to mask the lack of attention to element relation. Such attempts to mask a dull form are rarely successful and the result typically remains an unattractive structure.

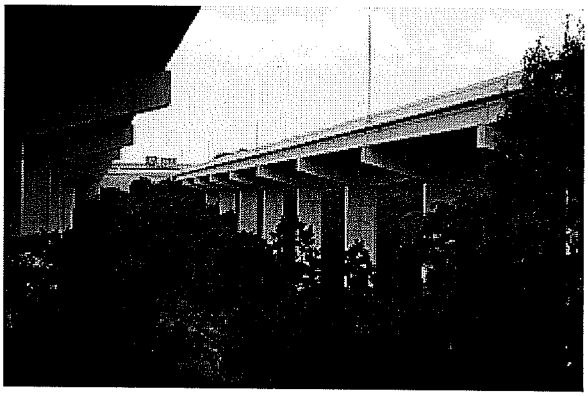


Figure 3. 62 The even, repetitive single-column bents provide an attractive and well-balanced appearance

A classic example of a coherent structure is the Linn Cove Viaduct along the Blue Ridge Parkway in North Carolina. The attractive setting alongside Grandfather Mountain demanded a structure that would enhance and not detract from the site's natural beauty. The vision then developed by the designers was one of harmonization with the environment with the least amount of environmental impact on the surroundings. The idea of harmonization was first addressed with the geometric layout through the decision to have the bridge follow the curve of the mountain side (Figure 3.65). This was carried out in superstructure design through the use of a segmental box girder - a form of construction well-suited to curved layouts. Segmental construction was used for the elegant substructure design as well. Pier segments were precast using local materials in a highly efficient form. They were lowered into position from the already built deck and later post-tensioned together. This novel construction technique ensured minimal disruption of the surroundings and thus complied well with the vision of harmonization with the

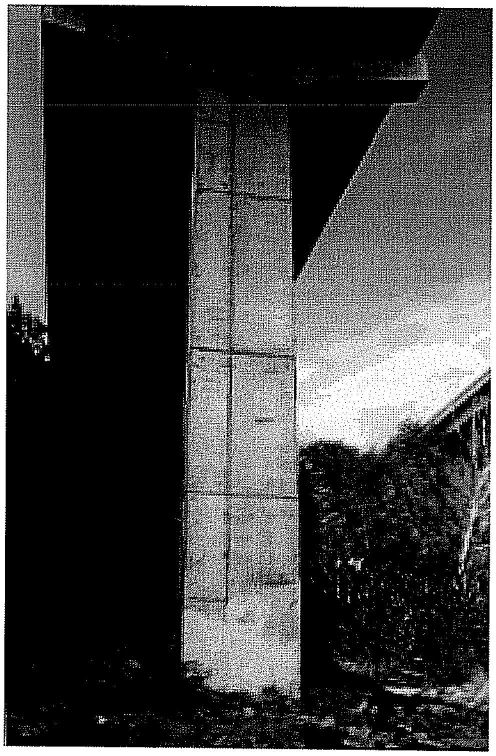


Figure 3. 63 *Lack of attention to concrete finish detracts greatly from the overall bridge form. These piers are heavily viewed from a popular hike and bike trail*

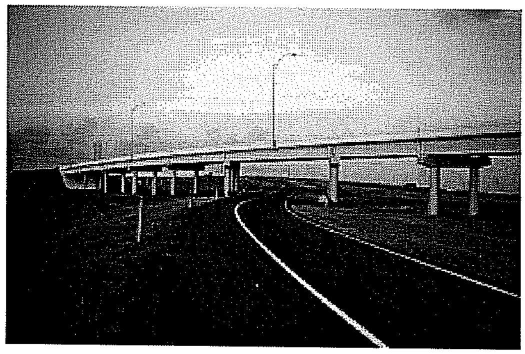


Figure 3. 64 *An attractive coat of paint does little to improve this awkward skewed layout*

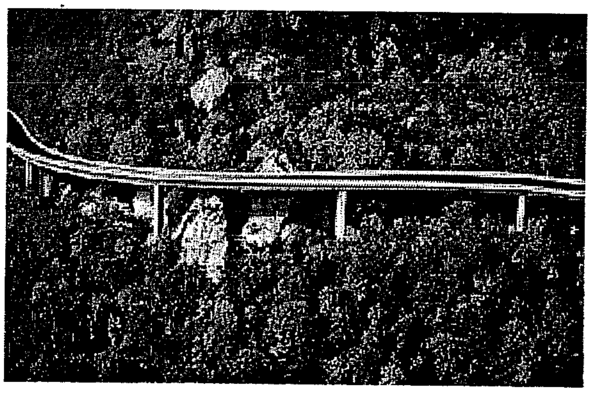


Figure 3. 65 *The Linn Cove Viaduct in North Carolina*

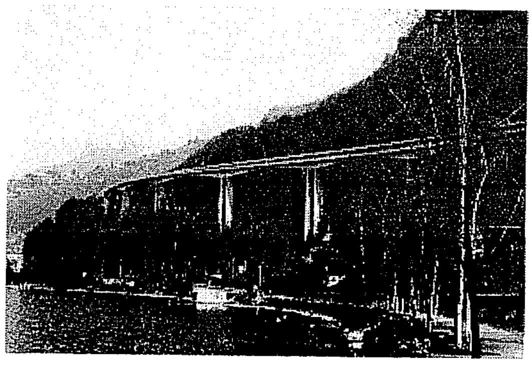


Figure 3. 66 *The Chillon Viaduct on Lake Geneva in Switzerland*

site. Further harmonization was achieved by coloring the concrete to match the natural rock surroundings.[35] This attractive, coherent project was the result of careful attention to the design concept. The concept had been developed at the outset and carried out through each decision - from the layout to the structural system to the non-structural details. The viaduct won a Presidential Design award in 1984.

The Chillon Viaduct in Switzerland was built in a similar environment of treasured natural beauty as the Linn Cove Viaduct. The Chillon Viaduct however, can be seen as carried one step further in terms of artistic shaping and a more coherent relationship between the superstructure and the substructure (Figure 3.66). The continuous segmental hollow box girders are haunched over the supports reflecting the larger moments at this location (the connection between the horizontal and vertical structural elements). The substructure is made up of two slender walls per pier. Both of these element forms (haunched girders and wall piers) have an improved material efficiency compared to the Linn Cove Viaduct and give the Chillon Viaduct a light, elegant appearance when viewed from the side - the most heavily viewed angle.

When coherence is referred to in the Guidelines, it is meant to remind the engineers both to combine their engineering decisions of efficiency and economy with their overall design concept and aesthetic intentions for their bridge and to carefully consider the relation of the different bridge elements to each other.

3.4.4 Summary

These themes appear in all sections of these guidelines. Ideas and principles from previous guidelines have been implicitly incorporated into the Guidelines. Some of the previous ideas can be specifically grouped under the headings of addressing aesthetics, efficiency and economics, developing a design concept, or striving for coherence (see Maryland and Minnesota Guidelines, Section 3.2.1). Other ideas such as those addressed by Leonhardt (Section 3.2.1) are techniques and tools that can be used to carry out the themes of the Guidelines.

The three themes of the Guidelines are presented with numerous examples and the ideals of the themes are continually referred to throughout the document. The intent is to have the engineers adhere to these ideals to improve the overall appearance of their bridges within their economic constraints.

3.5 Goals of TxDOT Aesthetics & Efficiency Guidelines

Texas is recognized nationally as being at the forefront of building highly efficient and economical precast prestressed concrete bridge superstructures. Therefore the Guidelines for bridge design are focused primarily on issues related to concrete bridge design. Presently, these standard prestressed girder and slab superstructure bridges dominate the Texas landscape. With more careful attention given to layout and substructure design, the overall attractiveness and efficiency of these bridges can be greatly improved.

Aesthetics is often a matter of individual preference. It is an issue that can be addressed by everyone. Many designers and engineers feel that factors such as safety, serviceability and function are too restrictive to allow for attention to aesthetics or that attention to aesthetics automatically means greatly increased costs. These guidelines are proposed to dispel these beliefs, to exhibit the numerous opportunities that engineers and planners have to make aesthetic decisions throughout the design process and to provide specific recommendations, principles and examples that can help designers and planners develop more attractive bridge structures. With an understanding of the limitless possibilities that may improve a bridge's appearance, more attractive structures can be built that remain safe, serviceable and economical.

3.5.1 Engineering and Aesthetics

These guidelines are meant to be used from the beginning of the design process, not as a type of "quick fix" once the design is complete. The reason for this is that artistic and visual impressions of bridges are made as a result of the *overall* structure (geometry, layout and structural function of elements) not ornamentation. Therefore the Guidelines emphasize the ways in which different engineering decisions will effect the aesthetics and efficiency of the project. Figures 3.67-3.70 are a few examples of such considerations taken from the Guidelines.

Figure 3.67 shows a number of different layout options possible for a four lane bridge. Each option effects not only the engineering design but also the appearance of the built structure. Figures 3.68a&b show the aesthetic results of using two 2-lane bridges in place of one 4-lane bridge, similar to the proposals of Options III and IV in Figure 3.67.

Figure 3.69 is another excerpt from the Guidelines that displays the benefits of making quick "back-of-the-envelope" calculations. In evaluating the cost of increasing the apparent slenderness of a three span overpass, a quick study was made to determine the economics of pushing abutment walls back and increasing span lengths. Various span length increases were examined for different bridge widths. In the case of pushing abutments back by 40 ft. each (Case II), an extra substructure unit would be required. Of course, this option is dependent on the use of the space underneath the bridge. In four of the six cases examined, either savings were achieved or minor costs were incurred in solutions which resulted in more slender and attractive structures. Only two of the six cases incurred appreciable costs. Most importantly, such quick studies in the Guidelines are used to show engineers how simple engineering decisions can lead to considerably different visual results. These studies and calculations displayed in the Guidelines are easy to perform - the cost data for instance, is readily available for each District. It is important to stress to the engineers the ease with which such studies can be made. As a result, the economic impact of layout changes that will effect the bridge's appearance can be made quickly therefore allowing for many alternatives to be examined. Examining many alternatives is essential in the early stages of a design when changes can still be made - before time-consuming analysis is conducted and designs are "locked in."

With the design options shown in Figure 3.70, the engineer may choose a continuous superstructure system with or without moment connections to the supporting piers. Where columns are not integral with the superstructure, continuity of the superstructure may be desired to minimize the number of deck joints required and therefore improve the riding surface. (Flexible supports could be used to further reduce the number of expansion joints required along the bridge.) A moment connection between the superstructure and substructure may be chosen and is often required in seismic regions. Clearly the visual impressions of these two structural systems are quite different.

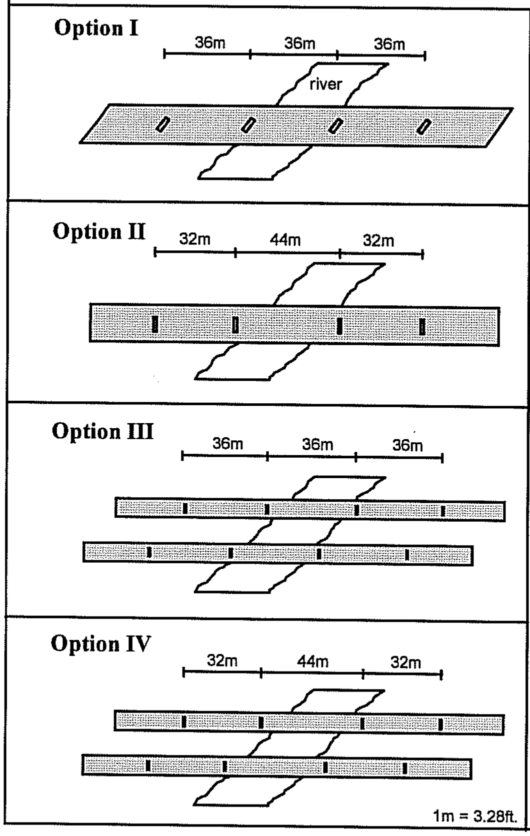
The examples in Figures 3.67-3.70 clearly show the ability of the designer to effect the bridge's appearance through straightforward engineering decisions such as structural system and layout choices.

For successful results, aesthetic considerations must be made at each step and should never be afterthoughts. While attention to non-structural details is important, it should not be the primary concern in bridge design. Details are best considered as a means to enhance the aesthetic decisions already made regarding the overall bridge structure.

3.5.2 Propose Questions Rather Than Rules

Engineers are most accustomed to Codes and Specifications that are basically books of rules. US Codes in particular are often prescriptive (rather than performance based) leaving little room for engineering

Alternate Solutions to Avoid Skewed Bents for a 4-lane River Crossing



Problem:

A four-lane bridge is required to cross a river. The roadway is not perpendicular to the river. For economic and environmental reasons, it is desirable to avoid having piers in the water.

Options:

I A single four-lane structure with three main spans of 36m requiring skewed bents.

II A single four-lane structure with a main span of 44m and side spans of 32m using orthogonal piers.

III Two two-lane structures with three main spans of 36m using orthogonal piers.

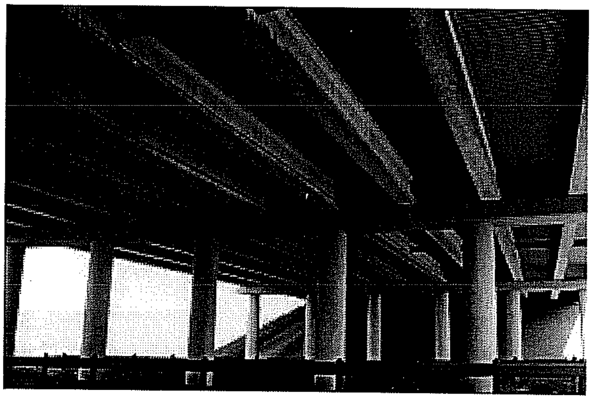
IV Two two-lane structures with a main span of 44m and side spans of 32m using orthogonal piers.

Discussion:

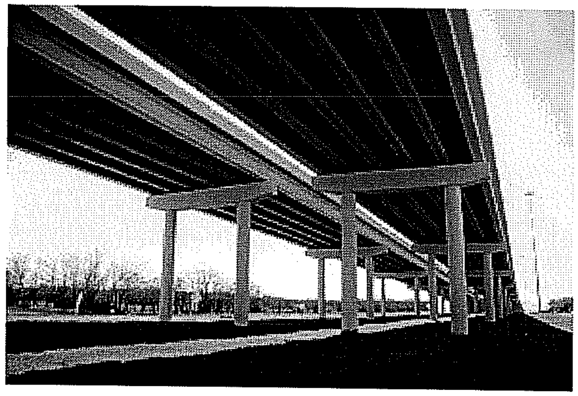
Options III & IV result in less imposing additions to the environment. More light will reach under and around these bridges. Skewed bents can be avoided to simplify design and construction and to reduce costs. Span lengths can be minimized (Option III) or a larger center span can be used to accent the river crossing (Option IV).

(Options I-III in this example are of a smaller scale but otherwise similar to the layout options considered for the Kishwaukee River Bridge in Illinois. The layout of Option III was chosen.[88])

Figure 3. 67 A "sidebar" for the TxDOT Aesthetics and Efficiency Guidelines



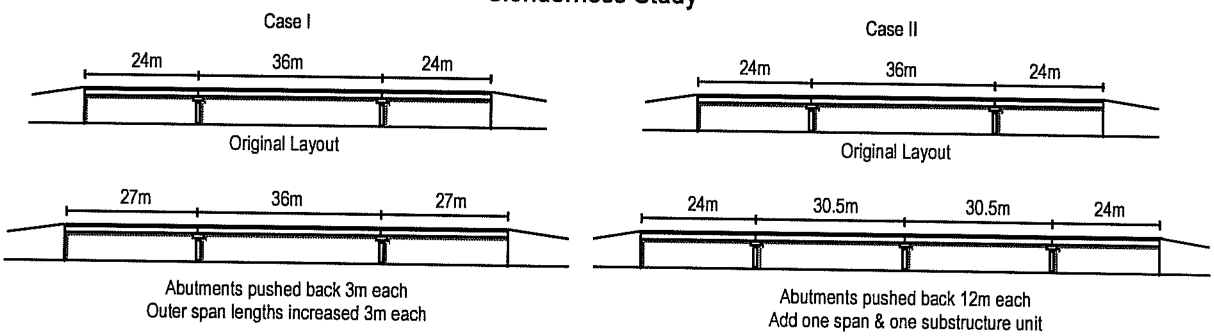
(a)



(b)

Figure 3. 68 (a) A wide bridge can create a dark, cluttered space; (b) Splitting a wide bridge into two separate bridges allows more light to reach underneath

Slenderness Study



	Bridge Width m	Original Cost $290/m²	Remove Wall* $205/m²	Remove Fill $4/m³	Remove Rail $100/lin. m	Add Bridge** $195, $290/m²	Cost Change $	% Change***
Case I	8.5	207,060	-14,760	-1,230	-1,200	+9,950	-7,240	-3.5
Case II	8.5	207,060	-59,040	-4,900	-4,800	+59,160	-9,580	-4.6
Case I	13	316,680	-14,760	-1,870	-1,200	+15,210	-2,620	-0.8
Case II	13	316,680	-59,040	-7,490	-4,800	+90,480	+19,150	+6.0
Case I	20	487,200	-14,760	-2,880	-1,200	+23,400	+4,560	+0.9
Case II	20	487,200	-59,040	-11,520	-4,800	+139,200	+63,840	+13.1

* Use retaining wall height of 6m
** Add $195/m² for Case I (add superstructure only) and add $290/m² for Case II (add superstructure and substructure)
*** A negative change indicates savings

1m = 3.28 ft.

Figure 3. 69 A "Sidebar" from the TxDOT Aesthetics and Efficiency Guidelines

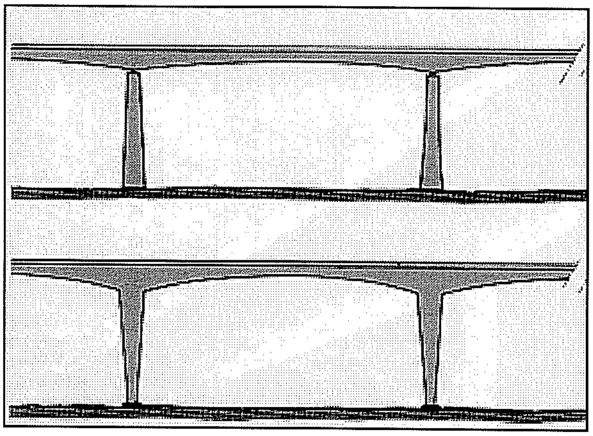


Figure 3. 70 Different structural systems creating different visual impressions[23]

ingenuity. This "rule-book" approach typical of codes would not be successful in Aesthetics & Efficiency Guidelines. Aesthetics in particular is subjective. There is never a unique "correct" solution for a bridge in a particular site. With aesthetics, the problem often arises that engineers feel they lack creativity. As aesthetics is so rarely discussed in most engineering curricula, the Guidelines have been developed as an educational document as well as a guide.

To spark creativity, the Guidelines propose questions for designers to ask rather than provide lists of "do's" and "don'ts" which tend to stifle creativity. Pointing out where the engineering decisions affect aesthetics is a way to join the familiar with the less familiar so as to result in more creative and more attractive bridge designs.

3.6 Outline of TxDOT Aesthetics & Efficiency Guidelines

3.6.1 Organization and Scope

An outline of the Guidelines is given in Figure 3.71. The entire Guidelines are presented in Appendix C of this report. The Guidelines are organized in the order of the design process. They contain suggestions of what to consider at each phase of design to lead to efficient and aesthetically pleasing structures. Typical decisions which can enhance aesthetics are illustrated and are related directly to other considerations such as function, safety, serviceability and economics. Possible aesthetic improvements are pointed out while still utilizing the most suitable and economical structural shapes and standard bridge components.

In each of the chapters covering the design process (Chapters 2-5), the many design options in terms of structural systems are presented. Potential aesthetic results or improvements are discussed. Each topic is presented along with illustrations of its relevance and effect on aesthetic results as well as implications for efficiency. Suggestions are given for the best implementation of proposed ideas. Case studies are made at each design step to outline aesthetic improvements and potential economic impacts of the suggestions offered.

At the conclusion of the guidelines, a chapter entitled "Particular Settings" addresses the most important considerations for given scenarios and site conditions. These scenarios include urban expressways, causeways, urban interchanges, over-crossings in both urban and rural settings, and bridges in environmentally sensitive areas. An additional small chapter is included that covers issues to consider when widening existing bridges.

Appendix A to the Guidelines presents different aesthetic "techniques" that may be employed throughout the design such as proportioning systems or optical corrections. These are techniques typically taught in architecture schools but rarely introduced in engineering education. These are helpful tools that are simple to use and easy to learn. Appendix B to the Guidelines presents information on surface treatments for concrete. Surface treatments discussed include exposed aggregate, formliners, color through staining or painting, and concrete pavers. These surface treatments are discussed in terms of aesthetic options,

TXDOT AESTHETICS AND EFFICIENCY GUIDELINES
(CTR PROJECT 0-1410)

I. INTRODUCTION

Attractive Structures and Design Challenges
Artistic Sensitivity and the Use of Guidelines
Existing Guidelines
The TxDOT Aesthetics and Efficiency Guidelines
- Theme 1 — Aesthetics, Efficiency and Economics: Interconnected Engineering Disciplines
- Theme 2 — Vision: The Development of a Design Concept
- Theme 3 — Coherence: Adhering to the Design Concept at Every Stage of the Design

Goal of the TxDOT Efficiency and Aesthetics Guidelines
Organization of the Guidelines

II. GUIDELINES

A. Planning / Layout

1. <u>Planning</u>
   - a) Teamwork
   - b) Site Visits
   - c) Special Site Conditions
   - d) Constraints
2. <u>Layout Considerations</u>
   - a) Importance of Layout
   - b) Useful Approaches
   - c) Integration
   - d) Visibility and Obstruction
   - e) Symmetry vs. Asymmetry
   - f) Repetition and Pattern
3. <u>Economics in Layout</u>
4. <u>Case Study</u> — US Highway 67, San Angelo, Texas

B. Superstructure

1. <u>Planning</u>
   - a) Superstructure Systems
     - (1) Pretensioned I-girders, T-beams
     - (2) U-beams, Box beams
     - (3) Post-Tensioned Segmental Box Girders
     - (4) Steel Plate Girders
2. <u>Considerations</u>
   - a) Simply Supported vs. Continuous
   - b) Slenderness / Proportion
   - c) Structural Expression
   - d) Transitions
   - e) Relationship to Substructure and Abutments
3. <u>Economics in Superstructure Design</u>
4. <u>Case Study</u> — Proposed US Highway 281, Wichita Falls, Texas

Figure 3. 71 Outline for the Guidelines (continued on next page)

- C. **Substructure Design**
  1. Planning
     - a) Substructure Systems
       - (1) Individual columns
       - (2) Walls
       - (3) Hammerhead bents
       - (4) Multi-column bents
  2. Considerations
     - a) Cast-in-Place vs. Precast
     - b) Visibility / Obstruction
     - c) Structural Expression
     - d) Transformations
     - e) Relationship to Superstructure
     - f) Proportions
       - (1) Chamfering
       - (2) Shaping ends of bent caps
  3. Considerations for Abutments and Retaining Walls
  4. Economics in Substructure Design
  5. Case Study— Cast-in-Place vs. Precast Bents for a 4-lane Bridge

- D. **Non-Structural Details**
  1. Planning
  2. Considerations
     - a) Pedestrian Access
     - b) Railings, Parapet Walls
     - c) Overhangs
     - d) Texture and Color
     - e) Drainage
     - f) Joints
     - g) Signs and Lighting
     - h) Landscaping
  3. Economics in Non-Structural Details
  4. Case Study— The Use of Color in El Paso, Texas

- E. **Considerations for Particular Settings**
  1. Urban Expressways
  2. Interchanges
  3. Causeways
  4. Overpasses - urban
  5. Overpasses - rural
  6. Environmentally Sensitive Areas

- F. **Considerations for Widening Existing Structures**

- G. **Examples— Applications of the Guidelines**

APPENDIX A— Design Tools

- A. Proportioning Techniques
- B. Optical Correction

APPENDIX B— Textures and Surface Treatments

1. Coloring of Concrete
2. Exposed Aggregate
3. Formliners
4. Concrete Pavers

APPENDIX C— Precast Substructure System Proposal

Figure 3.71 (continued) Outline of the Guidelines typical uses, maintenance concerns and relative costs. Appendix C to the Guidelines presents an alternative substructure system that is made up of primarily precast (match cast) column and cap elements. This system is presented more fully in Report 1410-3F.

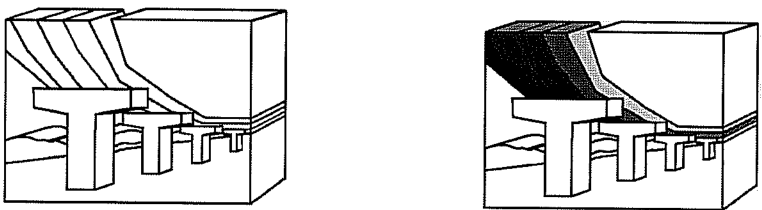
3.6.2 Layout

Determining the most appropriate layout for the Guidelines was an important task. It was essential that this document be "user-friendly" - helpful to both bridge and highway engineers at various levels and above all, easy to read, follow and implement. Meetings of the research team with various publishers led to the hiring of University Publications of Austin, TX, to design the layout of the document.

The "landscape" orientation of the page was chosen to allow more room for comparative photographs. The binding at the top of the page also allows for easier reading and reference on a desk full of other codes, calculation pads and plan sheets. The top half of the guidelines can be propped up against other books or a back wall.

The Guidelines were designed to be read at many levels, similar to the Maryland DOT Guidelines. Informative quotes are pulled out into side margins. These quotes can be read alone and give the reader a good understanding of the ideas presented in the Guidelines. Captions beside the figures as well allow for an understanding of the basic idea being illustrated. If a certain idea is particularly attractive to someone, they may then go in and read the text on that topic. The more curious reader will benefit from reading the entire text. There are also a number of pages referred to as "sidebars" that are not a part of the body of the text but are examples of applications of principles presented. Each of these "sidebars" occupies a full page and has a similar blue background. The case studies, also not part of the body of the text but still different from the sidebars have a similar background as the sidebars but are of a different color. A special logo was designed for the upper right-hand corner of each page to signify which chapter the reader is in. When in the Planning & Layout Chapter, only the ground of the logo is highlighted. In the Superstructure Chapter, only the superstructure of the logo is highlighted and so on (Figure 3.72).

The attractive appearance of the final product and the ability of the document to be read at different levels of interest is essential for this to be a useful document and not simply another manual that will collect dust.



Basic logo, no highlighting

Logo for Superstructure Chapter

Figure 3. 72 Example of logo used for the main chapters of the Guidelines

3.7 SUMMARY

Thorough investigation of existing guidelines, photo surveys of many short and moderate span Texas bridge types and interviews which indicated many concerns of the designers, owners and users of the standard highway bridges in Texas provided a strong background from which to develop the TxDOT Aesthetics & Efficiency Guidelines (Guidelines). The Guidelines are a manual that bridge designers and highway planners can refer to throughout the design process. This manual is meant to illustrate to the engineers how their engineering decisions are impacting the aesthetics and efficiency of their designs. The Guidelines offer suggestions and propose questions for designers to ask during design, rather than provide a book of rules with do's and don'ts.

Three major themes incorporating numerous ideas and principles for attractive structures have been emphasized throughout the Guidelines. The first theme asserts that designs must strive to balance aesthetics, efficiency and economics. The second theme stresses that each design must be carried out according to an initial vision or design concept for the bridge. Design concepts must be developed by all parties involved in a given bridge project. The third theme maintains that designers must strive for coherence in their projects by adhering to the design concept at each stage of the design process.

Developing aesthetic awareness can begin with such a set of Guidelines but must also be nurtured in all engineers through support from top managers in engineering offices. As well, there must be a willingness of all parties involved in a bridge design to come together and address constraints and pertinent issues at the outset of a project.

With more attention given to aesthetics and efficiency through use of the Guidelines, the Texas Department of Transportation can continue to design safe, serviceable structures that will enhance their settings and the Texas highway system. The Guidelines challenge State DOT engineers to be creative and to include aesthetics equally with the more commonly recognized engineering disciplines of economy and efficiency. More attractive and more efficient short and moderate span bridges, bridges that account for the vast majority of our highway bridges, must now be designed. Following the TxDOT Aesthetics & Efficiency Guidelines as an initial step toward more creative design, designers will be able to maintain pride in their work while the public maintains pride in their State.

CHAPTER 4

SUMMARY & CONCLUSIONS

4.1 SUMMARY

Standard highway bridges of short and moderate spans are typically designed for economy and function alone. Although these short and moderate span bridges often dominate the highway landscape, they typically detract from rather than enhance the environment in which they are built. Such an unimaginative display of structural engineering does little to express the rapid growth and exciting developments in this profession.

The improvement of standard short and moderate span bridges through the use of aesthetic guidelines and attractive, efficient concrete substructures has been studied and is reported herein and in the companion report, 0-1410-2F. This research was conducted through the Center of Transportation Research at the University of Texas at Austin as Project No. 0-1410.

Aesthetics & Efficiency Guidelines were developed that were primarily intended for use by bridge and highway engineers at the Texas Department of Transportation (TxDOT). Four example applications of the Guidelines showed general approaches and varied economic benefits and/or costs. Implementation strategies for further application of the research are given.

The research presented in this report includes:

- A literature review with particular focus on short and moderate span bridges (Chapter2)
- A photographic survey of short and moderate span bridge systems in Texas documenting successes and failures (Chapter 3)
- Interviews with Texas Bridge and Highway engineers to define the design process and aesthetic challenges (Chapter 3)
- Informal "face-to-face" surveys of the public's perception of and attitude towards standard bridges as well as willingness to fund aesthetic improvements (Chapter 3)
- The development of the Aesthetics & Efficiency Guidelines (Chapter 3)

The Guidelines included in Appendix C are a manual that bridge designers and highway planners can refer to throughout the design process. This manual illustrates to engineers how their *engineering* decisions impact the aesthetics and efficiency of their designs. Rather than providing a book of rules with do's and don'ts, the Guidelines offer suggestions and propose questions to be asked at each step of the design process.

Three major themes are carried throughout the Guidelines, providing a framework for the design of attractive and efficient bridges. The first theme stresses the importance of balancing aesthetics, efficiency and economics with each design. Efficiency refers to both an efficient use of materials as well as efficient methods of construction. The second theme asserts that each design must be carried out according to an initial vision or design concept for the bridge. Design concepts must be developed by all parties involved in a given bridge project. The third theme maintains that designers must strive for coherence in their projects by fulfilling the design concept at each stage of the design process.

The Guidelines challenge State DOT engineers to be creative and to include aesthetics equally with the more commonly recognized engineering disciplines of economy and efficiency. Following the Guidelines as an initial step toward more creative design, designers will be able to maintain pride in their work while the public maintains pride in their State.

The Guidelines were used to develop design options for four possible bridge projects in Texas. The results were documented in a series of Examples that were included in the Guidelines in Appendix C and that show convincingly the ease of application, the usefulness and the practicality of the Guidelines. The Examples also point to the future possibilities of precast substructure construction as an attractive and economical form of construction for short and moderate span bridge systems.

Implementation strategies include widespread distribution of the Guidelines to bridge and highway engineers across the State as well as short courses to introduce their use. The Guidelines may also be adopted for use during Value Engineering meetings. As the Guidelines are put into actual practice, additional Examples should be developed, documented, analyzed and judged in terms of the effectiveness, usefulness and aesthetic and economic impact the Guidelines have on actual projects.

4.2 CONCLUSIONS

4.2.1 General Conclusions

1. Current attitudes towards standardization have led to a highway landscape dominated by unattractive, unimaginative and often deficient short and moderate span highway bridges. Most problems are connected with substructures. The efficiencies and attractiveness possible with standardized bridge components are presently not being fully realized because the standard substructures widely used tend to be unattractive, have low durability, and are not always structurally efficient.

2. Aesthetics Guidelines for highway planners and bridge engineers are an essential first step towards improving bridge aesthetics for standard bridge systems and for developing an awareness of the ways in which *engineering* decisions effect the appearance of engineered structures.

3. Developing and promulgating a design concept for a bridge is essential for attainment of coherent projects in State highway transportation offices where a single project may be designed by numerous parties in different offices over long time spans. Economic savings in terms of both material efficiency and construction speed as well as improved appearance can be achieved when a visionary design concept is developed at the outset of a project.

4.2.2 Detailed Conclusions

1. Most literature on bridge aesthetics calls for more attention to be given to bridge aesthetics and presents generalized aesthetic principles. However, very little is written providing practical guidance on how to apply these principles with reasonably economical results.

2. While the efficient use of materials on long span bridges very often leads to the most economical design, the efficient use of materials for short and moderate span bridges is often secondary to utilization of standardized, efficient construction methods.

3. The aesthetics of standard bridge systems is most profoundly affected by the layout of the bridge and the substructure system chosen. Non-structural bridge components cannot improve the appearance of a dull bridge form.

4. Significant aesthetic improvements can be made to standard bridges with little increase in cost (often less than 5%) and sometimes with savings.

5. Application of the Guidelines from the outset of design will allow for the best use of the manual.

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APPENDIX B

SURVEY OF THE PUBLIC

The informal Survey of the public presented in Chapter 3 consisted of a series of questions proposed in face to face interviews to randomly chosen people across the State. A list of the survey questions is given on page 266. The interviews in Austin were conducted primarily by students at the University of Texas at Austin who were enrolled in the Graduate course, Concrete Bridge Design, in the Spring Semesters of 1995 and 1997. Each student conducted approximately 5 interviews. The interviews outside of Austin were conducted by the author. The breakdown of survey locations and number of surveys conducted is,

Austin	198
Corpus Christi	25
Dallas	24
El Paso	25
Houston	21
I-10 Roadstop near Luling	25
Rio Grande Valley	10
San Angelo	25
San Antonio	25
Wichita Falls	15
TOTAL	**393**

The breakdown of where the interviewees were from was slightly different and is given in percentages in Figure 3.32.

The survey is by no means scientifically rigorous. The variety of interviewers led to some difficulties in the author's interpretation of the results. Questions 3.1 and 3.5 in particular often had ambiguous responses. A number of responses to Question 3.1 that had asked how frequently the interviewee travels on the Texas highways were "frequently" or "often." In this case, "frequently" was treated as more than 3 times per week and "often" was considered to be 1-3 times per week. Question 3.5 that had asked which State if any, has nicer looking bridges than Texas was sometimes answered with "none" or "don't know." The answer "none" could be interpreted as none has nicer bridges than Texas or none of the States have nice bridges. The response "none" and "Texas" are represented together under "none" in Figure 3.39a. This loosely represents the opinion that bridges in other States are not necessarily nicer than those in Texas. In Figure 3.39b, the responses of "none" and "Texas" are not shown. This Figure therefore represents the geographical distribution of States identified as having bridges that are more attractive than those in Texas.

For Figure 3.38, the responses were grouped into positive appearance, negative appearance, three groups of categories that could be interpreted as either positive, negative or neutral (neutral being separated into "Safe, Sturdy", "Functional", and "Plain, Simple") and one miscellaneous group ("other"). A more thorough breakdown of the responses per location is given in Figure B-1. Figure B-2 gives a breakdown of responses for all locations combined.

The informal survey of the public did provide a good amount of information on a relatively "soft" topic. While many of the questions can be interpreted in different ways, a general feel about the appearance of State bridges was obtained. In the authors opinion, the most interesting response was that such a high percentage of the people interviewed do notice the standard bridges and do have an opinion about their appearance. The information gathered and the senior author's experience of speaking with such a wide variety of people from different parts of Texas about bridges helped develop two important ideas for the TxDOT Aesthetics & Efficiency Guidelines. The first was that standard highway bridges are an important part of our infrastructure both functionally *and aesthetically.* The second is that improvements to standard bridge systems must be striven for and must be within reasonable economic bounds.

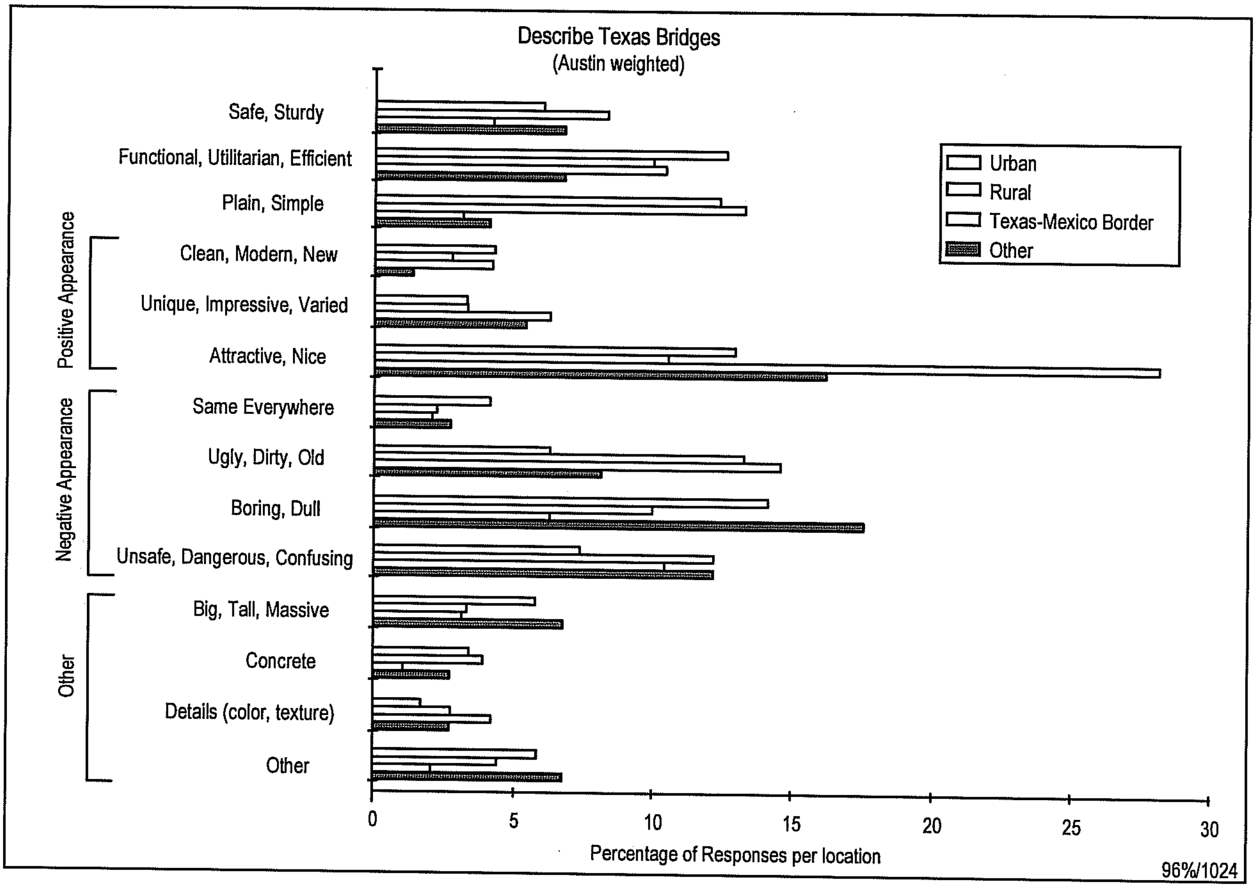

Figure B. 1 *Survey of the public*

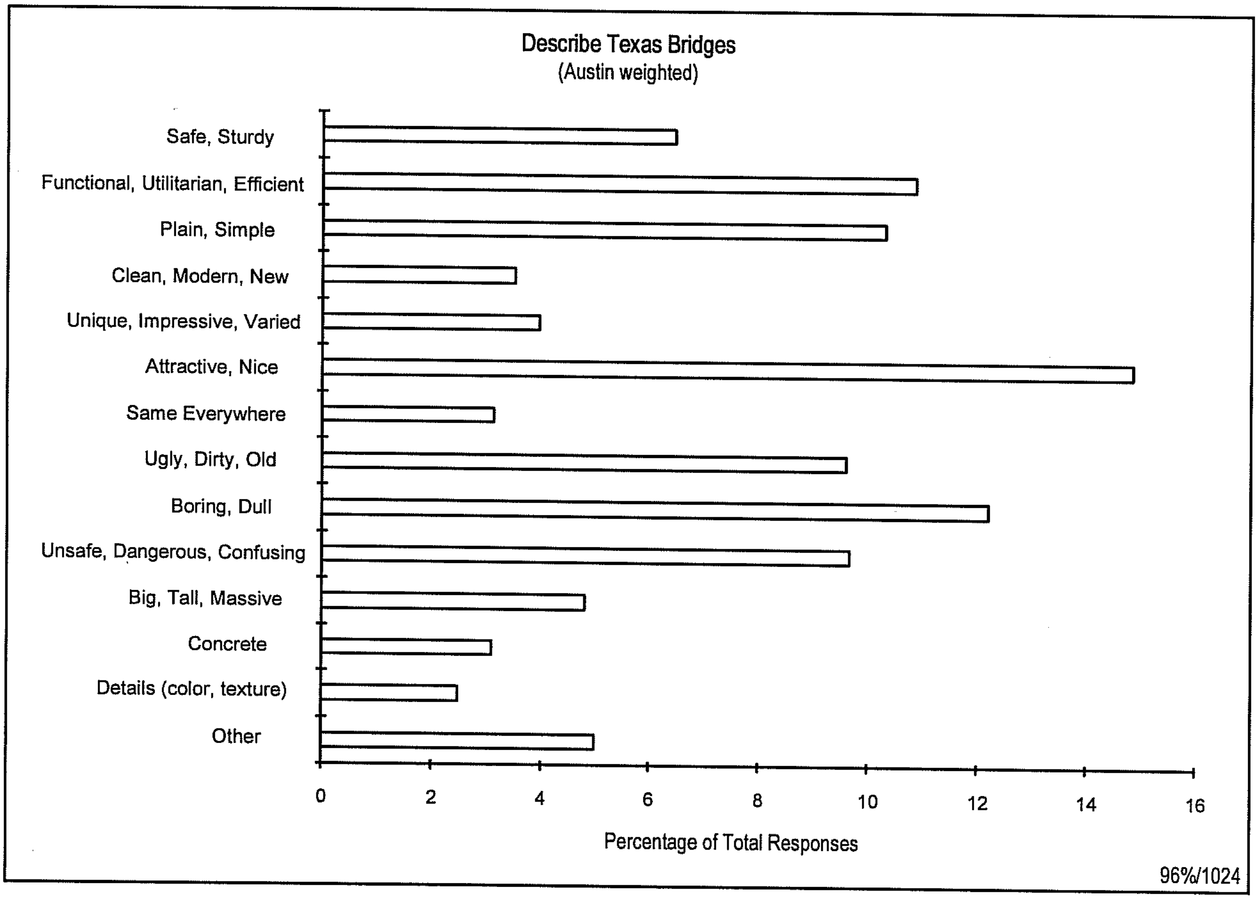

Figure B. 2 *Survey of the public*

INFORMAL SURVEY QUESTIONS

Locate yourself within sight of a "standard" simple span precast I-beam bridge in Austin (this is specifically for question 4.1). Try to get a mix of age groups and occupation types.

1.0 CONTEXT

1.1 What is your occupation?

1.2 Age? (*estimate if awkward to ask*)

1.3 Where would you say you are from?

1.4 Where is your current residence?

2.0 AESTHETICS AND STRUCTURES

2.1 Do you think a building's appearance effects how you feel about where you live/work/spend time?

2.2 Do you think the appearance of a bridge can have the same effect?

2.3 Do you have a favorite bridge? Why is it your favorite?

2.4 Do you have a favorite building? Why is it your favorite?

3.0 TEXAS BRIDGES

3.1 How frequently do you travel on Texas highways?

3.2 When you travel on the highways do you notice the bridges?

3.3 What are three words or phrases you would use to describe the Texas bridges?

3.4 If you could change Texas bridges, what would you do?

3.5 What State, if any, has nicer looking bridges than Texas?

4.0 SPECIFIC EXAMPLES

4.1 What do you think of that standard bridge and why? (*note location and type of bridge, below*)

4.2 Have you noticed the new US183 elevated highway and interchange at I-35 in north Austin?

4.3 If yes, what do you think of it?

5.0 TEXAS

5.1 What are three words or phrases you would use to describe Texas culture?

5.2 How would you change Texas bridges so that they would better represent Texan qualities?

6.0 THE MONEY QUESTION

6.1 Do you think the state would be justified in spending additional tax funds to make future bridges more attractive?

6.2 If yes, how much more (in terms of a % of the project cost) would be O.K. to spend on improving the short and long-term appearance? (*note: current precast I-beam bridges in Texas cost about $29 sq.ft. of roadway surface*)

7.0 ADDITIONAL COMMENTS

____

Location of interview:

Date:

APPENDIX C

AESTHETICS GUIDELINES