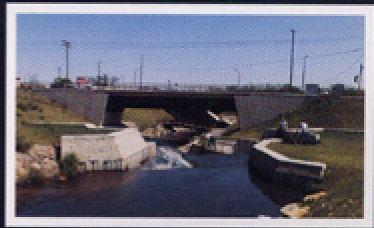
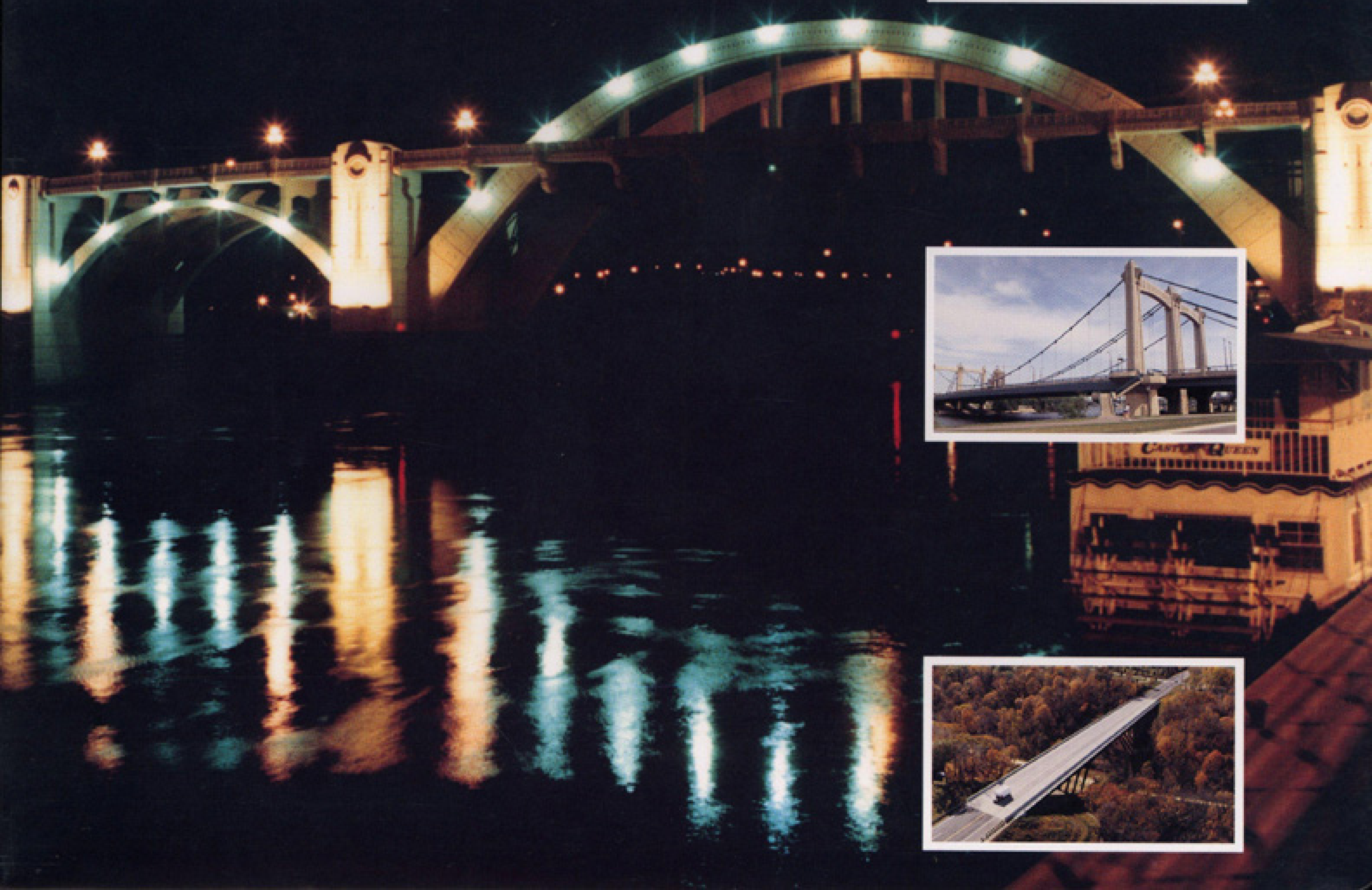
AESTHETIC GUIDELINES *for* BRIDGE DESIGN

MINNESOTA DEPARTMENT OF TRANSPORTATION

Office of Bridges and Structures





RAY CEKALLA

AESTHETIC GUIDELINES
for
BRIDGE DESIGN

MINNESOTA DEPARTMENT OF TRANSPORTATION

Office of Bridges and Structures

March, 1995

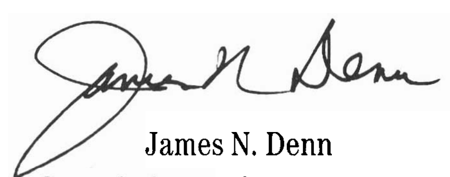
FOREWORD

Over the past several years, increasing interest has been shown in the aesthetic aspects of our bridges and structures. This interest has come from a broad spectrum of people, including Mn/DOT staff and the public at large. The Office of Bridges and Structures has been closely involved in this movement. Much of the public focus has been centered on several "landmark" bridges; however, the Office of Bridges and Structures has been increasing its efforts to improve the aesthetic design of all bridges.

In recognition of the need to expand and organize this effort, the Office of Bridges and Structures developed the *Aesthetic Guidelines for Bridge Design*. We believe that careful and early application of the concepts presented can make a significant improvement in the appearance of the bridges and structures throughout our state.

The *Aesthetic Guidelines for Bridge Design* is intended to serve all who are involved with bridges and structures from the early stages of preliminary layouts through final construction. It should find its greatest use by staff in the Office of Bridges and Structures and the consultants who are involved in bridge design. The manual has been written to serve as both a training tool and a reference. We are confident these guidelines will inspire users to create aesthetically pleasing bridge designs.

I sincerely appreciate the efforts of all those who have contributed to this manual.



James N. Denn
Commissioner of Transportation

ACKNOWLEDGEMENTS

The development of these aesthetic guidelines for bridge design is based on works and publications of numerous authors and agencies listed in the bibliography. Of particular mention is the *Aesthetic Bridges, Users Guide,* prepared by the Maryland State Highway Department and assisted by Mr. Frederick Gottemoeller. Without these pioneering predecessors' forethought, this publication would not be possible.

This manual of guidelines was prepared by **HNTB CORPORATION** with direction and input from the following participants, whose guidance is gratefully acknowledged:

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Fig. 1-1. Bridges within capital approach area, St. Paul, Minnesota

"Every bridge is in some degree a historical document, a demonstration of structural technique, a performance test of building materials, a comment on the values of a society which produced it, and a reflection of the richness or poverty of its designer's imagination."

Sinclair Gouldie

1.0 INTRODUCTION

Aesthetics, the study of the mind and emotions as they relate to the sense of beauty, is concerned with visual appearance and quality. In bridge design, as in architecture, excellence is achieved by integrating science, technology, and aesthetics. The bridge designer must strive to understand the creative artistic process, as well as scientific and technical principles, and merge the most fundamental concepts into a unified theme for an expressed purpose. The principles of aesthetics that stimulate the senses in most viewers are proportion, order, simplicity, balance, color, and texture. Design excellence requires designers to orchestrate these aesthetic principles with the physical and geometric components of a structure. The appropriate application and integration of these principles, together with sound structural and functional design, can result in bridge forms that exhibit strong visual character and quality. The blending of a bridge structure into its environment is also an important aesthetic consideration. Once a roadway corridor, bridge, or interchange is established, it becomes a prominent landscape feature, immediately changing the character of the environment. Compatibility with natural settings or developed areas is essential. It is vital that designers consider these influences and incorporate aesthetic values into the design of bridges and highway corridors so the structures enhance the beauty and character of the immediate environment and community.

To ensure that bridge designs exhibit a strong sense of visual quality and beauty, aesthetics must be an integral part of the bridge design. This application of aesthetic considerations must encompass all aspects of the design from bridge type selection to the careful application of each detail of the structure.

1.1 MINNESOTA DEPARTMENT OF TRANSPORTATION'S VIEWPOINT

The Minnesota Department of Transportation (Mn/DOT) – Office of Bridges and Structures developed these Aesthetic Guidelines for Bridge Design to promote the design of visually pleasing bridges. These guidelines outline the principles associated with sound aesthetic bridge design and identify the process used to integrate bridge aesthetics into the bridge design process. Just as function, safety, structural capacity, economy, and maintenance are considered during the design process, aesthetics must also be considered.

Aesthetic quality cannot be achieved through superficial cosmetic treatments. Aesthetic quality must be present in the basic concept from the inception of a design. A pleasing appearance should be considered an intrinsic requirement of good bridge design. Be it major structures, repetitive corridor structures, or any bridge, the responsibility for the aesthetic impression of a bridge form lies with the design team. The design team (engineers, architects, technicians, administrators) must acknowledge and accept this responsibility.

In our society, engineers have a professional, legal, and ethical responsibility for bridges. In addition, the public holds the engineering profession responsible for design decisions made. Each time designers locate a pier or size a girder, they are making an aesthetic decision as well as a structural decision. Indeed, it is the major structural elements of the bridge — its piers, girders, and abutments — that serve as major architectural features as well as primary load carrying members.

Bridge design, and the visual statement it represents, are legacies that can be identified with an individual, a program or an era, and the system of values that initiated the design. The success of a bridge design is often determined by the function of the structure and the level of acceptance by the public. Very often bridges become the symbols of communities and reflect the values, impressions, and aspirations of the community. Designing bridges that are visually attractive is a legitimate goal for all bridge designers and owners.

1.2 STATEMENT OF PURPOSE AND INTENT

Bridge design is a process requiring the use of science, technology, and artistic judgement for its finest design solution. Each of these three abilities brings a separate and distinct quality to the design process. Science contributes analytical skills of math and geometry. Technology incorporates pragmatic knowledge of bridge design to the search for design excellence; e.g., construction practices, material uses, economics. Artistic judgement tempers science and technology to blend the design into an appealing work of beauty. These three abilities, applied in equal parts, produce a synergistic design effect — design excellence.

Throughout the design process there are many aesthetic opportunities presented. Because aesthetics are innate emotions rather than calculated values, science and technology offer little or no help regarding these artistic judgements. It is hoped that these guidelines will raise the level of awareness regarding the importance of aesthetics and provide bridge designers with a basis for making aesthetic decisions.

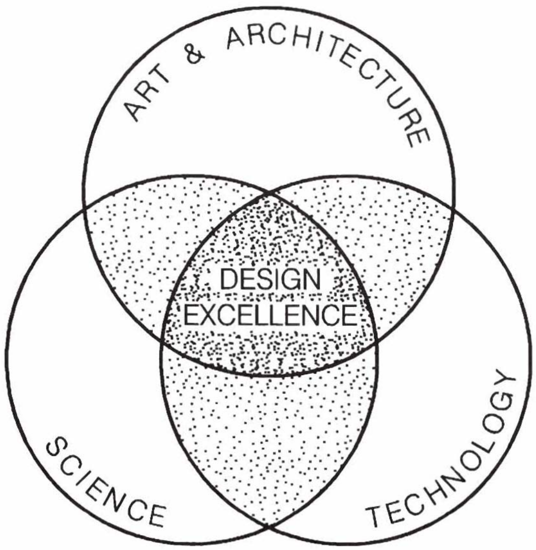


Fig. 1-2. Three components of design excellence (M.P. Burke, Jr., P.E. & J. Montoney)

While these guidelines provide aesthetic design considerations and comparative examples, designers are encouraged to develop their own perspective and creative abilities. An underlying goal of this document is to generate a recognition of each structure's potential aesthetic effect on its environment and viewers. Every bridge is unique, and designers need to recognize which of these guidelines apply, which must be adjusted, and when new guidelines need to be developed.

The ideas incorporated in these guidelines are drawn from varied sources and are the result of several generations of experience. These guidelines reflect the current belief of what constitutes an aesthetically pleasing bridge design. This document was developed for the State of Minnesota and recognizes the Minnesota Department of Transportation's bridge design practices and regional construction procedures.

The intent of these guidelines is to:

- Raise the level of awareness regarding visual, architectural, and aesthetic values that influence the appearance of bridges;
- Provide a ready reference for use during the design process;
- Provide both general observations and specific suggestions for designing bridges in and for the State of Minnesota;
- Encourage bridge designers to include aesthetics along with science and technology in the design of bridges and highway structures.

1.3 FORMAT AND INTENDED USE OF THE GUIDELINES

Within this manual, comparative examples are classified as "ordinary", representing designs that can be improved aesthetically, and "better", illustrating designs that are markedly improved by the application of aesthetic principles. Each section is accompanied by design recommendations and general considerations regarding the underlying principles that may improve the visual qualities of bridges. These better examples were selected because they are good illustrations of an underlying principle. They are included merely to guide designers in their search to find the best bridge design — one that best fits a particular site and criterion. The better designs are examples to surpass rather than imitate.

The loose-leaf format of this document allows for periodic updates to add ideas, concepts, and new recommendations as people working in the field develop insights in response to new technology, materials, and methods. This manual should be considered a working document as well as a reference and record of personal aesthetic investigations. Designers are encouraged to add their own sketches, notes, photos, excerpts from publications, and other information that may refine their aesthetic judgement. Lastly, designers should seek to learn from the experience of others.

Fig. 2-1. Lake Street/Marshall Avenue Bridge, St. Paul/Minneapolis, Minnesota

> ***"Aesthetics must be a part of the program for a bridge from the very beginning. They must be an active part of bridge engineering decisions at every step of the way, and they must be a part of the careful application of each detail of the bridge and its approaches. Thus aesthetics cannot be fully achieved if they are left to the bridge architect. Aesthetics must become the province and responsibility of every bridge engineer and, for that matter, of every administrator. This is true for both the public agencies which are responsible for bridges and for the in-house and consultant design staffs which design them."***
>
> K.E. Kruckemeyer
> Associate Commissioner
> Massachusetts Dept. of Public Works

2.0 INTRODUCTION

The fundamentals of aesthetic design involve basic visual ideas that summon innate emotional responses. These emotional responses are often subtle, but nevertheless, as real as any other emotion. The study of aesthetic design fundamentals includes the consideration of the visual relationship of a bridge and its site, as well as the mass, shape, and form of the structure.

The two visual concepts used to develop, describe, and express visual ideas are: visual design elements and aesthetic qualities. *Visual design elements* define visual perception. These elements include line, shape, form, color, and texture. They can be used to articulate visual concepts. *Aesthetic qualities* result from employment of visual design elements and are used to describe a visual composition. Aesthetic qualities include proportion, rhythm, order, harmony, balance, contrast, scale and unity.

Throughout the design process, opportunities are presented to enhance the appearance of the bridge. These opportunities are presented as design decisions. Designers must have aesthetic objectives that can be used as a guide in the decision-making process. Fundamental aesthetic design objectives, along with principle and secondary aesthetic design factors, are presented within this section to aid designers in the pursuit of design excellence.

The bridge design team, through a creative design process, can integrate the fundamentals of aesthetics with sound structural design and function to create a bridge form that is both visually attractive and compatible with its environment.

2.1 VISUAL DESIGN ELEMENTS

There are elements of visual design that apply to any type of structure, whether it is a building or a bridge. These are the tangible elements that the eye and mind seek to identify. Perception of mass and space consists of five major elements: line, shape, form, color, and texture. The characteristic of each element can be identified in any arrangement, although, sometimes one or more elements may dominate the structure's composition.

We all have an instinctive reaction to line, shape, form, color, and texture. Designers must develop powers of observation and critical reasoning to appeal to these instincts. We must not merely see, but observe objects and form judgements about them. Sound visual design is the result of a process that includes observation, critical analysis and experiment.

2.1.1 Line

A line may be thought of as a direct link between two points, either real or implied. Lines within the context of a bridge are seen in the profiles of railings, spans, piers, abutments, and wingwalls. They are likewise seen in the juncture of different materials and construction joints. Manufactured lines on the landscape may include roads, fences, and the outlines of structures. Lines that are long and straight tend to dominate natural settings that consist of predominantly short line segments.

Line has a psychological influence on the viewer as the eye and mind seek out the basic building blocks in identifying objects. Temperament and motion are often attributed to the orientation and shape of line. Vertical and horizontal lines are considered formal and stable, while oblique lines are considered dynamic, and curved lines can be considered dynamic or tranquil.

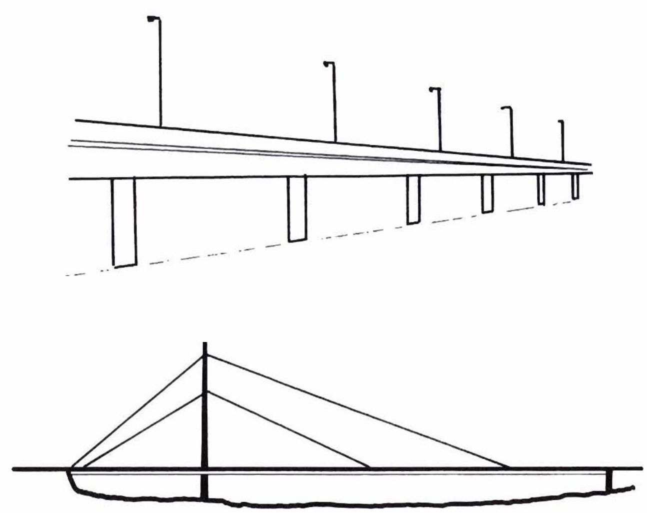


Fig. 2-2. Examples of dominant line themes

2.1.2 Shape

When a line closes, it forms a two-dimensional surface with spatial directions of height and width. This two-dimensional surface can be called shape. While shape delineates horizontal and vertical dimensions, it excludes depth and volume. Sought by the eye, shape quickly identifies many objects. The purest of shapes is a back-lit elevation view, or a silhouette. Depending on one's position and the time of day, bridges may appear as a silhouette. Shape stands out most when an object is clearly separated from the background, either by tone or color contrast, and when viewed from head on. Color contrasts also call attention to shape as the outlines are accentuated.

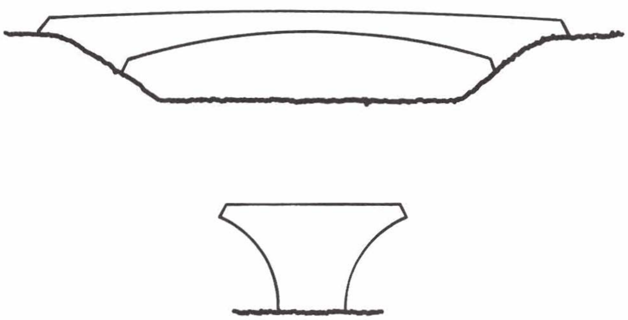


Fig. 2-3. Examples of shape concept

2.1.3 Form

Form reveals objects in three dimensions, adding depth to the height and width of shape. The visual experience of moving under or over a bridge is primarily influenced by the form of the bridge, its geometry, span arrangement, horizontal alignment, vertical profile, and relation to adjacent structures. The form of a bridge is seen in the context of space or sets of spaces that create its environment. Although the eye gathers stereoscopic cues, form is primarily revealed as volumes modeled in light and shadow. Nothing delineates the configuration of a surface as well as a shadow line.

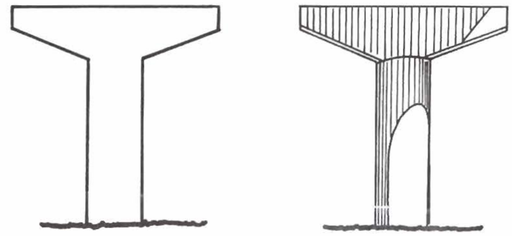


Fig. 2-4. Form concept

2.1.4 Color

Color plays both a practical role and an aesthetic role in the design of bridges. The perception of color conjures an immediate and rudimentary emotional response and is a means of conveying visual information.

Color is not simply cosmetic; when used with understanding, color can be applied to define, clarify, modify, accentuate, or subdue the visual effects of structural elements. Warm colors (reds, yellows, browns) tend to emphasize the presence and size of forms, whereas cool colors (blues, greens, purples) diminish the visual importance of elements to which they are applied. Intensity of color can reverse the effects just noted. For instance, an intense blue can be more insistent than a soft, muted red.

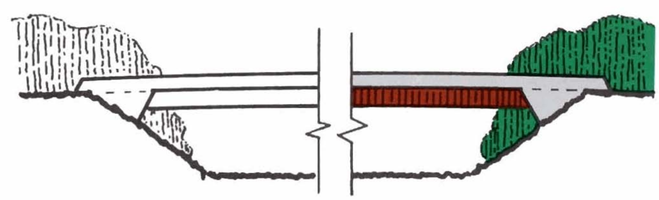


Fig. 2-5. Concept of color

There are differing theories on the use of color. One theory suggests that colors chosen for a bridge should reflect and harmonize with the predominant colors of the highway environment in which it is located. The other viewpoint holds that manufactured objects should look manufactured and should not attempt to match the color of trees, grass, sky or shrubbery because they are not related to such natural features by form. Rather, harmonious colors should be utilized. Both views have value. Success often depends on the purpose of the project, and how well and consistently a color scheme is designed and carried out. Overall design intentions may be to either contrast or integrate with the surroundings.

When selecting a color or color scheme, it should be recognized that the colors will appear different at various stages over the life of the project. This is because colors are perceived differently in the various hues of seasonal and daily light fluctuation.

2.1.5 Texture

Texture is found on the surface of all objects and is closely related to form. Texture helps define form through subtle surface variations and shadings. It can be used to soften or reduce imposing scale, add visual interest, and introduce human scale to large objects such as piers, abutments, and tall retaining walls. Distance alters our perception of texture. When viewed from a distance, fine textures blend into a single tone and appear flat. As a rule, the greater the distance or the larger the object, the coarser or larger the texture should be.

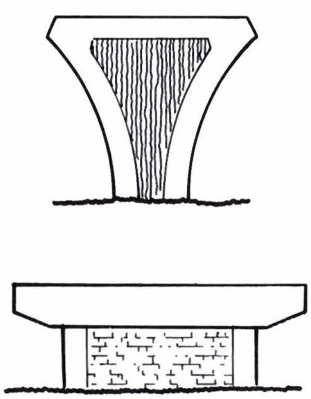


Fig. 2-6. Texture concept

2.2 AESTHETIC QUALITIES

Aesthetic qualities of design are intangible, perceived qualities arising from the relationships of design elements. The properties of aesthetic qualities are proportion, rhythm, order, harmony, balance, contrast, scale, and unity. These properties are basic elements of creative design compositions common to all fine arts as well as bridge architecture. The discussion below describes these basic qualities as they relate to aesthetic design.

2.2.1 Proportion

Proportion exists in geometry and in musical frequencies, or tones. The correlation between harmonic proportions in music, geometry, and color evolved in antiquity from a philosophical basis. This correlation between harmonic proportions in music and architecture is strongly suggested in classical architecture. Balanced and harmonious geometric proportions are fundamental characteristics in the development of graceful buildings and bridges alike. Fritz Leonhardt, German author and bridge designer, expressed the concept of geometric proportion very succinctly:

"For structures it is not sufficient that their design is 'statically correct.' A ponderous beam can be as structurally correct as a slender beam but it expresses something totally different."

Proportion helps to successfully define the relationship among structural elements and implies the order of significance of the elements. Proportion suggests the role played by elements in a structure — their relative size classifying some as performing principal functions and others as attending to secondary functions. For example, a slender column suggests a light load carrying function, whereas a very thick column suggests the opposite.

The concept of proportion may be thought of as a mathematical relationship. A graphical example of such a relationship is the Golden Rectangle. The Golden Rectangle is a logarithmic spiral constructed from the convergence of a mathematical series of proportions referred to as the Fibonacci series. This series is based on the proportion of a:b, b:(a+b), etc.

In design, the most obvious proportional relationships are based on relative size and shape of the elements.

There can also be proportional degrees of surface texture and color. Proportion may become a system of planned order that contributes to the unity of a design. Appropriate proportion must exist between the various parts of a structure: between its height, width, and depth; between solids and voids; between surfaces and openings; and between areas of sunlight and shadow.

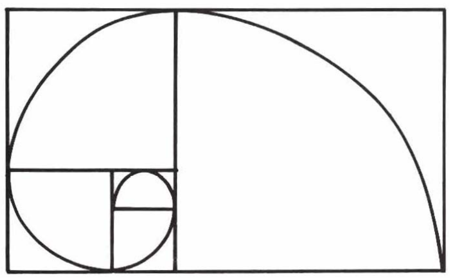


Fig. 2-7. Golden Rectangle is a study in geometric proportion

2.2.2 Rhythm

Rhythm is the regular recurrence of any like elements in, on, or around a structure. It requires that the elements have some similarity of visual characteristics in addition to a modulated placement. In bridges, for example, major rhythms are created by the repetition of similar pier shapes. Minor rhythms may be created by the spacing of light poles, post spacing within a railing, or even the horizontal rustication on a pier. Modulating the placement of these elements can create visual flow or movement across the scene. A good example of this is when pier spacing gradually increases near the main span when a bridge crosses a wide river or lake.

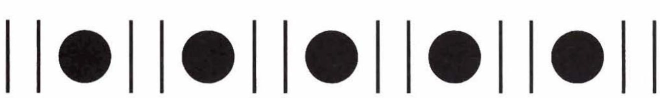


Fig. 2-8. Concept of rhythm

2.2.3 Order

Order refers to arrangement. It is the arrangement of design elements so that they work together as a unit without visual confusion. The whole arrangement works as a unit with each element having a proper place and function. The selection of a constant girder depth throughout the structure is an element of good order. Order is also achieved by limiting the lines and edges of a structure to only a few directions. Under the rule of order, the regular recurrence of similar elements in a composition creates a natural flow, known as rhythm, that is satisfying to the eye.

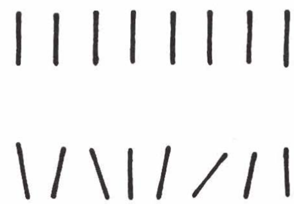


Fig. 2-9. Visual order and disorder, respectively

2.2.4 Harmony

Harmony is the relationship of the elements of a design based on similarity of their visual characteristics. The relationship must be complementary. If the planes or lines in a design have more dissimilar characteristics than they have similar characteristics, they are not likely to be perceived as harmonious. This is most readily achieved by using the Law of the Same or the Law of the Similar.

Law of the Same: Harmony may be perceived or created in a structure or composition of structures that attains order through the repetition of the *same* elements, forms, or spaces.

Law of the Similar: Harmony may be perceived or created in a composition that attains order through the repetition of *similar* elements, forms, or spaces.

Fig. 2-10. Harmony depicted as a function of shape, size, direction, and color

2.2.5 Balance

Visual balance is the perceived equilibrium of design elements around an axis or focal point. Rather than a physical balance, it may also refer to equilibrium of abstract elements of the design such as masses, visual weights, texture, etc. Visual balance is fundamental to all successful compositions.

Fig. 2-11. Visually balanced compositions

2.2.6 Contrast

One principle of contrast is the dynamic relationship among parts of a design based on complementary opposition of visual characteristics. Contrast relieves the monotony of simple harmony by complementing the harmonious characteristics of some design elements with their opposites, thus adding a heightened awareness of each other.

Swiss bridge engineer, Christian Menn, exemplified this concept in some of his works. In one instance, he erected a delicate and graceful concrete structure in a rugged, gray Alpine gorge. This graceful bridge is foreign to the natural character of the craggy mountain background. Yet, by sharply contrasting this elegant bridge with the rugged mountain setting, the strongest qualities of each were dramatized.

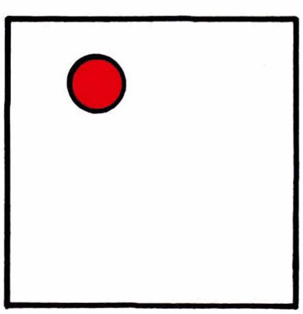


Fig. 2-12. Contrast in shape, size, color, and symmetry

Fig. 2-13. The Ganter Bridge designed by Menn in 1980, Switzerland

A second principle of contrast is that of dominance. This concept relates to one of two contrasting elements commanding the visual attention over the other. One becomes the feature and the other becomes the supporting background. In terms of design, a dominant theme is essential in organizing the design into a pleasing aesthetic experience.

2.2.7 Scale

Scale refers to the size relationship among various features of the structure and between the total structure and its surroundings. Since design concerns itself with things that are to be used by people, a connection exists between the human body and designed objects. We often refer to structures that respond to the size of the human form as having human scale. This would be particularly true for a pedestrian bridge or any bridge with high pedestrian usage. When a bridge becomes exceptionally large, many of the component elements lose their human scale. Elements such as piers, pylons, or superstructure members may take on monumental scale. Here it becomes more important that the structure be in scale with the surrounding environment.

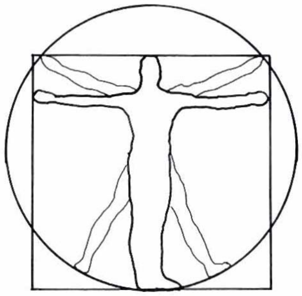


Fig. 2-14. Scale

2.2.8 Unity

Unity is presented last because it encompasses the perfect application of all the other qualities. It refers to the combined effects of all other aesthetic qualities applied simultaneously. Unity is the condition, or state, of full resolution of the site and project functions. Unity implies harmony where all of the elements are in accord, producing an undivided total effect. Unity provides the observer with a sense of wholeness, generated by some central or dominating perception in the composition.

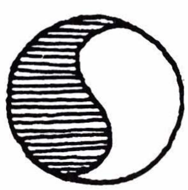


Fig. 2-15. Unity concept

2.3 AESTHETIC DESIGN OBJECTIVES

Throughout the design process, designers should have aesthetic goals or objectives for the bridges they design, just as we have engineering objectives for safety, economy, serviceability, etc. As with engineering objectives, aesthetic design objectives should be established prior to the start of the design process so they can serve as an aesthetic compass, of sorts. These aesthetic objectives should be considered throughout the design process when decisions are being made about the structure and its setting. Established objectives referred to during the decision making process will help guide designers toward a successful visual design.

Ideally, asthetic objectives would be quantitative and therefore easily measured. But, given the subjective nature of aesthetics, visual design goals will necessarily have to be qualitative. Only through subjective evaluation can the success of the visual design objective application can be measured. When evaluating a bridge, designers should evaluate each part of the structure in terms of the whole, and the whole structure in terms of the setting and highway corridor.

Several aesthetic design objectives are offered in the following paragraphs to aid designers in visualizing, evaluating, and articulating their designs. These objectives should be considered as a fundamental framework that designers can use to initiate the application of aesthetic design. The aesthetic quality concepts discussed previously can be applied to this framework to refine the appearance of the structure.

2.3.1 Functional Clarity

Need defines the purpose of a bridge. Therefore, a fundamental requirement is that the bridge design must fulfill its purpose. The structure must do so in an obvious manner. The structural design must provide an honest structural response to the load-carrying task at hand. The bridge should reveal itself in a pure and clear form.

The structure must also serve the physical circumstances of its particular location. Geometry of the roadway, the topography, and the presence or absence of other structures or buildings are all design considerations in the selection and development of bridge types and configurations. When evaluating functional clarity, designers should ask: Does the bridge serve its function in both deed and appearance? Is the form of the structure appropriate to the function of the structure?

2.3.2 Scale and Proportion

The structure should be in scale with its surroundings as well as with other parts of the structure. The primary structural elements, e.g., span lengths, girder depth, abutment height, should have good proportional relationships to each other and their structural chore. Generally, no single element should dominate the visual composition. The collective design of the structure should be in scale with the site and environmental considerations. The structure form should have an appearance of lightness.

When evaluating the scale and proportion of a structure, designers should ask: Are the substructure elements proportional to the superstructure? Is the size of each bridge element consistent with its respective structural assignment? Is the structure size suitable for its setting and purpose? Does the superstructure seem slender without appearing delicate, or is it ponderous?

2.3.3 Order and Balance

The bridge should exhibit a natural progression of assemblage. Order is achieved by limiting the direction of lines to a minimum. Repetition of visual elements should be used sparingly to develop rhythm; if used to excess it can create monotony. The orientation and interaction of the design elements should suggest balance between the elements. The layout and alignment of the elements should promote harmony rather than confusion.

When evaluating the order and balance of a structure, designers should ask: Does the arrangement of components work together as a unit or promote visual confusion? Are the lines of the bridge limited to a few directions? Does the visual weight, texture, and mass of the members promote visual balance?

2.3.4 Simplicity and Continuity

The bridge form should appear straightforward and uncomplicated. Simplicity of form and clean lines are considered attributes of attractive structures. The architectural features should enhance the overall appearance. The design should express an overall continuity in appearance. Shapes used to form elements should be from the same family. For instance, beveled piers should be used with a beveled barrier rail design; rounded pier designs with a rounded railing. The number of materials, colors, and textures should be kept to a minimum. Details should appear consistent.

When evaluating the simplicity and continuity of a structure, designers should ask: Does the visual composition present a consistent design theme? Can a viewer comprehend the bridge in a glance, or does it require concentration of the viewer?

2.3.5 Site/Environment Integration

Bridges must be integrated with their environment, landscape, city scape, or surroundings. This is particularly true where dimensional relationships and scale are concerned, as pedestrians are uneasy and uncomfortable with heavy, brutal forms. The dimensions of the structure must relate to human scale when pedestrians are involved. Bridges should make a positive contribution to the immediate environment in which they are placed.

Fig. 2-16. Wornall Road Bridge – sensitive to urban setting, Missouri

When evaluating environment integration, designers should ask: Does the structure type, color, and color scheme complement its surroundings? Does the bridge visually conflict with its adjacent buildings or landscape? Are the materials, and finishes of the bridge native or foreign to the setting?

2.4 AESTHETIC DESIGN HIERARCHY

Adornments such as lighting, ornamental railings, and extravagant use of color are often associated with a high level of aesthetic treatment. However, it is the general physical characteristics of the bridge that establish the fundamental visual properties of the structure form. In short, the general physical characteristics establish the visual essence of the bridge. The visual essence conveys the functional clarity, along with scale and proportion of the bridge form. It also makes significant contributions to order and balance, along with continuity. Lighting and railing should simply reflect the physical characteristics of the bridge structure, not define the visual statement.

2.4.1 Principle Aesthetic Design Factors

As one might expect, there is no single design parameter that controls the general physical characteristics of a bridge. An attractive bridge is the orchestration of design parameters employed simultaneously to complement each other. Designers can interpret these design parameters to constitute principal aesthetic design factors.

The principal aesthetic design factors fashion the visual basis upon which the balance of the appearance is built. Designers should concentrate on developing the best design solutions for these design parameters prior to considering other visual treatments. To find the best design solution, designers must consider the aesthetic objectives outlined previously when making decisions regarding these design parameters.

Principal Aesthetic Design Factors:

- Superstructure type and shape

  Vertical and horizontal geometry and their relationship to the surrounding environment
- Pier placement and shape
- Abutment placement and shape

  Interaction between the bridge and its surroundings/environment

2.4.2 Secondary Aesthetic Design Factors

Secondary aesthetic design factors can be used to accentuate the positive qualities that have been created with the principle aesthetic design factors. The texture, color, and shape can be engaged to draw attention to, or to detract from, the role of structural elements. When considering the secondary aesthetic design factors, designers should consider the aesthetic qualities defined previously.

Secondary Aesthetic Design Factors:

- Railing details

  Surface colors and textures

  Architectural embellishments

  Lighting

AESTHETIC DESIGN PROCESS

Fig. 3-1. Robert St. Bridge, Crookston, Minnesota

"Beauty is at last revealed not simply as outward visible form, not simply as a matter of appearance, but as a quality implicit in the whole existence, permeating the entire essence of our work. The essential prerequisite to its achievement is an enthusiastic and sympathetic desire to understand and to satisfy those for whose use we design."

R.H. Evans and H. Houghton-Evans

3.0 INTRODUCTION

The Minnesota Department of Transportation, as part of its environmental review process, examines issues related to visual quality of all its projects. Mn/DOT applies the Federal Highway Administration (FHWA) *Visual Impact Assessment* (VIA) process during preliminary design to determine the effect of proposed projects on visual quality. The VIA process is used to identify and mitigate adverse impacts to visual quality and to identify opportunities for enhancing visual quality in the project area. For bridge projects, the VIA process is incorporated into an aesthetic review procedure.

The aesthetic review procedure is used to uniformly incorporate aesthetic considerations into the design of bridges. This process requires an aesthetic assessment for each bridge design project. The process is coordinated by the Preliminary Bridge Plans Engineer in conjunction with the District Project Manager, and includes review and input by an interdisciplinary committee made up of architects, landscape architects, engineers, and the District Project Manager. The use of an interdisciplinary committee promotes integration of science, technology, and artistic judgement in the search for design excellence.

The aesthetic design process identifies which disciplines and functional groups (identified in section 3.2.2) participate in the design, and at what point they participate in the design. Through this process, aesthetics are integrated into the scoping and design development process through studies, concept development, and recommendations. The aesthetic design process uses the fundamentals of aesthetic design to address the following considerations:

- The influence of the bridge project on the natural and manufactured environment
- The influence of the bridge project on the adjacent communities – urban and rural
- The influence of the bridge project on existing bridges within the transportation corridor or immediate vicinity
- Recommendation of structure type(s) based on location compatibility, design suitability, safety, and economics
- Recommendation of an architectural design direction to establish aesthetic and visual suitability for corridors or site locations
- Recommendation of component design details such as railings, medians, abutment types, pedestrian protection, lighting, walkways, bridge heads, signing attachments, etc.

3.1 DETERMINING AESTHETIC REQUIREMENTS

The aesthetic impact of a bridge is not merely the impression created by a bridge's surface features, such as color, materials, ornamentation, etc. Rather, it is the effect made on the public by every aspect of the bridge — its individual parts as well as its whole. Every decision made about the structure's overall design has an aesthetic consequence.

Once this association is appreciated it becomes clear that bridge aesthetics is similar to other criteria that govern bridge designs, such as structural integrity, safety, or maintenance. A decision regarding one feature will likely influence other features. A design improvement in any of these areas may, or may not, increase the project cost. The designers' challenge is to optimize the design through creativity and ingenuity, without requiring a significant increase in cost. This challenge stands for aesthetics as well as other design parameters.

An aesthetically pleasing bridge structure has good proportions, both in its individual parts and in the space outlined by its collective parts. Size, shape, color, and texture on superstructure, columns, and abutments can be engaged to call attention to or subdue the role of these various structural parts. The relationship of the structure design and details to its location and environmental surroundings is the final test. This relationship will influence public perceptions and attitudes concerning transportation design.

3.1.1 Public Visibility/Community Involvement

The visibility of a highway bridge, from both the structure itself and the roadway, must be considered during design. This includes assessing the primary and secondary viewpoints, the numbers of individuals viewing the structure and the duration of view. Structures that have a high visibility or are located in an area of visual, historic, and cultural significance, warrant more attention to aesthetics than do their less celebrated counterparts.

Bridges may also function as local or regional landmarks, gateways to cities, or symbols for communities. People want to be proud of where they live and they take an interest in the appearance of property they own. Bridges form an important part of an area's public environment; the prominence of landmark structures can have an enormous impact on the impressions created of an area or community.

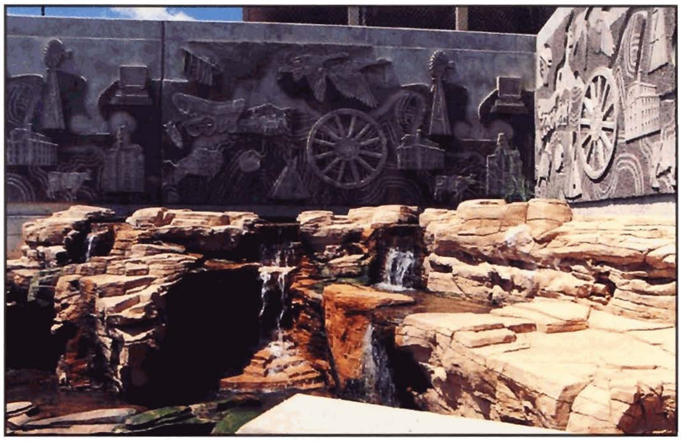


Fig. 3-2. Relief in concrete used to depict icons of local significance, Rochester, Minnesota

The designer should recognize and understand the local values, goals, and community impacts that are related to each project. The project setting and its visual resources may be valued by public interest groups for reasons not evident in a visually based assessment nor widely known outside of the community. Meeting with local groups may be necessary to discover cultural, educational, recreational, and historical values. Bridges located in settings with significant levels of these values warrant more attention to aesthetic design to insure integration of the bridge into the local environment.

Public involvement in the bridge planning and design process can be very important. To fully realize public input opportunities, project managers should include comprehensive communications between the general public, public interest groups, state and federal agencies, and the lead members of the design team. This communication should occur early in the project. Coordinating all aspects of the project at an early stage in the design development will result in improved safety, appearance, and economy, as well as eliminating project delays.

Fig. 3-3. Noise walls and public green space incorporated in design, Wabasha, Minnesota

3.1.2 Highway Corridors

Parkways, expressways, and interstate segments are all examples of routes that, due to their unique location or function, may require corridor-specific architectural guidelines to develop a special identity or maintain a consistent appearance throughout a project. The corridor-specific architectural guidelines usually consist of uniform visual treatment for several bridge components as well as retaining walls. Interstate segments and major interchanges offer opportunities for economy through repetition. Repetitive use of architectural treatments for bridge columns, piers, abutments, and architectural details allows contractors to reuse formwork, thus reducing the project cost.

The appearance and architectural concept of a river crossing is usually considered independent of the architectural theme of the highway corridor. This is based on the assumption that highway users should experience a unified, compatible style as they travel along a route. The river crossings are usually not within the motorists' viewing area and, therefore, may vary from the corridor architectural concepts.

Fig. 3-4. Retaining walls and bridge elements share common visual design elements, T.H. 77 interchange, Bloomington, Minnesota

3.1.3 Interchanges

Interchanges need special design considerations since several structures may be visible at one time. They may even be physically linked together with retaining walls and/or noise walls. Increased functional complexity tends to create visual confusion and disorder. Various structures having different requirements can be visually integrated by using uniform details and uniform structural systems that will provide unity and harmony. This requires close coordination between the designers of the individual structures, along with the application of a comprehensive design theme utilizing common elements. These consistent features serve to improve the drivers' psychological comfort.

Early attention to the appearance of the structures may result in slight horizontal and vertical alignment adjustments that can significantly improve bridge appearance. Full realization of these potentials requires early and comprehensive coordination between highway designers, bridge designers, traffic engineers, and landscape architects.

Fig. 3-5. Uniform details minimize confusion of complex interchange, Duluth, Minnesota

3.1.4 Scenic/Environmentally Sensitive Sites

Sites having outstanding natural beauty or spectacular viewpoints demand a structure that responds to the site either by blending in with the surroundings or by dramatically contrasting with the surroundings.

Designers should be aware of the viewers' sensitivity to visual details, character, and quality of the structure. On a pedestrian bridge, for example, viewers are more aware of scale and detail than they would be on an interchange bridge. The designer also needs to consider the viewers' expectations of the setting. For example, the viewer expects a bridge crossing a large body of water, or deep ravine, to reflect the unusual requirements of the site.

Fig. 3-6. Natural beauty of site reflected in bridge type and materials, Black Hills National Forest, South Dakota

3.1.5 Multi-Modal Transportation

The development of transportation projects increasingly involves several modes of transportation including: light rail, transit facilities, bikeways, aircraft and water craft. The needs of each mode of transportation, present and future, should be anticipated and planned for in the project development. The users' visual comfort should be considered throughout the project development of multi-modal projects.

3.2 BRIDGE DESIGN PROCESS

In order to achieve a successful bridge design, a design process must address several considerations simultaneously. These design considerations include structural capacity, safety, project costs, function, visual appeal, and the environmental impact. Design excellence can be achieved through the use of an interdisciplinary approach in which a team of professionals cooperate in an effort to achieve design goals.

Highway engineers, bridge engineers, architects, and landscape architects, who are familiar with the fundamentals of aesthetic design, may be consulted to provide input from their own areas of professional training. Mn/DOT's aesthetic design process includes coordination among these parties, in addition to an aesthetics review. The Preliminary Bridge Plans Engineer coordinates the implementation of the aesthetic design process as it relates to bridges. Once the project reaches the final design stage, the Bridge Unit Leader directs the coordination to completion of the final bridge plan with assistance from the Preliminary Bridge Plans Engineer as needed.

The overall project development process is directed by the District Project Manager. The procedures for accomplishing this are outlined in several sources including, the Highway Project Development Process (HPDP) manuals, the Visual Impact Assessment Process, and by Systematic Development of Informed Consent (SDIC) principles. SDIC is a strategy for public agencies to use in developing informed consent systematically, between all parties involved in project development. SDIC and citizen participation are important parts of the highway development process. The process of bridge aesthetic design is a branch of the highway development process and is interwoven throughout it.

3.2.1 Bridge Aesthetic Review Procedure

The Preliminary Bridge Plans Engineer initiates the aesthetic design process. At this point in the design process preliminary concepts are reviewed and a level of aesthetic attention is determined. In an attempt to achieve design excellence and efficient production, all bridge projects are subject to an aesthetic review. The findings of the aesthetic review are documented in a bridge aesthetics design plan. The bridge aesthetics design plan may include preliminary design recommendations, architectural treatment recommendations, sketches, written text, and computer simulation studies. The size of this document will vary in proportion to the level of aesthetic consideration and size of the project. The aesthetic design plan will be briefly described on the preliminary plan and references for further detail. Depending on the level of aesthetic consideration and size of the project, the aesthetic review may include the following tasks.

- A visual site review and analysis to determine the effect the structure will have on the natural, cultural, and highway environment
- Identification and assessment of the predominant viewing population whose views would be affected by the proposed project
- Evaluation of existing bridges and highway structures in the vicinity or transportation corridor
- Recommendation of structure type(s) to establish aesthetic and visual compatibility with the existing or proposed highway corridor
- Architectural recommendations that establish aesthetic and visual compatibility with the highway corridor

- Recommendations for component and element design including railings, abutments, pedestrian protection, walkways, bikeways, trails, lighting, signing attachments, textures, surface treatments, and color treatments

3.2.2 Aesthetic Design Process

Early in the design development the Preliminary Bridge Plans Engineer will initiate the aesthetic design process. At this point in the design, preliminary concepts are reviewed, and a level of aesthetic attention is determined. The level of aesthetic attention determines the number and type of participants in the aesthetic design process, the depth of the process, and, to some extent, the resources to be devoted for aesthetic considerations. Three levels of aesthetic design have been established: Levels A, B, and C.

- Level A aesthetic process is intended for bridges with major cultural or aesthetic significance.
- Level B aesthetic process is used for mid-level structures.
- Level C aesthetic process is implemented for a low level of aesthetic consideration.

The Preliminary Bridge Plans Engineer may convene an aesthetic design team to investigate the aesthetic considerations and environmental significance of Level A and Level B bridges. This team would consist of the Preliminary Bridge Plans Engineer, the District Project Manager, representatives from the Office of Environmental Services and from the Site Development Unit of the Office of Technical Support, and others as needed.

Following on subsequent pages are flow charts indicating the design process for the three levels of aesthetic attention. These figures indicate an ideal process that can be implemented for most bridges. There are, of course, exceptions for projects with extenuating circumstances. For these cases the Preliminary Bridge Plans Engineer may modify the process while insuring the intent of the process remains intact. The participation of various disciplines and service groups is particularly general and is offered as a guide only. Participation in the aesthetic design process by various disciplines and service groups may be adjusted to meet project specific needs.

The terms Environmental Services and Site Development, are used throughout the description of the aesthetic design process. These terms are meant to include professionals in Mn/DOT's Office of Environmental Services, and the Site Development Unit of the Office of Technical Support. Either or both of these organizations may be involved as project needs dictate. The Office of Environmental Services is generally involved in the scoping phase of the project. At this juncture in the project development, Environmental Service personnel may work with district personnel prior to the Office of Bridges and Structures becoming involved. The Site Development Unit is often involved in the final and detail design phases. Smaller projects initiated in the Office of Bridges and Structures may involve the Site Development Unit for assistance without involving Environmental Services.

Following, the three levels of aesthetic design are defined, along with their respective design processes. Throughout these flow charts, the different disciplines and service groups are represented by letter codes. These same letter codes are also used for the same purpose in a subsequent table indicating participation by various disciplines and service groups.

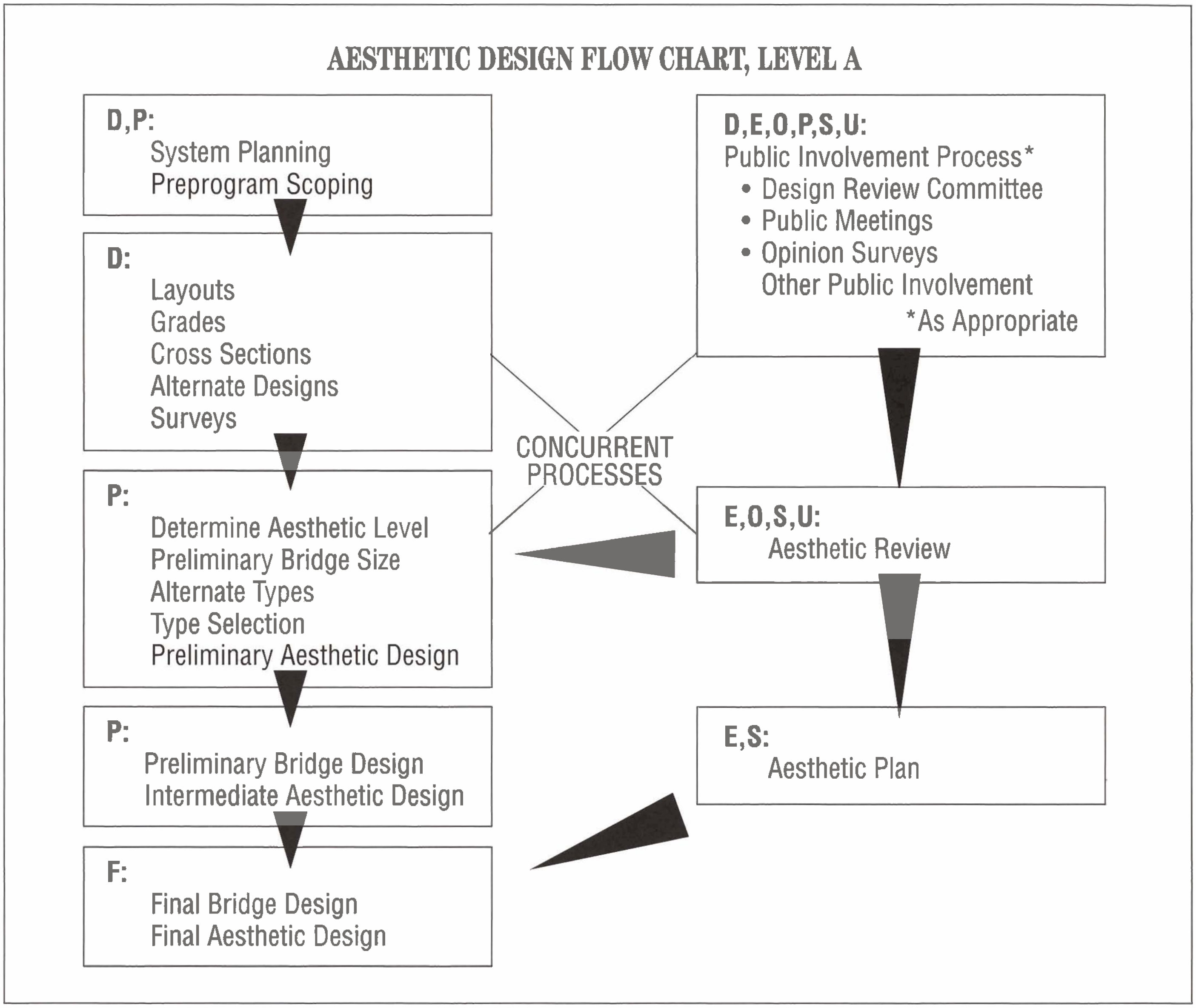


Fig. 3-7. Flow Chart, Level A

- **Level A**

Level A is used for projects of major aesthetic importance. Characteristics of structures in this category are highly visible bridges, bridge projects that generate substantial citizen interest, bridges located in environmentally sensitive and historic locations, and bridges that are historic themselves. Aesthetics may be a significant factor in determining the structure type for Level A projects.

Flow Chart Key:
- P – Bridge Design Preliminary
- F – Bridge Design Final
- D – District Preliminary Design, Final Design, Maintenance and Construction
- S – Site Development
- E – Environmental Services
- U – Public
- O – Other Agencies (State Historical Preservation Office, Dept. of Natural Resources, local government units, etc.)

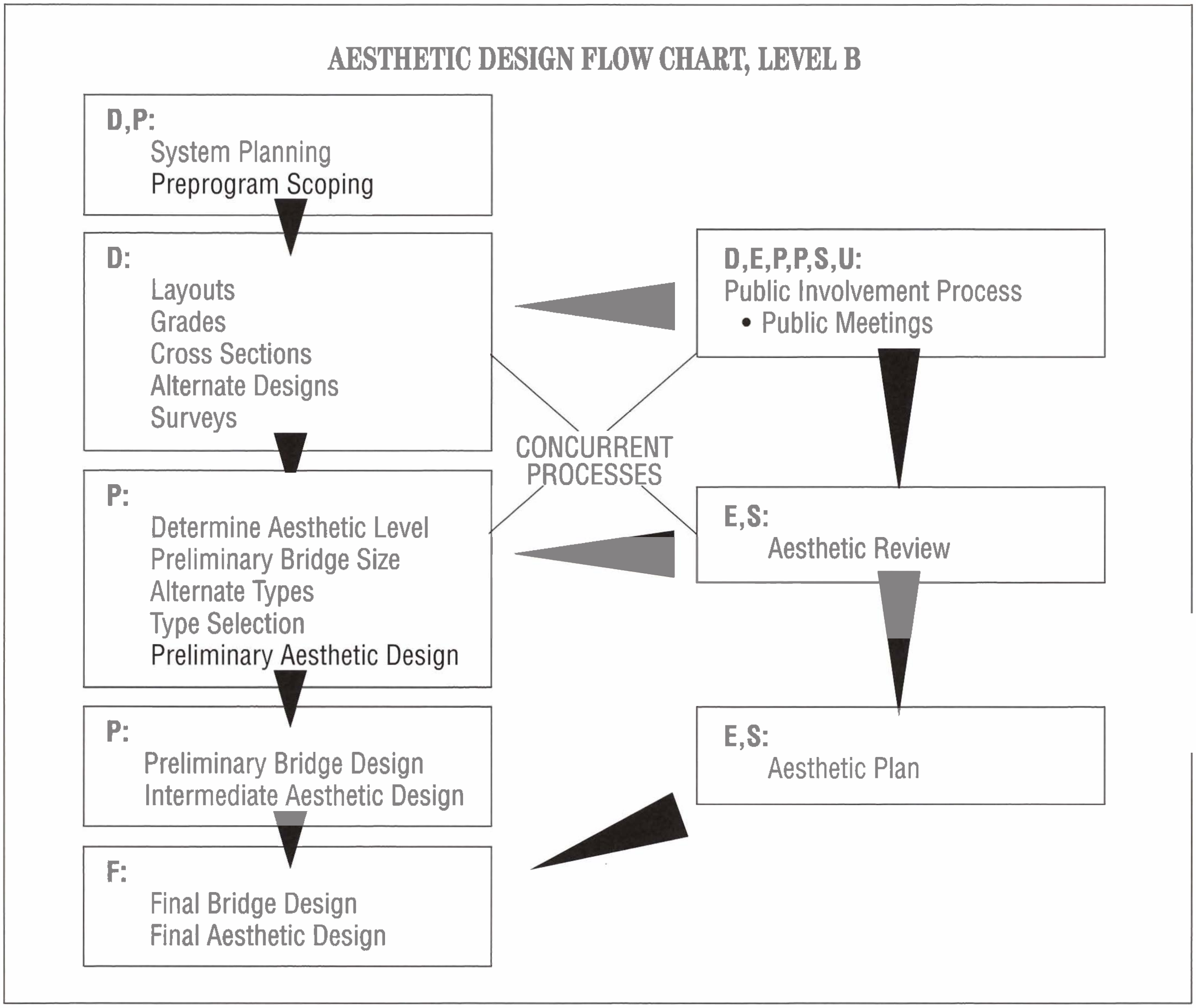


Fig. 3-8. Flow Chart, Level B

- **Level B**

Level B is used for bridges where moderate aesthetic treatment is appropriate, but not to the extent that it controls the design. This level includes grade separations over higher volume roads, and bridges near recreation areas, parks, or recreational waterways. Corridor bridges (generally when three or more new bridges are built in close proximity) would be included in this level.

Flow Chart Key:

- P – Bridge Design Preliminary
- F – Bridge Design Final
- D – District Preliminary Design, Final Design, Maintenance and Construction
- S – Site Development
- E – Environmental Services
- U – Public
- O – Other Agencies (State Historical Preservation Office, Dept. of Natural Resources, local government units, etc.)

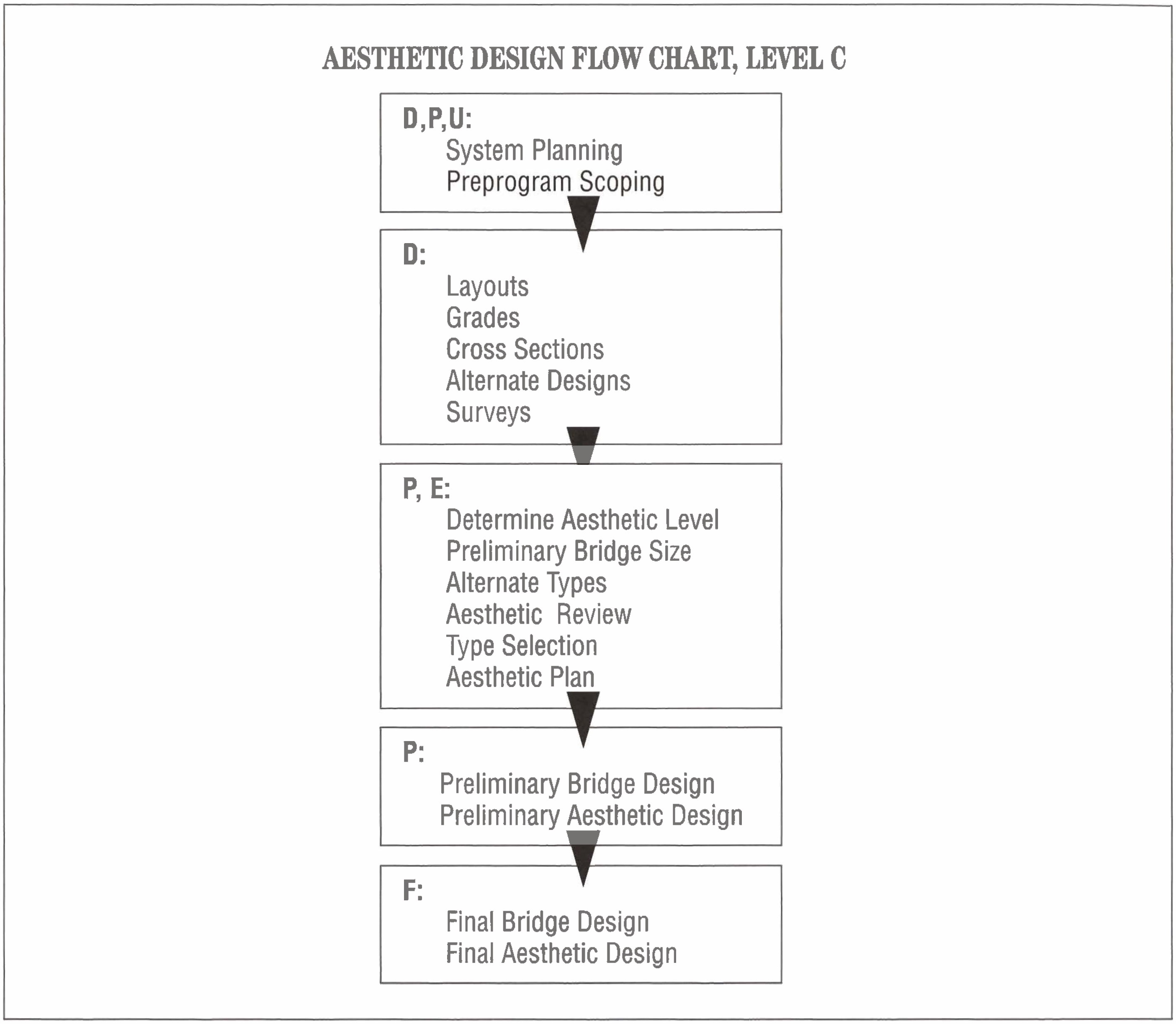


Fig. 3-9. Flow Chart, Level C

- **Level C**

Level C is used for the smallest or most routine of bridges where minor aesthetic treatment is appropriate. This level includes low visibility bridges, bridges over non-recreational waterways, bridges over railroads, or overpasses of low-volume roads. Corridor bridges would not be included in this level.

Flow Chart Key:

- P – Bridge Design Preliminary
- F – Bridge Design Final
- D – District Preliminary Design, Final Design, Maintenance and Construction
- S – Site Development
- E – Environmental Services
- U – Public
- O – Other Agencies (State Historical Preservation Office, Dept. of Natural Resources, local government units, etc.)

FUNCTIONAL GROUP PARTICIPATION TABLE

PRINCIPLE AESTHETIC FACTORS	AESTHETIC LEVEL A		B		C	
	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
Superstructure Type and Shape	DEPS	U	PS	DE	P	D
Superstructure depth-span ratio	P	DEFSU	P	EFS	P	F
Vertical and Horizontal Geometry	D	EPSU	D	P	D	P
Pier Placement	DP	EFSU	P	DEFS	P	DF
Pier Shape	PS	CDEFU	PS	CEF	FP	C
Abutment Placement	DP	EFSU	P	DEFS	P	DF
Abutment Shape	FS	DEPU	FS	EP	FP	
Bridge/Site Integration	DEPS	U	PS	DE	P	D

SECONDARY AESTHETIC FACTORS	AESTHETIC LEVEL A		B		C	
	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
Embellishments	PSOU	CDEF	PS	CEF	FP	C
Railing Details	FPSOU	E	FPS	E	FP	
Surface Colors and Textures	FSOU	EP	FS	EP	FP	S
Lighting	STOU	EF	ST	EF	T	F

Prim. denotes primary participation Sec. denotes secondary participation.

DEFINITIONS:

C - Bridge Construction
D - District Preliminary & Final Design
E - Environmental Services
F - Bridge Design Final
P - Bridge Design Preliminary
S - Site Development
T - Traffic
U - Public

3.3 TOOLS OF ANALYSIS

A harmonious relationship between the site corridor and structure must exist for the project to be successful. In order to evaluate the design qualities and visual appearance of a bridge, designers often require more than the standard plan, elevation, and cross-section drawings. Designers should use methods that accurately and realistically portray what people will see and the viewpoints from which they will see it.

In order to explore, review, and evaluate design recommendations and bridge element relationships, visual aids must be developed. Computer-generated models of the proposed bridge, superimposed over photographic images regenerated by computers, can be used to effectively illustrate the three-dimensional aspects of the structure and its relation with the environment. An aerial oblique view of a bridge is best for showing the overall context of the structure and its relation to the site, but offers little in way of portraying an observed, relevant perception. Views from the underpassing roadway, natural vantage points, or ground level oblique views are excellent for showing features and the character of the bridge. Often, renderings of details are useful to illustrate railings, architectural delineations, textures, colors, and patterns.

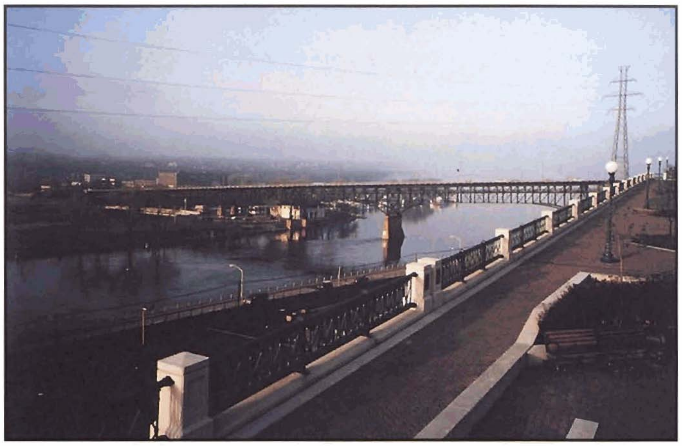


Fig. 3-10. Original photographic image of existing bridge, Wabasha St. Bridge, St. Paul, Minnesota

Fig. 3-11. Computer-enhanced image of proposed concrete box girder alternate, Wabasha St. Bridge, St. Paul, Minnesota

Rough perspective sketches are generally adequate for examining ideas at the early stages of design development. However, at the final decision-making stage, all perspective drawings must accurately portray the proposed structure within its surroundings, be it by computer-enhanced imaging or architectural rendition. Even small differences in girder depth or pier width can make enormous differences in the final appearance of the structure. This is especially critical when deciding between alternate structural solutions. Final renditions should include ancillary bridge components such as signs, pedestrian screens, and guard rails as they will impact the appearance of the structure.

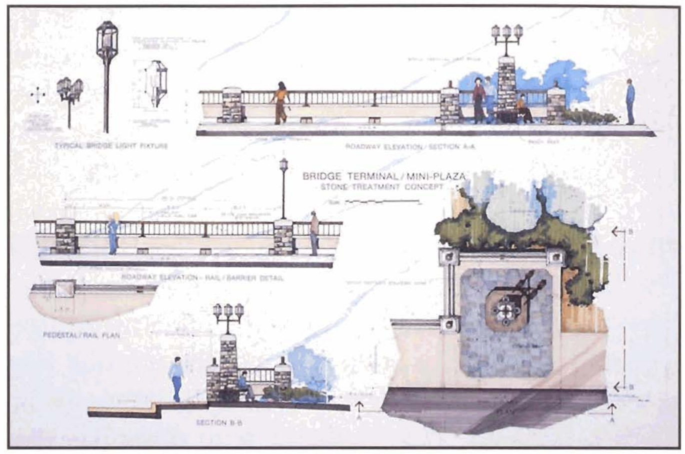


Fig. 3-12. Detail rendering of bridge appurtenances, Lake/Marshall Bridge, Minnesota

For proper evaluation, a bridge should be viewed from several different angles and distances with the most attention given to those views most generally seen by the public. Traditional viewpoints used to evaluate bridges and piers follow.

- Longitudinal elevation: Look for rhythm and order of spans, overall proportions, balance, and scale.
- Transverse cross-section: Study pier proportions; horizontal and vertical pier transitions as the roadway widens or branches, or rises and falls; and railing scale and dimension.
- Oblique angle or 3/4 view: Check the stacking effect of multiple piers; look for continuity between adjacent pier shapes.
- Detail renderings: Illustrate significant details such as railings, architectural delineations, textures, colors, and patterns.

3.4 COST EVALUATION/ANALYSIS

Beautiful structures that satisfy the aesthetic needs of a particular site can be designed at little or no additional cost by following sound architectural design and structural principles. In general, designers should let form follow function, maintaining a simple, straightforward solution while simultaneously avoiding unsightly and nonfunctional appurtenances. Sound structural bridge design that incorporates good proportions, balance, and order, and respects existing site conditions will inherently exhibit pleasing aesthetic qualities, with little or no additional costs.

While it is true that the most attractive structures will also be effective and economical, the converse is not true. Every structurally and fiscally effective bridge will not necessarily be attractive. Herein lies the potential for bridge designers to make a difference in the environment. The challenge is to recognize the need for aesthetic consideration and act on that need with the same commitment that other design criteria receive.

Just as engineers make economic judgments related to features of safety, maintenance, or structural capacity, so too, should they make economic judgments concerning aesthetics. Designers must consider appearance along with cost, safety, and durability as a factor in the bridge design process. Aesthetics must also become one of the criteria by which the success of a bridge project is measured. Application of sound aesthetic treatments should be applied with the same restraint of time, budget, function, and technology as the other aspects of the design.

Recognizing the importance of aesthetics, Mn/DOT practice has been to invest additional funds in a structure for special aesthetic treatments when a site warranted unique considerations. Generally up to 15% above the cost of a conventional bridge has been accepted as a reasonable maximum amount for aesthetic treatment of a Level A bridge and lessor amounts for Level B and C bridges, such as 5% to 10%. When communities have requested more costly treatments or special treatments for routine sites, local participation in the cost of the treatment has been sought. Mn/DOT Districts have negotiated these agreements with local communities. Frequently communities have requested architectural bridge railings. Technical Memorandum 90-13-B-1 entitled Participation Architectural Bridge Railings addresses the cost participation policy for these railings.

3.5 BRIDGE MAINTENANCE CONSIDERATIONS

Throughout the design process, designers must understand the effects of time and service on the structures under consideration. Eventually, all bridges will require maintenance and repair of some sort. Designers should recognize this need and plan the structure to facilitate future maintenance and repair operations. In particular, details should not inhibit access to the individual bridge elements and should be resistant to vandalism. Examples of these considerations include: providing a convenient location from which beams can be jacked to perform maintenance on bearing pads, providing grills over light fixtures to discourage vandalism and, locating light fixtures such that they are not vulnerable to vandalism.

Repetition of details promotes ease of maintenance and also reduces costs. For example, use of a single length of ornamental railing length simplifies fabrication of the original railing and replacement of damaged sections. Designers should also consider including replacement elements of any non-standard bridge elements to be included in the initial construction phase of the project. Such non-standard replacement items can be kept in inventory until such time as they are needed. These items may include: pavers for walkways, special surface finishes, ornamental railing and light poles, glazing and light fixtures.

Designers should also consider providing direction to the maintenance forces. Such direction may be as simple as a note on the construction drawings or as detailed as a separate maintenance and operation manual for unique features of the structure.

Circumstances often require the retrofit of bridges to accommodate unforeseen utilities, signs and repairs. When such occasions arise, maintenance and operations personnel should respect the aesthetic qualities of the bridge and consider the ramifications of any proposed work on the appearance of structure. In short, regard for aesthetics should be applied to the design of bridge modifications or retrofits in the same manner as it applies to the initial design. Examples of application of aesthetic considerations to bridge modifications would include: placement of a proposed watermain, or electrical conduit, between the fascia girder and the first interior girder in lieu of hanging it from the outboard side of the fascia girder, and routing utilities behind the abutment in lieu of attaching the utility to the face of the abutment. The Office of Bridges and Structures should be consulted early in the planning stages of all bridge retrofits and modifications. Aesthetic guidelines regarding bridge appurtenances are provided in section 6 of this document and will not be repeated here.

AESTHETIC DESIGN GUIDELINES – SUPERSTRUCTURE

Fig. 4-1. Smith Avenue Bridge (High Bridge), St. Paul, Minnesota

"Bridges are the punctuation marks in the 'script' comprising the unfolding freeway system. They outline the phrasing of the highway sections, accent major intersections, call for pause at the take-offs and entrances, and raise the question mark of expectation of new experience to one passing under them. As such, they are focal points which give expression to the freeway; and they are the prime target for aesthetic demands of the whole freeway system, and thus should receive proportionate attention in design."

Thomas C. Kavanaugh

4.0 INTRODUCTION

Aesthetic design requires the designer to visually analyze projects by reviewing components to determine their visual characteristics and then by exploring opportunities for a successful design solution. For bridge design, the design elements include structure types, spans, piers, abutments, railings, wall systems, and other detail components. The objective of aesthetic design is to integrate all facets of the design – environmental, structural, functional, and visual – into a solution in which all the conditions of design are simultaneously resolved. The superstructure and substructure, major details, and the immediate site environment should be orchestrated so that the bridge is well-coordinated and its composition is visually successful.

This section addresses the aesthetic considerations associated with superstructure design. While the section attempts to treat the superstructure individually, the designer should remember that all elements of a bridge must be considered in relation to the whole and the whole bridge in relation to its site location. Because the majority of bridges in Minnesota fall within the band of span lengths where girder bridges are predominant, the majority of this section deals with girder bridges.

4.1 NOMENCLATURE

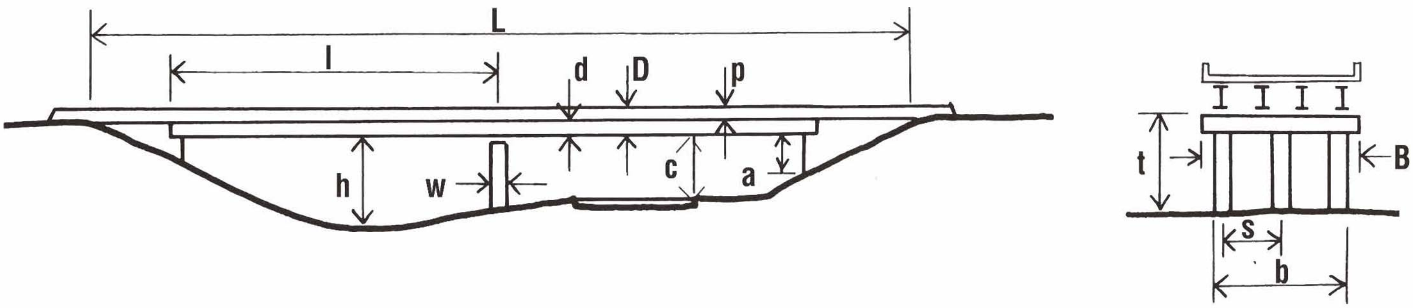


Fig. 4-2. Guideline nomenclature

Guideline Element Abbreviations:

a – dist. bottom of girder to bottom of abut. face
B – pier length at cap or top
c – vertical clearance at pavement edge
D – total superstructure depth
h – vertical clearance to the ground
L – total bridge length
p – rail ht., top rail/bot. of deck
t – pier height
b – pier length at base
d – girder depth
l – span length
s – spacing of columns
w – pier width

Throughout this section and the balance of these guidelines, specific letters will be used to denote physical aspects of bridge elements. These aspects and their representative letters are shown above.

4.2 GIRDER BRIDGES

4.2.1 Structure Layout

Early in the design process, the designer must make several decisions that effect the overall appearance of the bridge. These decisions involve determining the number of spans, the orientation of the substructure units to the superstructure, the location of the abutments, and establishing the span lengths. Collectively, all of the decisions define the layout of the bridge.

As with other aspects of bridge design, the structure layout is influenced by several factors including geology, economy, right-of-way, and roadway geometry. However, there are often refinements that can be made and alternatives to be considered. The visual aspects of the structure layout are presented for consideration along with other aspects of design.

The structure layout will have far-reaching effects in the visual formulation of the structure. This is because it establishes several of the principle aesthetic factors for the bridge. The designer should strive to develop a layout that embraces the fundamental aesthetic objectives defined in Section Two of these guidelines. At this stage in the design process the designer should be considering functional clarity, scale, and proportion, along with order and balance. The designer should also be thinking ahead to consider the impact of the layout on other bridge components, e.g., the abutment heights, the vertical and horizontal geometry, the location of the piers, and the predominant vantage point from which the bridge will be seen.

Within limitations, the structure layout can be adapted by the designer to accommodate aesthetic and other considerations. Options available to the designer to modify the layout include adding or eliminating a pier, moving the abutments, changing the number of beam lines, using different materials, modifying the depth of the structure, etc. Bridge designers should make a conscious effort to control the structure layout to the benefit of the visual appeal of the structure as well as other aspects of design.

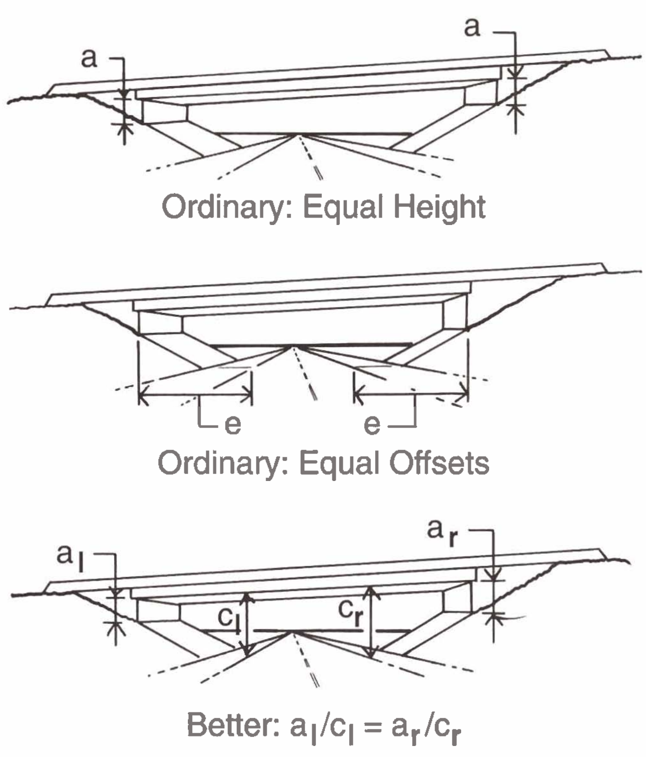


Fig. 4-3. Substructure should be proportional to vertical clearance

Fig. 4-4. Prestressed concrete beams used on slightly curved alignment, I-94 entrance ramp, Minneapolis, Minnesota

Fig. 4-5. Steel girders reflect lines of horizontally curved alignment, Minnesota

For shorter spans, harmony of proportions depends upon the relation of the structural mass to the size and shape of the openings. When the structure is on a slope, such that one end of the bridge is higher than the other, the abutment heights should be proportional to the clearance at the roadway edge. Structure layout considerations should include the following.

- A single-span structure represents the ultimate bridge – provided consideration is given to the proportions of the structure.
- Two-span structures lend themselves to a freeway environment, but cause a split-composition effect in natural settings.

Multiple-span structures with an odd-number of spans will appear visually correct because of the absence of a pier in the center of the bridge.

From an aesthetic standpoint, horizontally curved alignments call for curved superstructures (curved steel girder or box girder) because they allow the structure to reflect the lines of motion and reinforce the structure's function. Curved superstructures also eliminate the scalloped shadows created by the overhangs of curved decks on straight girders.

- Structures with vertical clearance limitations lend themselves to integral, or framed-in, pier caps. Integral pier caps can provide flexibility in pier location and emphasize the continuity of the superstructure by visually eliminating the pier cap.

4.2.1.1 Viaduct and Ramp Structures

Developing the structure layout for viaducts and ramps requires consideration of the vertical geometry, the height of the bridge, and the general outline of the topography. The orientation of the bridge to the ground creates different-shaped spaces beneath the bridge. These spaces can be rectangular or triangular depending on this orientation. Because pronounced valleys are rare in Minnesota, the superstructure will tend to parallel the ground line beneath the bridge, thus creating rectangular shapes. The geological conditions will influence the cost of the substructure units and, therefore, impact the economical span length.

If favorable foundation material is present, the relative cost of the substructure units will be low and economics will dictate shorter span lengths. In this instance the designer should consider placing slender piers at uniform spacings for the majority of the bridge. Near the ends of the bridge the span lengths should be shortened to mediate the transition to the abutments. Within the economic limitations, the designer should strive for span lengths that exceed pier heights. This will dramatize the vertical relief of the structure. Because of the close pier spacing of this option, use of slender piers is necessary to minimize visual obstructions when viewed from an oblique angle.

Fig. 4-6. Favorable foundation conditions – viaduct

If poor foundation material is present, economics will dictate longer span lengths. In this instance the designer should consider utilizing more substantial piers with an odd number of aggressive span lengths. The pronounced dimension in this span arrangement is the horizontal direction. Again, the span lengths should be decreased near the ends of the structure to mediate the transition to the abutments.

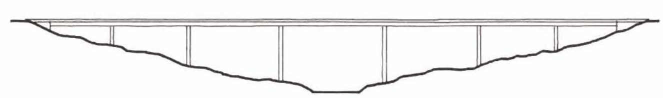


Fig. 4-7. Poor foundation conditions – viaduct

In those instances where the topography is varying in elevation, or when a ramp structure is descending to a lower elevation, the superstructure, ground line, and piers will form a polygon shape of sorts. Under these circumstances, harmony is obtained when the span lengths decrease as the structure height decreases. The span lengths should be modified in such a way that the diagonals through the openings keep the same angle of inclination (repetition of equal proportions). Varying the span lengths in this fashion produces similar proportions of each opening (ratio of height to span length).

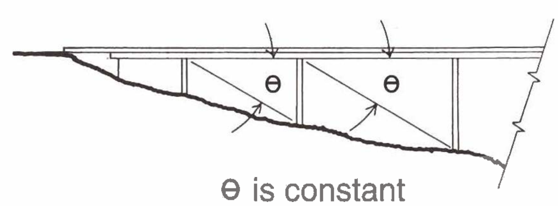


Fig. 4-8. Spans proportional to height

4.2.1.2 Skewed Structures

Roadway alignments often result in skewed structures. Skewed bridges can create visual obstacles as well as structural difficulties. These structures often present design challenges to deal with: side piers, elongated pier caps, superelevation effects on piers and abutments, difficult wing-wall configurations, and skewed vantage points of the structure. Oblique views of the bridge from the roadway beneath (or from nearby communities) are important. Often several piers are visible from a given location. The designer needs to consider the possible adverse effects of piers stacking up against one another visually. It is important to minimize the number of piers and keep the pier shape simple.

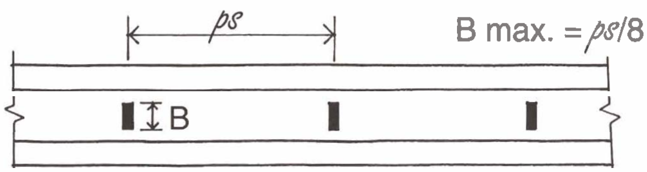


Fig. 4-9. Pier width considerations – skewed bridges

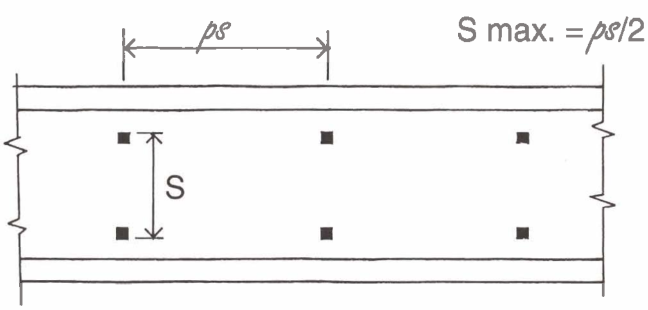


Fig. 4-10. Column spacing to span length ratio – two-column piers

Considerations for skewed bridge layout should include the following.

- Maximize the deck overhang to minimize the width of the substructure units.
- Maintain piers parallel to each other or radial to a curved superstructure.
- Keep the pier shapes as simple as possible.
- Consider abutment relocation to eliminate side piers.
- Consider the use of integral pier caps when necessary.
- Consider the use of single-shaft piers with shaft widths no more than 1/8 of the pier spacing.
- Consider 1/3 of the pier spacing to be the maximum width (b) for multiple column piers.

4.2.2 Structure Depth and Proportions

In girder bridges, the most characteristic and dynamic elements are the horizontal members that span over the feature to be crossed. Generally, the primary aesthetic goal is to achieve a slender superstructure while maintaining continuity and proportions. The aim should be to make the structure appear as a thin horizontal ribbon running from abutment to abutment, resting lightly on intermediate piers.

The slenderness of the structure depth may be defined as the ratio of the girder depth (d) to the span length (l). It may be expressed either as a fraction or whole number, i.e., d:l = 1:20 or l:d = 20. The slenderness can range from l:d = 10, to l:d = 40, depending on structural and economic considerations.

This slenderness of a girder bridge will greatly influence the visual composition of the structure. If left to structural design considerations, the structure depth may tend to appear quite thick and heavy. As such, it is the designer's challenge to make the structure appear thin and light. The structure depth can be controlled, to some degree, through adjustments in the span lengths, girder depths, material selection, superstructure shape, and detail. Along with economy, durability, and other design aspects, aesthetic considerations should be engaged in the design of girder bridges to achieve a slender appearance.

Modern materials and advances in technology have made it possible to achieve shallower structure depths than previously possible. Customarily, this affords a more slender structure and, hence, a more graceful appearance. While slender structure should be a visual goal to achieve, this objective can be carried to extremes. Designers are cautioned to maintain proper proportions. Slenderness is desirable up to the point at which the structure appears fragile and the superstructure proportions are not commensurate with the structural task at hand. When solid railings are used, girder elements begin to appear too thin when they are shallower than the rail.

Consideration for structure depth should include the following items.

- Continuous girders will provide a more slender structure than simple spans.
- Steel girders will provide a more slender structure than precast concrete I-beams.
- Concrete slab bridges often look very light because of their minimal structure depth.
- Pay special attention to proportions when the depth of a girder (d) is less than the rail height (p).

Steel girder bridges may utilize either rolled sections or welded girders for both simple and continuous spans. Conventional steel girder bridges have a span range of 12 to 24 meters for simple spans and 18 to 36 meters for conventional continuous spans. Span lengths of approximately 60 meters have been achieved with simple span steel girders and beyond 135 meters for continuous haunched steel girders. For conventional steel structures the slenderness ratio may vary between l:d = 15 to 32. Simple span slenderness ratios often fall below l:d = 25, while continuous span slenderness ratios can often exceed l:d = 25.

Concrete bridges are primarily prestressed concrete beam bridges or concrete slab bridges. Occasionally, designers choose concrete box girder bridges or concrete frame structures. In prestressed concrete beam bridges, span-to-depth ratios of 19 to 23 are common in the span range of 12 to 45 meters.

4.2.2.1 Single-span Structures

Single-span bridges are the simplest of highway structures. The appearance of single-span bridges is sensitive to the appropriate proportions between bridge elements. Fitting proportions should exist between the (suspended) superstructure and the height and width of the openings; and between the beam depth and span length. For most single-span bridges, the general location of the abutments will be determined by horizontal clearance requirements, structural constraints, and economy. However, once the general layout has been developed, it should be refined based on aesthetic analysis.

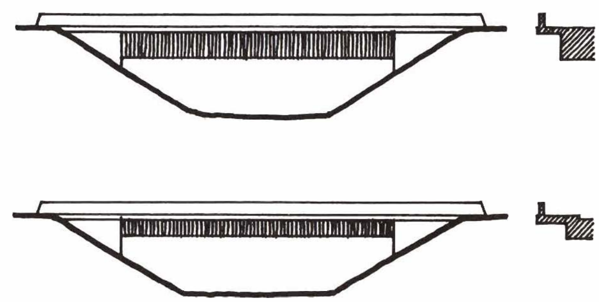


Fig. 4-11. Need for slenderness controls over need for proportion on longer spans

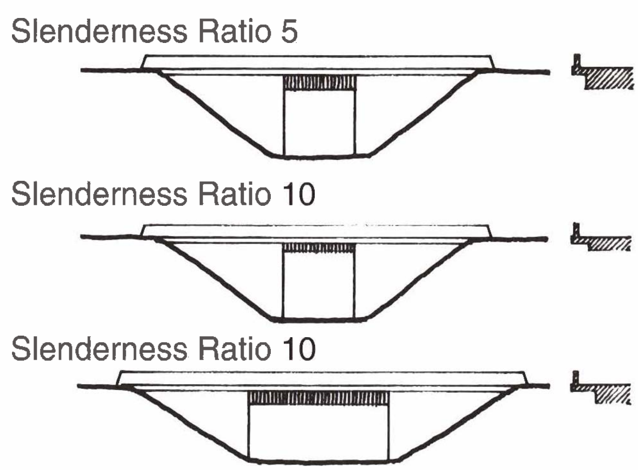


Fig. 4-12. Need for proportion (deeper structure depth) controls over need for slenderness on short spans

The slenderness ratio for single-span structures may vary between l:d = 5 to 30. Depending on the slenderness and proportions, the structure may appear heavy and clumsy. Conversely, it may appear light and elegant. For a single-span bridge, the designer should consider the relations among the opening beneath the bridge, the mass of the abutments, and the slenderness of the structure depth. These relations can be idealized in two visual compositions.

- At one end of the spectrum is a bridge with deep abutments and a short span length. The opening beneath this bridge will approximate a square, i.e., the total bridge length (L) approximately equals the vertical clearance (c). In this instance, the abutments provide a large mass, and the proportions play a more important role than does slenderness. A lower slenderness ratio of, perhaps 10, is appropriate for this idealized situation.
- At the other end of the spectrum is a bridge with shallow abutments and a long span length. The opening beneath this bridge will form a flat rectangle. As the span length begins to exceed the height, the slenderness begins to play a more important role. Abutment depths should be proportional to girder depth with shallower abutments used for shallower depth girders. In this instance, a slenderness ratio of 20 is more appropriate for harmonious proportions.

4.2.2.2 Two-span Structures

The total bridge length (L) of two-span bridges is typically much greater than the vertical clearance (c). Thus, the opening beneath the bridge is that of the flat rectangle. The principles of proportion are the same for two-span structures as for single-span structures with flat rectangular openings. That is, the slenderness ratio and proportions of the abutments to the superstructure should be considered. For a two-span bridge with shallow abutments, the designer should strive for a slender superstructure, perhaps l:d = 24 to 30. For a two-span structure with deep abutments the proportion of the structure depth to the mass at each end of the bridge becomes increasingly important. In this later instance, the designer should consider a lower slenderness ratio, say l:d = 18 to 22.

Two-span bridges have the potential of creating an undecided duality. That is, the observer has difficulty in finding the central focal point of the structure form. Designers have two options for avoiding this visual distraction.

- Increase the mass of the central pier to organize the composition around this element.
- Increase the visual prominence of the abutments and superstructure while decreasing the visual importance of the pier. This later option diminishes the duality by returning attention to the whole structure form. The appearance of the bridge is reminiscent of a single-span structure with this approach. Use of this later approach is recommended for most structures.

Fig. 4-13. Prominence of abutments and super-structure focuses visual attention of entire composition, Burlington Northern over Beam Avenue, Maplewood, Minnesota

For grade separation bridges, the pier location is generally determined by the geometry of the roadway beneath the structure. The pier should support the superstructure as unobtrusively as possible, allowing the horizontal lines of the girder and railing to dominate the view. The designer should attempt to minimize the influence of the pier on the visual composition.

4.2.2.3 Three- and Four-span Structures

As safety issues have effectively eliminated the use of shoulder piers, three- and four-span bridges are uncommon for grade separation crossings. When unusual circumstances require such span arrangements, the proportion principles previously outlined would apply. The design should emphasize the superstructure, which holds the bridge together by providing a visual link from abutment to abutment. The harmony and balance of a three-span bridge form is enhanced when the center span is discernably longer than the end spans. Other measures that can be used to promote a graceful structure include:

- Maintain a constant depth of structure throughout the length of the bridge.
- Minimize the height of the abutments to keep the end spans visually balanced.

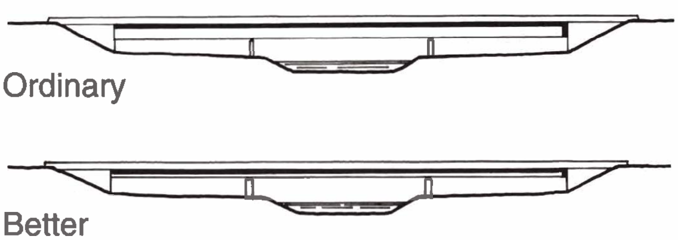


Fig. 4-14. Slender structure on proportionate piers provides a better appearance than a deep structure on slight piers

4.2.3 Superstructure Presentation

The appearance of a bridge is greatly influenced by the continuous horizontal lines that span between the substructure units. These horizontal lines are commonly composed of a collection of elements: the railing, deck fascia, deck overhang, and fascia girder. Each of these elements can affect the appearance of the bridge as a whole and the appearance of the other elements. But collectively, they define the most prominent visual aspect of the bridge, the superstructure presentation. The *superstructure presentation* determines the visual slenderness of the superstructure, which is a distinct determinant of appearance.

A primary aesthetic design objective should be to minimize the slenderness of the superstructure presentation. This can be accomplished by minimizing the structure depth and height of the railing. However, the designer often has little, if any, control over the railing height, and structural concerns place limits on the structure depth. Other visual techniques can be used to reduce the apparent slenderness of the superstructure presentation. These techniques include using color to attract or detract attention, emphasizing horizontal lines, and contrasting the intensity of light on bridge elements.

The shadow cast on the fascia girder by the deck overhang diminishes the prominence of the fascia girder by visually concealing it. When the visually diminished fascia girder is contrasted with the highlighted surfaces of the railing and deck fascia, the railing and deck fascia stand out by comparison. This effectively reduces the apparent slenderness by focusing the visual attention on a relatively slender element, the rail and deck fascia.

Fig. 4-15. Deck overhang creates strong shadow on fascia beam, fascia beam colored darker than abutments and rail, Victoria over I-694, Shoreview, Minnesota

The distance the deck overhangs the fascia girder will directly effect the amount of light reaching the fascia girder. For girder bridges, the deck overhang should be proportional (within structural limitations) to the girder depth. From an aesthetic standpoint, the deck overhang should be about 2/3 the girder depth. This magnitude of overhang will produce a strong shadow or completely shade the fascia girder.

Fig. 4-16. Haunched beam contrasts with straight rail, resting on visually prominent abutments, Hwy. 10, Little Falls, Minnesota

The surface of the railing, deck fascia, and girder fascia can be inclined toward the sky to capture and reflect sunlight. This will attract the visual attention to the element. Conversely, elements can be inclined toward the ground to escape and diffuse light, thus diminishing the appearance of the element. Designers may use these techniques to emphasize the relatively thin railing and deck fascia with bright reflective light and downplay the massive structural members with diffused light.

Considerations for controlling light include the following.

- Provide a substantial deck overhang to maximize the shadow cast on the fascia girder.

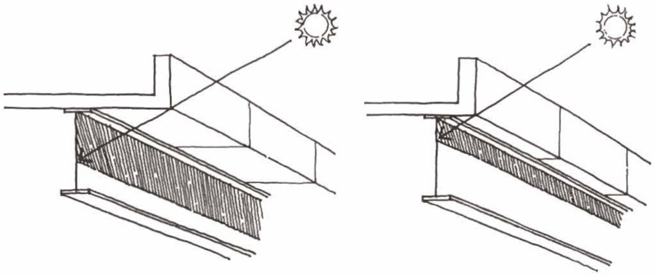


Fig. 4-17. Overhangs proportional to fascia depth creates a strong shadow line

- Vary the relative brightness of the surfaces by changing their inclination to catch more, less, or no light at all.

Emphasizing the horizontal lines of the fascia girder, railing, and deck fascia will further enhance the apparent slenderness of the superstructure presentation. This can be accomplished with rustication and shape. Using darker colors on the fascia girder than on the railing will reduce the slenderness of the superstructure presentation. Vertical stiffeners on the outside of the fascia girder disrupt the flow of the lines between substructure units, making the girder appear heavier than it is.

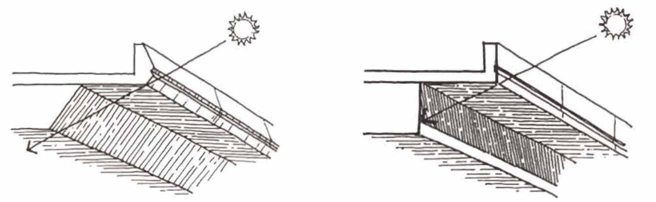


Fig. 4-18. Surface inclination effects perceived depth

Considerations for the structure presentation should include the following.

- Use horizontal rustication of fascia surfaces to promote the horizontal lines.
- Use a darker color on the fascia girder than on the railing. The darker color will tend to make the fascia girder less dominant than its brighter counterpart.
- Add horizontal offsets, bevels, or grooves in unequal proportions to make the railing appear longer and lower.
- Space vertical divisions in the railing at least three times the railing depth when selecting patterns for the railing face.
- Avoid the use of substantial vertical rustication on railings, as they diminish the horizontal lines. Shallow vertical rustication will appear as a texture and will not detract from the horizontal lines.

- Avoid the use of vertical stiffeners on the outside of fascia girders except at bearing points where the stiffener confirms the viewers' sense of an appropriate structural supporting point.

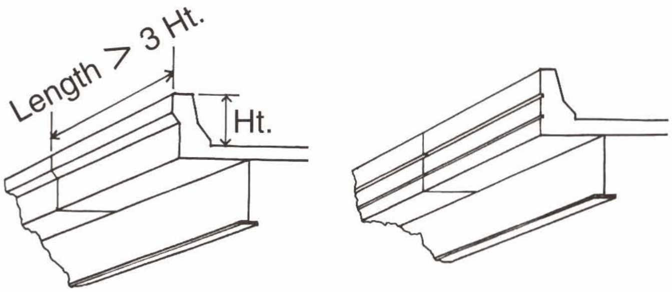


Fig. 4-19. Emphasize horizontal lines of railing

Additional aspects of the railing details, utilities, and bridge related components affect the superstructure presentation. These aspects are addressed in Section Six.

4.2.4 Haunched Girders

Constant-depth girders are those girders having top and bottom flanges that are parallel. Typically the flanges run parallel to the deck profile. Reduced fabrication costs make this girder type desirable for the majority of bridges in Minnesota. They are, in fact, the most common type of steel girders used. An alternative to constant-depth girders are haunched girders. Haunched girders are not economically competitive until the span lengths reach 60 meters or more. Generally, designers should avoid using haunched girders unless a Level A bridge is being considered.

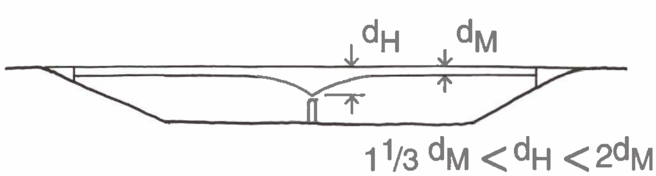


Fig. 4-20. Haunch depth

Haunching the girder at the piers will produce a slender structure. The haunches make the bridge seem thinner by reducing the average depth while maintaining the length. In addition, they visually demonstrate the flow of forces in the bridge. Haunching is attractive for multi-span structures with a large main span and for long three-span river crossings where the haunch occurs only at the main span.

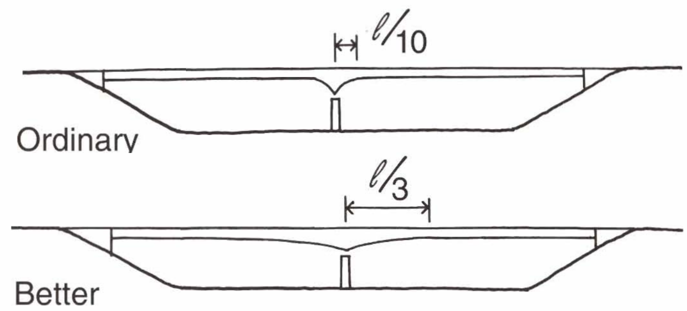


Fig. 4-21. Haunch length

Considerations for haunched girders should include the following.

- Provide parabolic haunches rather than circular or linear haunches.
- Avoid the use of haunches on tall piers when the openings are predominantly vertical.
- Provide a substantial pier beneath the haunches. This element should provide a corresponding strong visual support for the concentrated loads at that point.
- Haunches should be proportional to the span length. Use 1/3 the span as a guide for the length of one side of the haunch.
- Limit the depth of haunches to twice the mid-span depth.
- Limit the angle subtended by the haunch to between 135 and 160 degrees; otherwise the bearing point will look too delicate to support the girder.

4.3 BOX GIRDER BRIDGES

Box girder bridges are inherently elegant because of their simplicity and structural efficiency. The form and shape of box girder bridges present clean structure lines, whether viewed in elevation or from an oblique vantage point. The clean girder fascia and bottom soffit also promote a streamlined appearance. The solid bottom soffit can provide excellent reflective properties that tend to naturally illuminate the area beneath the structure. The natural lighting increases the comfort level of those passing beneath the bridge, pedestrians in particular. Most box girder structures are also readily adaptable to accommodate horizontal curves without variable overhangs that produce scalloped shadows. This bridge type also provides a convenient method of concealing utilities that can otherwise detract from a pleasing appearance.

The structural efficiency of box girders allows relatively shallow structure depths that contribute to their graceful and light appearance. This graceful appearance is further enhanced by the structure's torsional capacity of the closed section. The torsional capacity affords flexibility in pier location and the use of slender, single-column piers without benefit of pier caps or hammerheads. The form of the girder fascia can easily be integrated into the pier design to promote continuity.

Box girder webs and bottom flanges are commonly constructed of either steel or concrete. Both material types can achieve considerable span lengths with a corresponding increase in structure depth. This structure type can economically span from 25 to 245 meters. Constant-depth structures often use span lengths up to 90 meters. Beyond this point, variable-depth structures begin to be more economical. Constant-depth precast, prestressed concrete trapezoidal box girders can be used for span lengths of 35 to 50 meters.

Like deck girder bridges, the structure presentation of box girder bridges is dependent on the railing, deck fascia, girder fascia, and deck overhang and has a pronounced impact on the appearance of the bridge. However, box girder bridges offer the designer the option of inclining or slanting the girder fascia to reduce its visual preeminence. The girder fascia can be slanted slightly to simply downplay its appearance or slanted more radically to diminish its appearance even more. The optimum enhancement is achieved when the girder fascia is slanted to the extent that the shadow from the deck overhang completely covers the girder fascia.

Fig. 4-22. Steel box girder provides graceful, slender presentation, Rochester, Minnesota

While box girder bridges offer many advantages over deck girder bridges, this structure type should not be proposed without recognition of its construction and maintenance limitations. Because the deck is typically an integral structural element, its replacement or resurfacing may present difficulties. Box girder structures are also inherently difficult to inspect, and the closed cells are considered a "confined space" under OSHA regulations.

Considerations for box girder structures should include the following.

- Slant the girder fascia to reduce the apparent slenderness of the structure.
- Integrate the pier shape with the form and shape of the superstructure.
- Consider removing the divisions between fascia surfaces by introducing curvature, leaving the viewer no clues by which to judge the depth of the structure.

4.4 RIGID-FRAME BRIDGES

Rigid steel frames are occasionally used as highway structures with either vertical or inclined legs. Visually, this structure type has the positive values of simplicity and continuity. This structure type looks best when the transverse width is limited to less than half the main span length and the design allows spans and legs to taper from their junctures toward lighter stress points at footings, abutments, and main span centers. Consideration for rigid frame structures should include the following.

- Use rigid frames where there are strong land forms at the ends to contain the visual thrusts.

  Slant the legs enough to maximize their length and develop the visual illusion of additional bridge length.

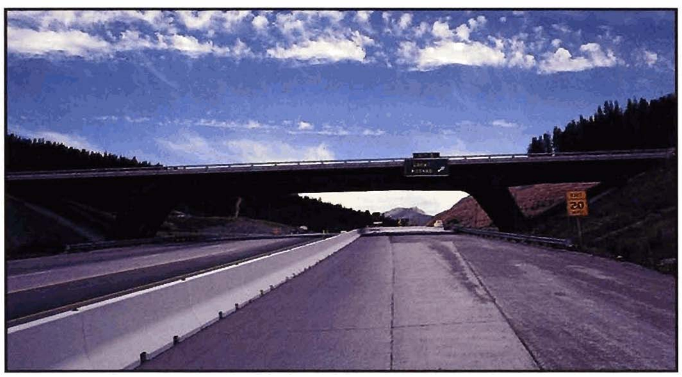


Fig. 4-23. Steel rigid frame clearly exhibits structural function, Idaho

4.5 ARCH BRIDGES

The arch is the most natural of all bridge forms and is generally considered one of the most aesthetically pleasing bridge types. Its shape clearly expresses its ability to carry loads across a river, valley, or gorge. Historically arches were constructed of masonry. Presently, the arch has been adapted to suit current technology and is a viable structural type with spans of up to 525 meters. The true arch is parabolic in shape and carries predominantly compressive axial forces. This type of arch can be constructed of either concrete or steel. Compared to masonry arches, concrete and steel arches are relatively flat arcs that can be pleasing and exciting in appearance. Considerations for arch bridges should include the following.

- The arch should be stronger (thicker) than the deck and the supporting walls or spandrel piers.
- Deck supports should be uniform in size and shape and continue the same column spacing over the entire length of the bridge.
- Consider arches where strong land forms contain the visual thrust of the arch, as in valley or highway cuts.
- Minimize sway bracing and floor system members. Develop a simple arrangement for these elements to promote a clear and consistent relationship to the main members.
- Provide continuity with approach structures. For example, use arch floor system stringers the same depth as the approach girders.
- Allow an open spandrel between the deck and the crown of arch on steep arches with spandrel columns.
- Merge the deck and the crown of arch on shallow arches with spandrel columns. The thickness of the arch should remain visible with a slight protrusion of the arch at the crown.
- Hold the number of spandrel columns to a maximum of 3 in the transverse direction.

A series of shallow arches can be attractive at a low level, especially over water. At high levels they become monotonous.

When the soil in flat country is unable to resist the high thrust forces of the arch, the bridge can be converted to a tied arch. The tied arch can be supported at the abutment similar to a girder, without the need for lateral restraint. The best appearance occurs when the arches are designed to carry all loads and bending moments and when the deck is as slender as possible to emphasize the character of the deck suspension.

A steel deck-stiffened arch, in which the deck beams are as large or larger than the arch, produces a clumsy appearance. The relatively thick horizontal tie member dominates the appearance, leaving the arches appearing too small to do their intended function.

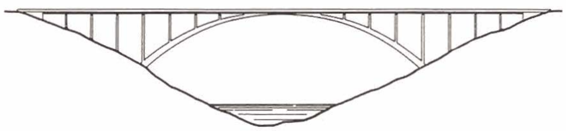


Fig. 4-24. The arch and deck should merge on shallow structures

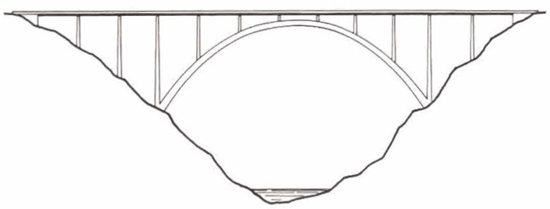


Fig. 4-25. Steep arch bridges should maintain separate arch and deck elements

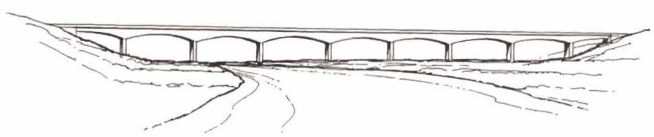


Fig. 4-26. Ordinary, piers conflict with rhythm of arches

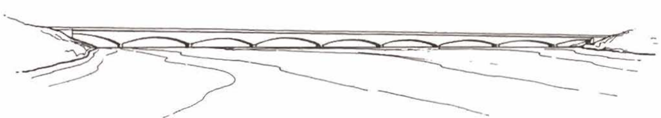


Fig. 4-27. Better, low-level arch produces pleasing appearance

In most steel through-arch bridges, the arch ribs must be stabilized in the lateral direction above the roadway. Cross bracing is used to provide this lateral support. This cross bracing can be multi-angled, medium size, X or K bracing; or heavy vierendeel struts. The designer should study the appearance from significant viewpoints to determine the type of bracing to use.

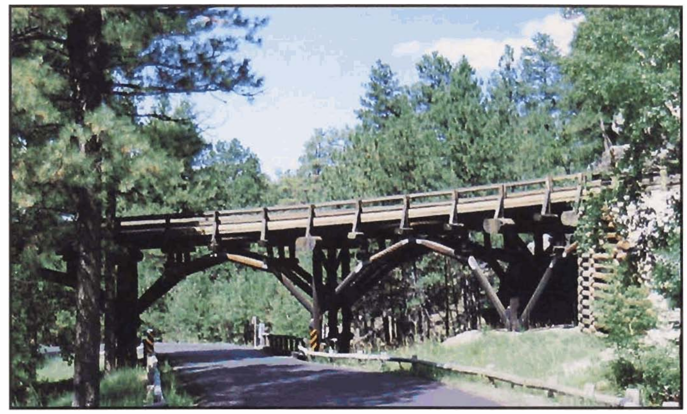


Fig. 4-28. Timber arches provide natural structure type in rustic setting, Pig Tail Bridge, Black Hills, South Dakota

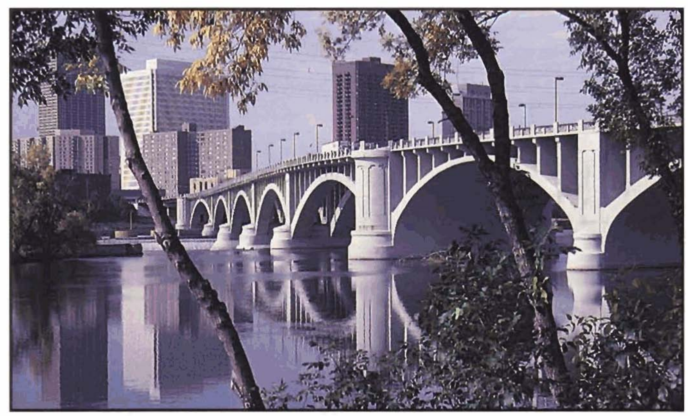


Fig. 4-29. Arches and piers form the strongest visual element, repetitive arches demonstrate a pleasing rhythm, 3rd Avenue, Minneapolis, Minnesota

Fig. 5-1. Robert St. Bridge, St. Paul, Minnesota

"Dominating the landscape, a bridge may make or mar its surroundings for centuries to come. Consequently a striving after beauty of form and harmony with surroundings is a social obligation which structural engineers must recognize and educate themselves to perform."

C. E. Ingilis

5.0 INTRODUCTION

The substructure provides the visual, as well as literal, base for the bridge. Visually, the substructure moderates the suspended superstructure and the earth foundation. The visual appeal of bridge forms is greatly influenced by the substructure units. This is primarily due to their size and prominence. The placement and size of the substructure units will inspire the viewers' perception of scale and proportion, along with order and balance. The shape of the substructure units will effect the viewers' perception of line and mass. The surface treatment of the units will impact the continuity of the structure. Collectively, the substructure units will influence the visual appeal of the structure as much as any other aspect of the bridge.

This section addresses the aesthetic considerations associated with substructure design. Although the section attempts to isolate the treatment of the substructure, designers should remember that all aspects of the structure must be considered in relation to the whole bridge, and the whole bridge in relation to its site location. Because the majority of bridges in Minnesota fall within the band of span lengths where girder bridges are predominant, the majority of this section deals with substructure units for girder bridges.

5.1 PIERS

The term *pier* is used to refer to the collective system of columns (or shafts) and pier caps that support the superstructure at a single location. The appearance of piers is primarily influenced by their proportion: their width relative to their height and the configuration of the pier cap with the pier column. Tall piers benefit from simplicity, fewer lines, and slender proportions. Traditional short piers are more difficult to design from an aesthetic standpoint because the pier cap is often large and visually clumsy in relation to the total pier.

Generally, piers should not be the visual focal point of a bridge composition. The main visual emphasis of the visual formation should remain on the horizontal lines of the superstructure. Piers that appear larger than necessary to support the superstructure look disproportionate and are undesirable because attention is directed away from the superstructure. Piers are required to support the superstructure and should appear to be of sufficient size to perform their function, i.e., they should be proportional to their structural task. Piers that appear too slender impart a precarious feeling of instability. As such, a lower limit of 760 mm should be used for the width of piers. For these reasons, piers directly effect the visual balance of a bridge.

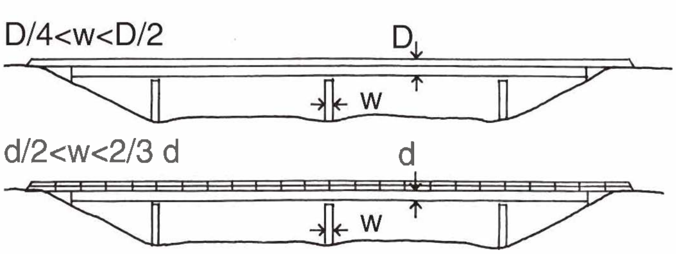


Fig. 5-2. Pier proportions

5.1.1 Pier Families

Multi-span bridges often have piers of widely varying heights. Bridges over rivers, large bodies of water, and deep valley cuts are examples. The designer's challenge is to create a family of pier designs that look good individually and as a group. The designer should select a basic pier shape, or type, and vary its proportions through the different heights. An even greater challenge is to design piers when the bridge widens or branches.

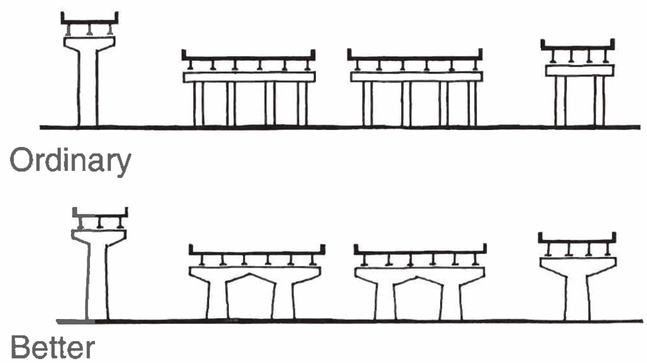


Fig. 5-3. Family of piers that vary by width

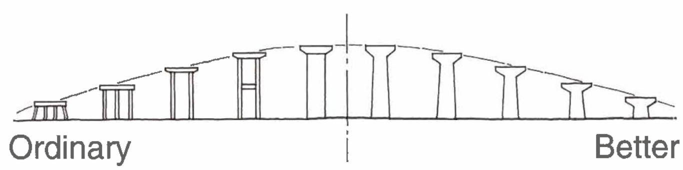


Fig. 5-4. Family of piers that vary by height

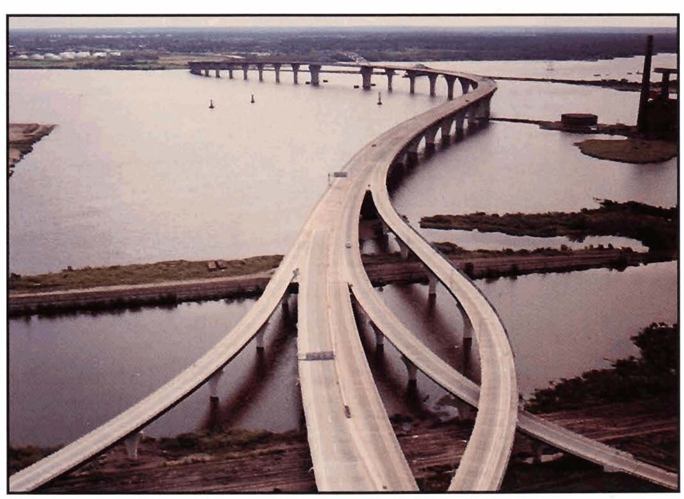


Fig. 5-5. Family of piers that vary by height, Bong Bridge, Duluth, Minnesota

Fig. 5-6. Family of piers that vary by height, Kilebrew Drive, Bloomington, Minnesota

5.1.2 Short Piers

Short piers are considered to be those piers with lengths (B) that exceed their height (t). The majority of piers that designers deal with are short piers. This type of pier is common on grade separation crossings and shallow stream crossings. Short piers can be constructed in several shapes: hammerhead piers, V-shaped piers, Y-shaped piers, and the traditional multi-column bents.

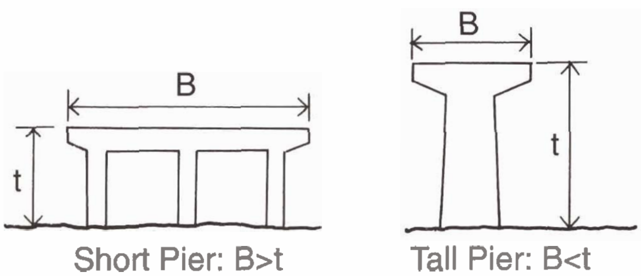
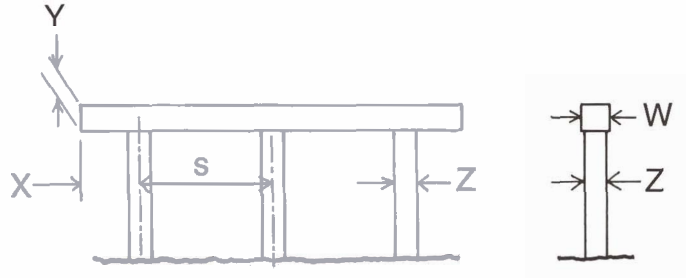


Fig. 5-7. Short and tall piers defined

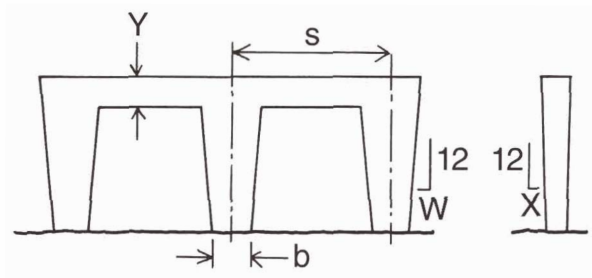
A design issue that is common among all types of short piers involves the geometrics of the columns, shafts, and pier caps that are used to construct the pier. The geometry of these individual elements should be selected from the same shape family: circular, rectangular, etc. As such, this guideline suggests that rounded pier cap ends and circular columns would appear more visually correct than square pier cap ends and circular columns. Ideally, a consistent shape will be carried to the abutments, railings and other elements of the bridge.

- Use a single shape family for all elements of the piers. This family shape should be used on the abutments.



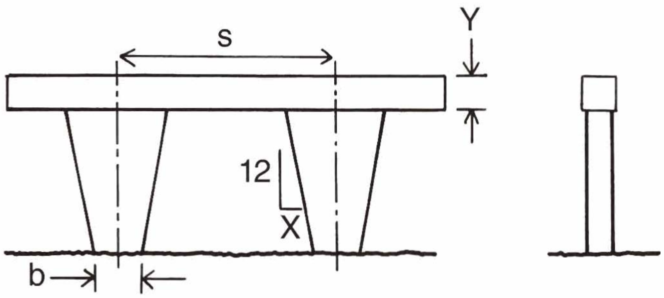
Y: Minimize (> 760 mm)
X: 1 3/4 Y min. to 4/10 S max.
Z: Minimize (> 760 mm)
W: Minimize (> Z + 150 mm)
s: Maximize (< 6000 mm)

Fig. 5-8. Multi-column bent with cantilevered pier cap guidelines



b: 750 mm to 1600 mm
Y: 750 mm to 3/4 b (proportional to D)
X: 0 to 3/4
W: 0 to 2
s: 3900 mm to 6000 mm

Fig. 5-9. Multi-column bent with integrated pier cap guidelines



b: 1300 mm to 1900 mm
Y: 1/2 b to 3/4 b (proportional to D)
X: 2 1/2 to 3 1/2
s: 4800 mm to 6700 mm

Fig. 5-10. V-shaped columns with cantilevered pier cap guidelines

5.1.2.1 Pier Columns

The width of columns perceived by the viewer is normally controlled by light reflecting from the column surfaces and edges. A square or rectangular column with strongly beveled edges will appear more slender than a circular column due to the edge lines and varying shades of reflective light. An octagonal column will appear even slimmer because of the greater number of surfaces. The viewer sees the surface area broken up by several planes. The designer can use this principle of light reflection to slim down a massive column or increase the apparent size of a column to offset a massive superstructure.

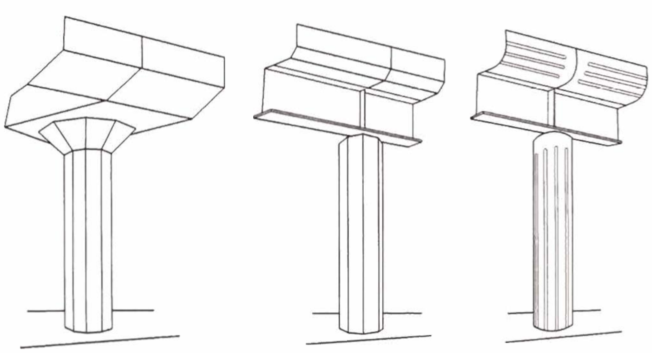


Fig. 5-11. Beveled edges and surface treatment make columns appear thinner

Columns do not always have to be vertical shafts. They can be shaped to achieve a desired visual effect. Square and round columns are easy to form, but they lack imagination. The use of V-, X-, or Y-shapes can add variety and interest, particularly when combined with flat superstructures.

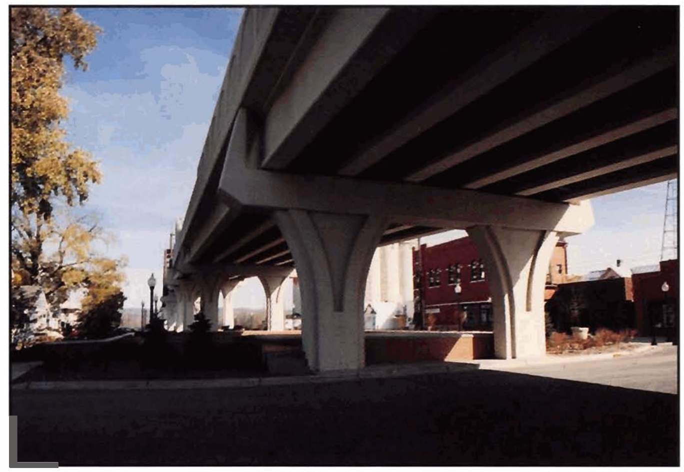


Fig. 5-12. Geometry of pier shafts vary to provide interest and reduce the apparent mass, Wabasha, Minnesota

The capitals of standard architectural columns can be curved, arched, or flared to visually integrate the column with the superstructure. This treatment is most compatible when used with the sloped fascia of a box girder. Following the lines of the superstructure into the connecting shapes of the piers will produce a smooth visual effect of continuity.

5.1.2.2 Pier Caps

Contemporary pier caps, which sit on top of the columns, were born of utilitarian function and are probably a holdover from trestle construction. Their function is to distribute the loads of the narrowly spaced girders among the wider-spaced columns. When viewed from beneath the bridge, normal to the pier, this makes perfect sense. However, when viewed from a position approaching the bridge, the function of pier caps becomes less obvious and the observer is left with a subtle question regarding the purpose of the pier cap. The pier cap is clearly separate and distinct from the horizontal lines of the superstructure. But it does not quite relate to the predominantly vertical lines of the columns. The result of this element, when viewed from a position approaching the bridge, is visual confusion and disruption of the horizontal flow of the superstructure. The more dissimilar the shape of the pier cap to other elements of the bridge, the more of a distraction it becomes.

The end of a pier cap further aggravates the visual disorder. Pier cap ends are often relatively large, flat surfaces extended to the same plane as the deck fascia. As the ends of the pier cap protrude from beneath the structure, they typically reflect the full intensity of whatever light is available, thereby creating a visual hot spot in the composition. The eye is immediately drawn to this distraction – to the detriment of the horizontal flow of the structure.

Designers should attempt to diminish the prominence of the pier cap and the pier cap ends. The most effective methods of diminishing the visual impact of the pier cap are to eliminate the pier cap entirely, or eliminate the cantilevered ends of the pier cap.

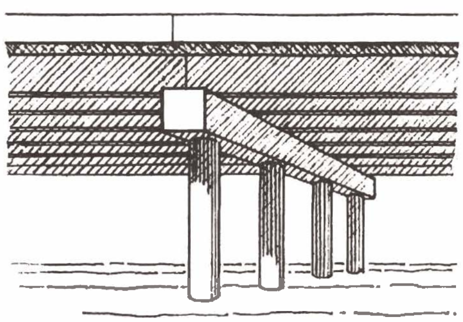


Fig. 5-13. Pier cap end creates disturbing visual hot spot

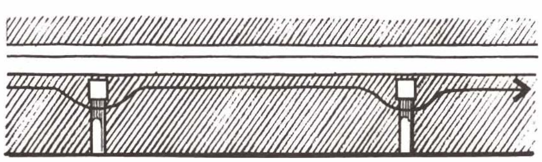


Fig. 5-14. Prominence of the pier cap end surface disrupts flow of horizontal lines

Pier caps can be eliminated or minimized by:

- Use of inverted T-shaped pier caps
- Eliminating the cantilevered portion of the pier cap
- Incorporation of the pier cap into the superstructure (integral pier cap)
- Incorporation of the pier cap into the columns (integrated pier cap)

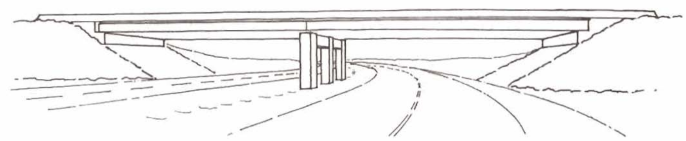


Fig. 5-15. Pier cap integrated with columns minimizes visual disruption

Fig. 5-16. Integrated pier cap used on Jackson St. Bridge, St. Paul, Minnesota

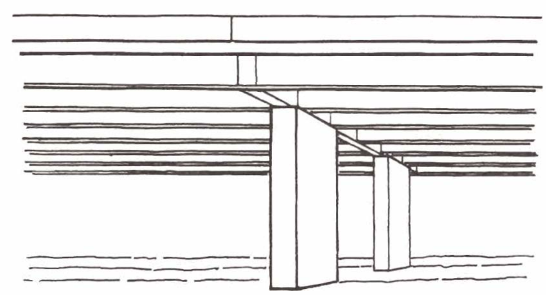


Fig. 5-17. Integral pier cap eliminates visual disruption

The end of the pier cap can be minimized by:

Reducing its mass and reflective surface

- Beveling or tapering the surfaces of the pier cap end
- Minimizing the height of the pier cap

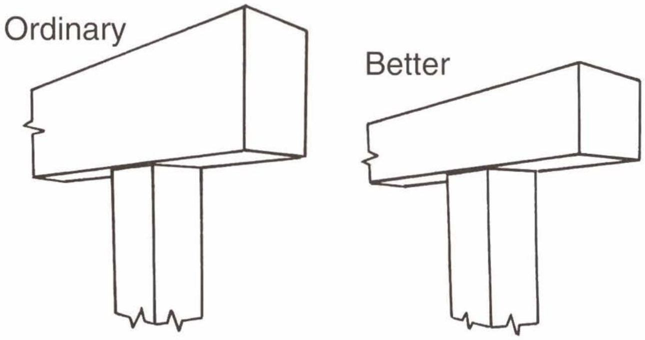


Fig. 5-18. Reducing pier cap height diminishes visual hot spot

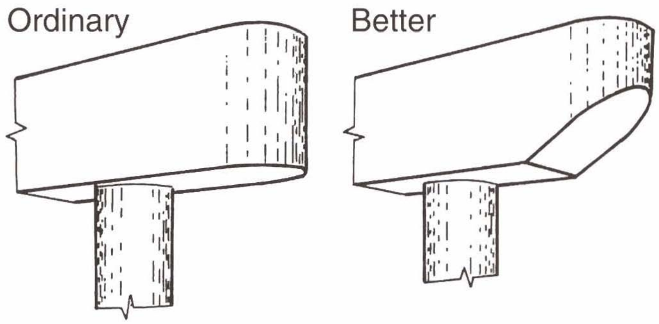
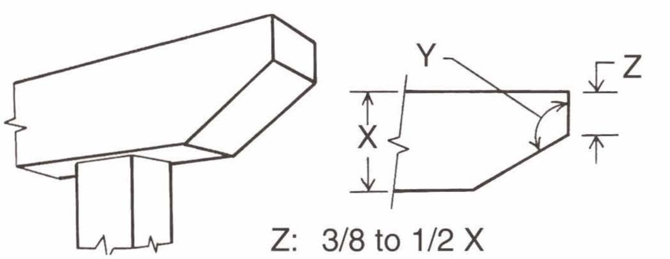
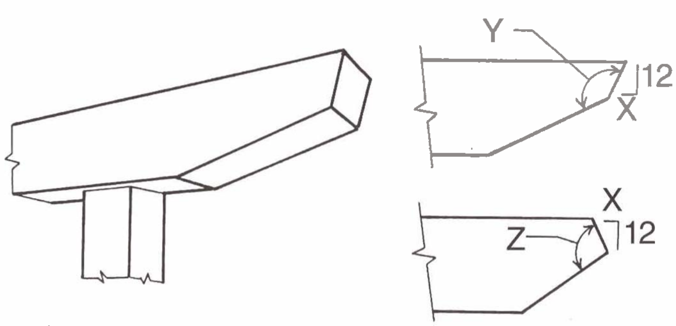


Fig. 5-19. Rounding the pier cap end reduces its prominence



Z: 3/8 to 1/2 X
Y: 120° to 130°

Fig. 5-20. Beveled pier cap end guidelines



X: 3 to 5
Y: Approximately 120°
Z: Approximately 90°

Fig. 5-21. Double beveled pier cap end guidelines

Pier caps supporting bridges with superelevation should follow the cross-slope of the deck at the point of support. Under these conditions, designers should use a constant height of the pier cap end on both sides of the bridge. If a beveled pier cap end is used, the angle of the bevel may need to be referenced to the slope of the bridge deck for proper appearance.

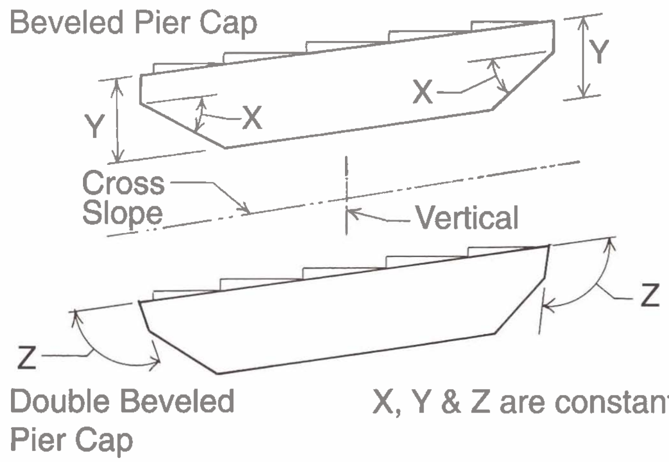


Fig. 5-22. Superelevated pier cap guidelines

Pilasters and closure walls are sometimes used on pier caps to hide bearings. Similar to the ends of pier caps, these elements visually interrupt the horizontal flow of the superstructure lines, breaking it up into individual segments. The effect of this is to make the structure appear thicker. Designers should avoid the use of closure walls on pier caps.

Avoid the use of closure walls on pier caps

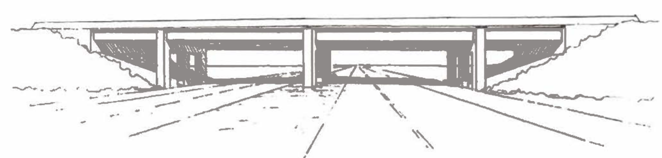


Fig. 5-23. Pilasters break up the horizontal flow.

5.1.2.3 V-shaped Piers

Columns and pier caps can be eliminated entirely by using a wall that is narrower at the base than at the top. This type of pier is referred to as a V-shaped pier. While V-shaped piers eliminate the pier cap, they create other visual problems. The solid wall can appear disorderly if several are used, and they may effectively block the observers' sight when viewed at an oblique angle. Considerations for V-shaped piers should include the following.

- Emphasize visual stability. V-shaped piers that are too narrow at the base will look unstable.
- Make base lengths at least 2/3 the pier length.

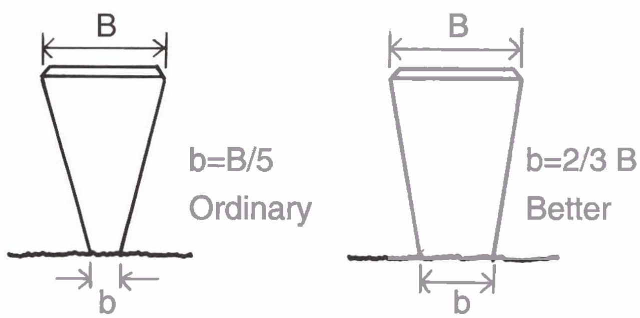


Fig. 5-24. Base length versus pier length

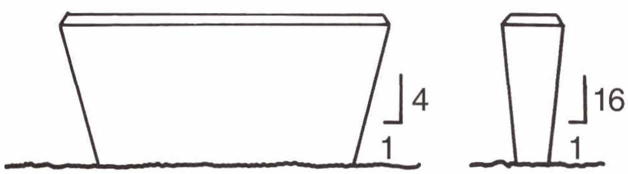


Fig. 5-25. Suggested batter of V-shaped piers

Fig. 5-26. V-shaped piers

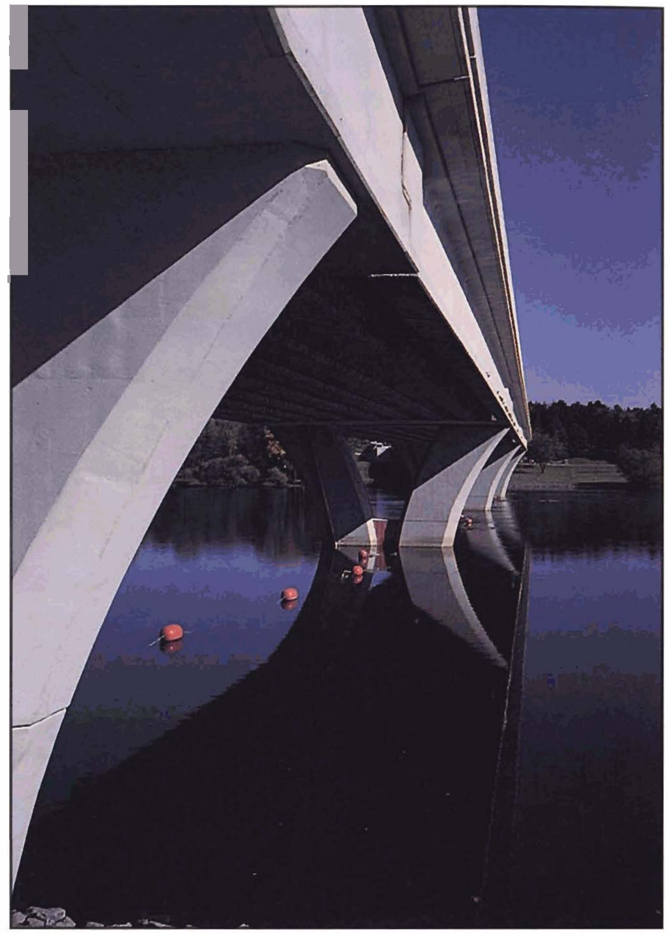


Fig. 5-27. V-shaped piers, University Bridge, St. Cloud, Minnesota

5.1.2.4 Hammerhead or T-piers

The appearance of hammerhead (or T-piers) is sensitive to its relative proportions. The design intention should be to provide a visual element with enough mass to balance the total visual composition while maintaining a slender shaft and harmonious proportions between the shaft and arms and between the pier and superstructure. Designers should examine hammerhead designs for long, cantilevered arms that make the pier look top heavy. Conversely, short arms on a wide pier will tend to look fragile. Considerations for hammerhead piers should include the following.

Hammerhead piers in a series should be consistent in appearance, e.g., same size, shape, proportions, details.

- Hammerhead pier shafts should not be shorter than the cap-beam depth plus 2 meters. When this height is not available, the designer should consider transition to a wall pier.
- Short hammerhead piers may use either vertical or battered sides, depending on the desired aesthetic effect.
- Tall hammerhead pier designs should attempt to use a common batter for all piers.

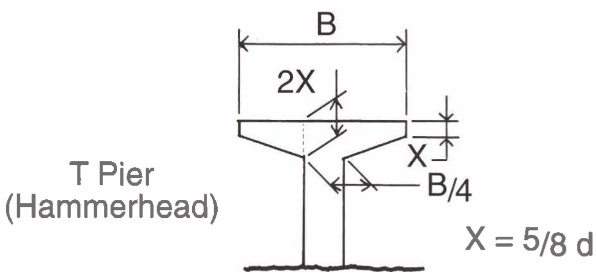


Fig. 5-28. Hammerhead pier proportion guidelines

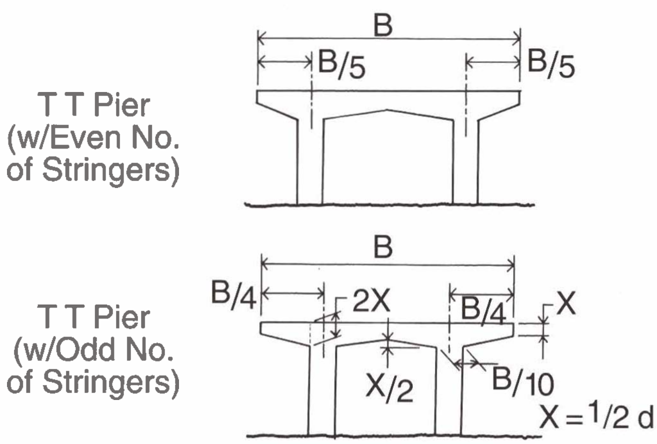


Fig. 5-29. Double hammerhead pier proportion guidelines

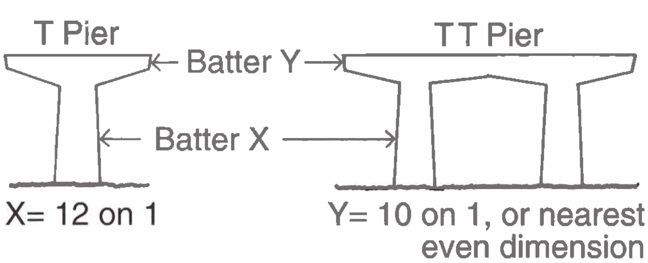


Fig. 5-30. Battered hammerhead guidelines

5.1.3 Tall Piers

Tall piers are those piers whose height (t) exceeds their length (B). Tall piers are easier to design than short piers because the structure and aesthetics work toward the same goals: proportion and simplification. The taller a pier is, the more it lends itself to single-shaft elements. Straight pier shafts are appropriate for most any height of a tall pier. When pier heights (t) begin to approach the span length (l), tapering the shaft can maintain the structural capacity required at the base and preserve the slenderness of the pier. Tapers of 1:24 to 1:40 work well in most situations, with lesser tapers used for taller piers. Consideration for tall piers should include the following.

- Accentuate the vertical aspects of the pier.
- Consider tapering exceedingly tall shafts.
- Simplify and consolidate line segments.
- Integrate the pier cap to the shaft or to the superstructure.
- Use simple vertical shapes, emphasizing the vertical members and de-emphasizing the horizontal members.

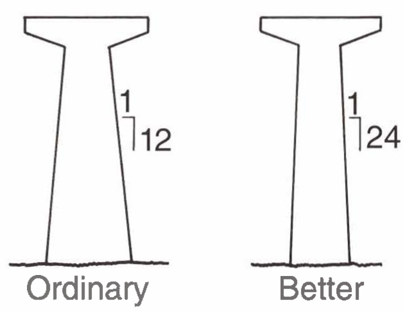


Fig. 5-31. Tapering tall piers

5.2 ABUTMENTS

Visually, abutments define the start and end of a bridge. The viewer perceives the bridge to initiate at the first sign of exposed concrete and terminate at its counterpart on the opposite end. Depending on the setting of the structure and aesthetic design, the abutments can serve as a definitive point of origin and conclusion of the structure, or as more subdued points on which the superstructure simply rests.

The shorter the bridge, the more influence the abutment plays in the creation of the overall visual image. As such, the proportions of the abutment are crucial to the mass, scale, and proportion of short to medium-span bridges. The aesthetic objective for these bridges is to provide good proportion between the mass of the abutment and superstructure and to provide balance in the structure.

On larger and longer multiple-span structures, abutments have less impact because they are a smaller part of the overall structure. For these structures, the main goal is to provide an appropriate support for the end span and an attractive ending for the railing.

Designers have many aesthetic considerations to contemplate when designing an abutment. Included in these considerations are using mask walls or exposing the bearing assemblies, providing texture on the wing walls or leaving them as board-form concrete, varying the height of the abutment, and incorporating a common geometric shape into the element. All of these choices will affect the overall appearance of the bridge. Care should be exercised to ensure consistent shapes and details with other parts of the structure. Shapes and surface treatments should be kept simple.

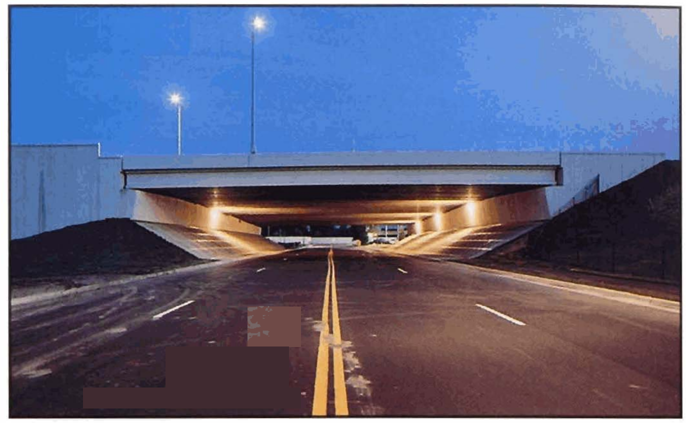


Fig. 5-32. Battered abutment face without mask wall, General Mills Boulevard over I-394, Minneapolis, Minnesota

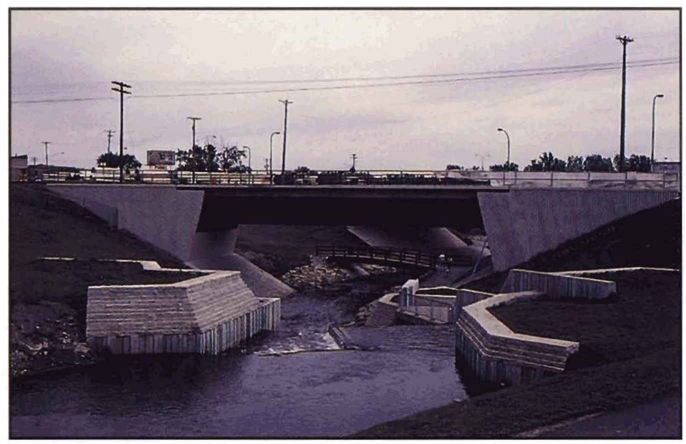


Fig. 5-33. Battered abutment face with mask walls, Soo Line over Shingle Creek, Minneapolis, Minnesota

5.2.1 Abutment Face

The face of the abutment can be battered inward or outward or can be placed in a vertical plane. A vertical face reinforces the vertical lines of the piers. This option produces an appearance that is formal and static. This static appearance is characteristic of classical architectural themes and should be used when that category of aesthetic design is the goal. Battering the face produces a more dynamic effect. When battered inward, the abutments contribute to the flow of horizontal lines from abutment to abutment. In this instance, the abutment and superstructure appear to work toward a common functional goal. Alternatively, the front face of the abutment can be battered outward. In this instance, the predominant abutment lines contrast with the horizontal lines to produce a dynamic composition with visual interest. Battering the ends of the railing reinforces the visual effects of the abutments. Also, extending the railing past the point of slope intersection makes the abutments appear to flow from the earth. Considerations for battering the face of an abutment should include the following.

> Consider battering the front face of the abutment if the overall visual design theme is dynamic.

Consider using a vertical front face of the abutment if the overall visual design intention is formal.

- Battering the front face of stub abutments and semi-deep abutments is appropriate, depending on the visual intention of the design.

  Generally, battering the front face of deep abutments creates a visual impression of instability and should be avoided.

Fig. 5-34. Abutment face battered outward

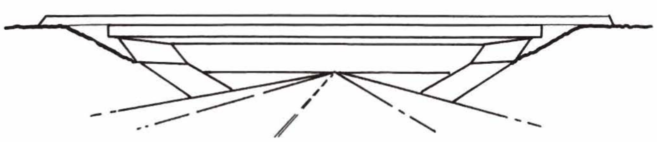


Fig. 5-35. Predominant abutment lines contrast horizontal flow

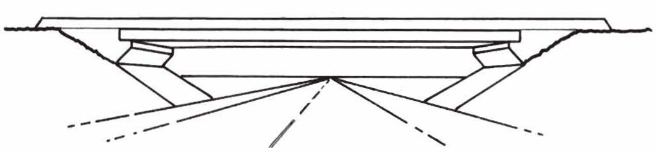


Fig. 5-36. Predominant abutment lines complement horizontal flow

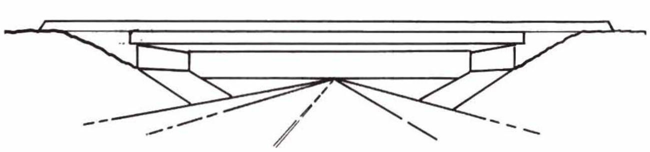


Fig. 5-37. Vertical abutment face presents a static visual image

5.2.2 Mask Walls

The designer has the option of exposing the bearing assemblies or concealing them behind a mask wall (curtain wall). Full view of the bearing assemblies exposes details that attract the eye, thus distracting from the overall visual theme of the bridge. Concealing the bearings with a mask wall hides the function of the abutment, as the viewer searches for visual confirmation that the superstructure is resting on the abutment.

Mask walls also influence the viewer's perception of the abutment's importance in the total composition and height. When mask walls are used in combination with a battered abutment face, they reinforce the dynamic lines of the abutment. Mask walls also simplify the overall appearance of the bridge. The use of mask walls will increase the visual mass of the abutment and increase its apparent height.

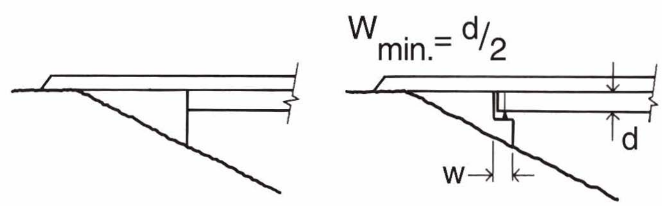


Fig. 5-38. Mask wall/exposed-beam seats

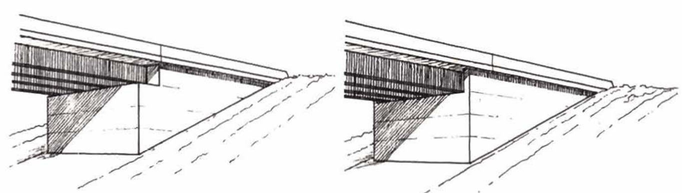


Fig. 5-39. Alternate abutment methods present simple and formal images

The intersection of the mask wall with the bridge seat creates an opportunity for a crack to develop because of the pronounced change in mass of concrete. This interface often cracks along the edge of the bridge seat leaving an unsightly blemish on the outside of the mask wall. Consider use of rustication at the construction joint between the mask wall and the bridge seat to hide the potential crack. Otherwise, require the mask wall to be poured monolithic with the bridge seat, using a substantial fillet on the inboard side of the mask wall, and placing additional reinforcement through the plane of the potential crack.

Mask walls should extend from the top of the bridge seat to the bottom of the deck. Insufficient detailing of the top of the mask wall may result in an uneven, or excessive, void between the top of the mask wall and the bottom of the deck.

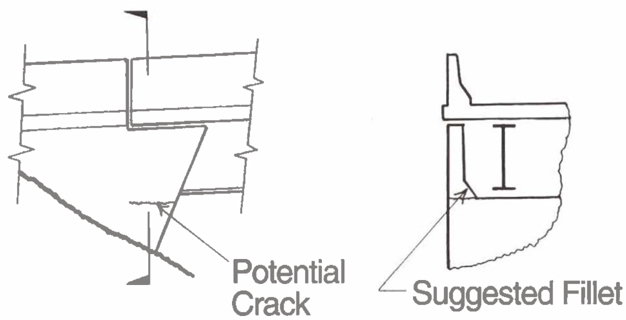


Fig. 5-40. Mask wall details

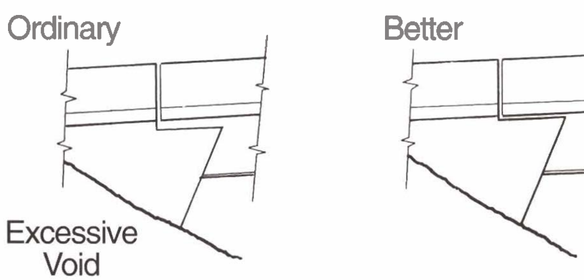


Fig. 5-41. Mask wall detailing

Considerations for use of mask walls should include the following.

- Fundamental to the use of mask walls is the visual balance of the structure. Consider the use of mask walls if the bearing assemblies create a visual distraction from the balance of the composition.
- The use of mask walls is recommended when the face of the abutment is battered.
- Consider the apparent increase in mass, scale, and proportion of the abutment when using mask walls.
- Align the face of the mask wall with the face of the wing wall.
- Provide top of the mask wall elevations. Consider a fillet and abundant reinforcement at the intersection of the mask wall to the bridge seat. Consider the effect of a construction joint at this interface.

5.2.3 Abutment Walls

Abutment wing walls generally look best when aligned with the upper roadway. This provides a logical place to tie in fencing and guard rails, and it makes the bridge appear longer. Occasionally, when structures are on an extreme skew, they will require long wing walls. In this instance, another option is to bisect the angle between the upper and lower roadways, shortening the wall.

Retaining walls are often aligned parallel to adjacent abutments. Under these conditions, the abutment should be treated as a continuation of the retaining walls, avoiding any abrupt changes. Surface treatment of the abutment face should be consistent with the adjacent retaining wall surface treatment.

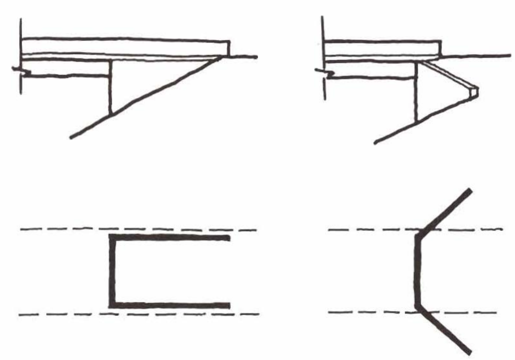


Fig. 5-42. Parallel and angled wing walls

Considerations for wing walls should include the following.

- Plan the layout of the abutments and any adjoining walls to promote continuity.
- Provide a logical point to tie in guard rails and right-of-way fences.

- Aesthetic design objectives should address and coordinate expansion, contraction, and construction joints.
- Emphasize continuity from the superstructure to the abutments through textures, overhangs, or fascia projections.
- Use wall treatments that are consistent with other elements of the bridge and adjacent structures.

5.2.4 Abutment Families

Most abutments fall into one of three categories: stub abutments, semi-deep abutments and deep abutments. The stub abutment is the shortest and commands the least attention. It is commonly constructed of a simple pile cap and parapet wall. Deep abutments are decidedly higher than stub abutments and are usually constructed of a massive vertical cantilevered wall. The semi-deep abutment can be regarded as a transition between the stub abutment and the deep abutment. Each type has its own appropriate function as well as visual bias. Within the limitation of the structure layout, the designer can choose between abutment types to achieve different visual outcomes.

5.2.4.1 Stub Abutments

Stub abutments are the most economical abutment type and should be used unless there are overriding aesthetic or structure layout conditions. They work well with small multi-span bridges that have shallow superstructure depths because their limited mass defers visual attention from the abutment to the horizontal lines of the superstructure.

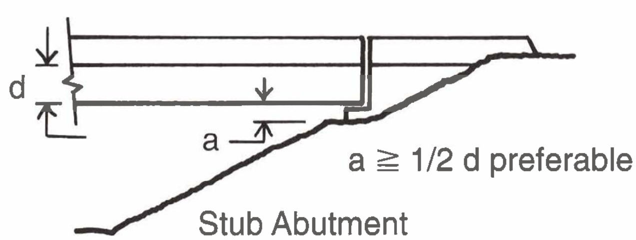


Fig. 5-43. Stub abutment

The minimum height (a) of the exposed abutment face should approximate 1/2 of the girder depth that rests atop the abutment. If the exposed height is less than that, the element will not appear appropriate for its structural function. Considerations for stub abutments should include the following.

- Minimum height of the stub abutment should be 1/2 of the girder depth that rests atop the abutment.
- Use slender girders with stub abutments to promote slender appearance and horizontal flow from touchdown point to touchdown point.
- Treatment of the exposed face of the wing wall is appropriate, depending on the visual intention of the design.

5.2.4.2 Semi-deep Abutments

Semi-deep abutments can be used to shorten the end spans of the bridge and draw attention to the terminus of the bridge. They work well with two-span overpass structures because their increased mass tends to complement the increased structure depth required for medium-span highway structures. This type of abutment is very common within the Minnesota State Highway System. The semi-deep abutment plays a more important role in the visual composition than its shorter counterpart, the stub abutment. As the abutment begins to become more predominant, the designer needs to be more concerned with balancing the mass of each abutment with the remainder of the bridge.

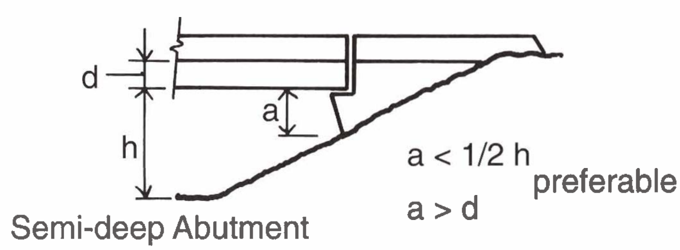


Fig. 5-44. Semi-deep abutments

As with all types of abutments, the use of mask walls increases the visual mass of this element. Use of mask walls on tall semi-deep abutments may make the abutment appear disproportionate with the superstructure. Designers should pay special attention to the relative proportions of the visual composition when semi-deep abutments are needed. If the abutment appears too massive, designers have the options of eliminating the mask wall or using rustication on the wing wall to reduce the apparent height of the element.

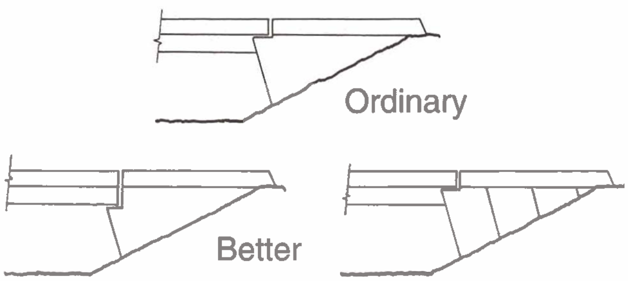


Fig. 5-45. Methods of reducing the apparent height of an abutment

Considerations for semi-deep abutments should include the following.

- To limit the mass of the abutment, the abutment height (a) should be no greater than 1-1/2 the total superstructure depth (D).
- Use of slender girders continues to be important with semi-deep abutments. However, the designer should keep the structure depth proportionate to the abutment mass.
- Use of surface textures and/or landscaping to reduce the visual scale of the abutment walls is appropriate depending on the intention of the visual design.

5.2.4.3 Deep Abutments

Deep abutments are often used adjacent to retaining walls in cut situations or when right-of-way limitations restrict the length of the bridge. As such, they are more conducive to urban environments and are commonly used with depressed roadways and within the limits of cities. The height (a) of deep abutments can equal that of the vertical clearance (c). The deep abutment produces a strong visual statement due to its mass. The designer should recognize the visual effect of this mass in the design of the bridge. This type of abutment can be flanked by either: triangle-shaped wing walls oriented normal to the abutment face or; retaining walls with heights similar to the abutment oriented parallel to the abutment face.

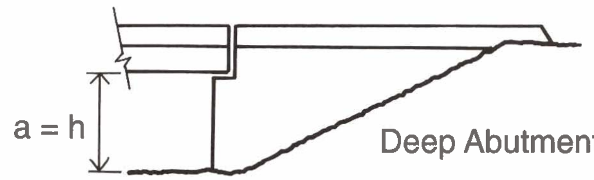


Fig. 5-46. Deep abutment

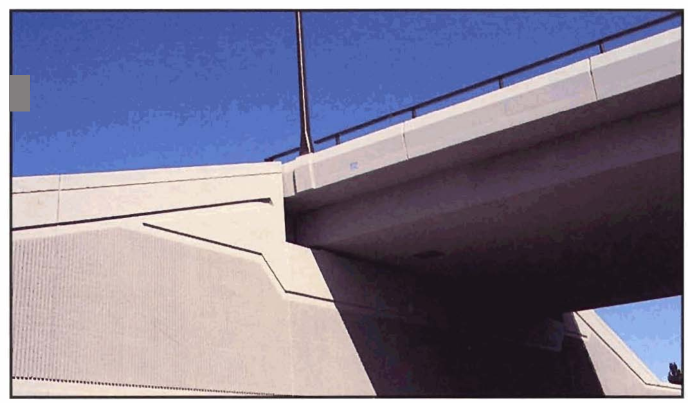


Fig. 5-47. Deep abutment, Duluth, Minnesota

Consideration for deep abutments should include the following.

- Abutment height (a) may approach that of the vertical clearance (c) beneath the structure.
- The relative proportions of the superstructure and abutments suggest that designers should not attempt to minimize the depth of structure.
- Use of a battered front face is not appropriate for deep abutments.
- When deep abutments are used with triangle-shaped wing walls, reduce the visual scale of the wall area with either surface textures and rustication or landscaping along the sides.
- When flanked by adjacent retaining walls, match aesthetic treatment and visual design of walls and abutments.

5.3 BRIDGE SEATS

Conventional pier caps and abutments must often provide support for multiple girders at different elevations. On wide structures and on bridges with superelevation, the difference in elevation between bridge seats can be substantial. The designer has the option of either providing individual seats of varying height to account for the elevation difference, or stepping the top of the pier cap or abutment. The designer should incorporate the changes in elevation into the pier cap geometry rather than providing excessively high bridge seats. The upper edges of the pier cap, or abutment face, should also be formed separate and distinct from the bridge seats. Making this distinction will provide a continuous visual line from one end of the pier cap or abutment face to the other.

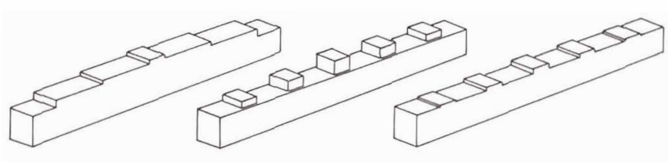


Fig. 5-48. Ordinary bridge seats

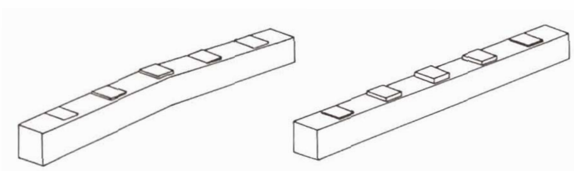


Fig. 5-49. Better bridge seats

Considerations for bridge seats should include the following.

- Limit the height of the tallest bridge seat to 200 mm. If more than 200 mm in elevation difference is required, step the top of the pier cap to accommodate the elevation difference.
- Detail the edge of the bridge seat 75 mm back from the face of the pier cap.
- Vary the elevation of the bottom of the pier cap to approximate a constant depth.

Fig. 6-1. Lake Place walkway, Duluth, Minnesota

"I believe that the structural engineer who is taking further studies in the field of architecture, or an architect who is spending his late hours by taking extra structural engineering studies, are broadening their knowledge, not to compete with the 'opposite side', but to fulfill their own professional requirements."

Julis G. Potyondy

6.0 INTRODUCTION

The viewer perceives a structure as the summation of its elements to form a whole and then the whole in terms of its setting. If all aspects of the visual composition are well orchestrated, the result is a pleasurable experience for the viewer. Designers must consider all elements of the bridge and its setting throughout the design process to achieve excellence in design. The surface textures, colors, details, landscaping, and railing treatments should be judiciously used to enhance the appearance of the bridge and allow the bridge to complement its environment. When proper attention is given to all aspects of the design, the visual appeal of the whole composition is greater than the sum of its parts.

Unlike most other visual designs, the observers fall into two separate and distinct categories: those using the structure and those viewing it. As such, bridge designers have two masters to serve. Bridge designers must consider the audience that will view the composition.

The highway traveler is constantly bombarded with information that is competing for attention. Visual information is presented as a cascade of moving images: seen and examined briefly in the context of constant motion, undulating ground surfaces, frequent decisions and dramatic events (e.g., passing beneath a bridge at high speeds). Because of these conditions, designers should seek to assist the traveler in comprehending what is being seen. Designs with orderly composition of forms, textures, and colors will support clarity and enhance the observers' comfort level.

Observers positioned external to the corridor view bridges from points adjacent to the highway, such as neighborhood areas, sidewalks, and adjacent streets. These observers may or may not be moving at high speeds. If the observer is not moving at a high rate of speed, finer details of the bridge will stimulate the observer's visual senses. The importance of the visual effect on these observers is as great as it is for the highway traveler.

Because bridge components involve the detailing of the total composition, consideration of both types of observers must be respected by the designer. Designers should identify primary observers, the conditions the observers will be subjected to, and their primary vantage points.

6.1 RAILINGS

The railing, deck fascia, and fascia girder are often the most visually prominent parts of a bridge. Collectively, they have a major impact on the overall appearance of the structure. The aesthetic design of this collection of elements is introduced in Section 4.2.3 – "Superstructure Presentation" and will not be repeated here. The discussion within this section deals with barriers, railings, and parapets as a separate element. However, as with all other elements of the bridge, designers should consider the railing in terms of the total visual image of the structure.

6.1.1 Vehicular Barriers and Parapets

The terms *railings, barriers* and *parapets* are sometimes used interchangeably to refer to a section of wall placed along the edge of the bridge deck. Within this subsection, *barrier* will be used to refer to a bulkhead constructed at the edge of the driving pavement specifically designed and tested to contain stray vehicles, e.g., Jersey-Barrier, GM-barrier.

Parapet is used to refer to short walls constructed at the edge of the bridge deck that are designed in conformance with AASHTO specified loads but are not tested for purposes of containing vehicles. Mn/DOT F-rail is an example of what is referred to as a parapet.

Railing is used to allude to metal elements. These may be placed between masonry pilasters, on top of barriers and parapets, or simply as a free standing unit fastened to the deck. Railings are further addressed in Section 6.1.2. In this context they serve as pedestrian railings and architectural embellishments. The term *rail system* is used to refer to parapets, barriers, or railings when differentiation between them is not necessary.

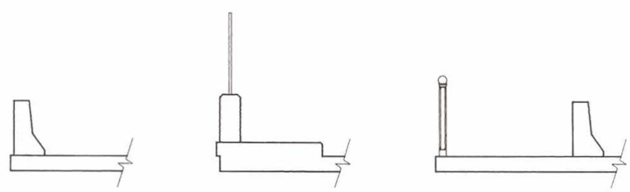


Fig. 6-2. Barrier, parapet, and railing defined, respectfully

Rail systems observed by the highway traveler are seen at a distance and at a high rate of speed. For standard grade separation bridges, the predominant views are from the underpass roadway approaching the structure and from the bridge deck. The designer should consider these predominant vantage points from which the rail system will be viewed. The high-speed highway traveler will have neither the time, nor the appropriate distance, to perceive fine detail. Therefore, highway rail system design should be simple, and architectural treatments should be pronounced and easy to distinguish. A bridge within a historic district that carries heavy pedestrian traffic presents an entirely different set of circumstances. In this instance, an ornate rail system reminiscent of the period architecture would contribute to the visual environment and offer the pedestrian visual stimulus.

Fig. 6-3. Treatment of parapet and metal railing offers pedestrian visual stimulus, Crookston, Minnesota

The latitude the designer has with the design of the rail systems for vehicular bridges is dependent, in part, on the design criteria set for the roadway carried by the bridge. Bridges with design speeds in excess of 64 km/h require barriers that have been physically tested in a controlled environment to a specified level (Performance Level 2). The Preliminary Bridge Plans Engineer should be contacted for determination of the railing requirements for all vehicular bridge projects.

Once a barrier has passed physical tests specified by the Federal Highway Administration, it is referred to as *crash tested*. Crash tested barriers are designed to contain and redirect vehicles with varying levels of performance. Designers have the option of architecturally treating the outboard face of the barrier as long as the structural integrity of the barrier is not compromised. Alterations to the inboard face of the barrier will have a significant effect on its ability to redirect vehicles and therefore will not be allowed. Open-faced railings, in particular, may cause snagging that can lead to injury and damage. When a crash-tested barrier is required, a crash-tested approach transition is also necessary.

Fig. 6-4. Parapet and pedestrian railing designed to allow drivers to see through, allowing a view of the scenic area, Lake St. Bridge, St. Paul/Minneapolis, Minnesota

For those bridges with design speeds less than 64 km/h, a crash-tested barrier is not required. The designer may use parapets and railings that have been designed to comply with the appropriate AASHTO design standards. These elements should be developed to complement the overall visual theme of the bridge. Options available to the designer include use of ornamental metal railing, stone or precast concrete caps, graphic reliefs in the railing face, and surface treatment or rustication.

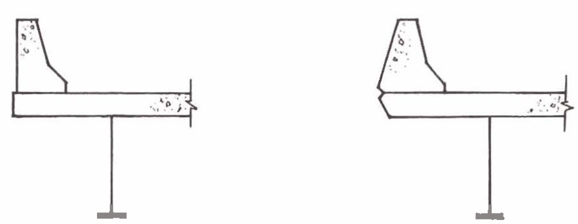


Fig. 6-5. Methods to conceal deck/railing joint

The interface of the deck and rail system typically forms a construction joint that may create unsightly distractions if not treated appropriately. The general objective in treating this detail is to avoid placing the construction joint within a flat plane of concrete.

Techniques used to address this concern are to set the face of the rail-system back from the deck fascia, to provide rustication along the joint to conceal the construction joint, and to form the face of rail-system over the edge of the deck.

On vehicular bridges, the top of the rail system often runs nearly parallel to the line of sight of the driver. From this vantage point, any inconsistencies in the line or grade of the rail system becomes magnified and creates a visual discontinuity. The use of slip-forming construction techniques is susceptible to the development of inconsistencies in the line and grade of rail systems. The superelevation transition areas also present problems in sustaining the correct line and grade. Designers should consider these aspects of construction and address them with special provisions as necessary. Options available to the designer include precluding slip-formings or requiring close tolerance to the correct line and grade.

The outboard face of the rail system is a prominent feature of the structure presentation. Because it is often light-colored, the appearance of the rail system (and bridge) is very sensitive to discolorations. The rail system may be discolored or stained by the sealing of cracks, corrosion of railings or pedestrian screens, or dripping of excess lubricants when applied to connections. Maintenance personnel and designers should be aware of this potential distraction. Designers can develop details that are less prone to corrosion and lubrication stains. Options available for consideration include the use of corrosion-resistant screens and railings, elimination of details with nuts and bolts on the outboard face, and pitching the top surface of the rail system toward the inside.

Considerations for railings should include the following.

- The outboard face of crash-tested barriers may be architecturally treated for the aesthetic benefit of the structure.
- The Preliminary Bridge Plans Engineer must be consulted for all bridge projects to determine the rail system requirements or architectural treatments that may be considered for a particular bridge.
- If crash-tested barriers are not required, consider treatment of the parapet and railing to complement the overall visual design theme of the bridge.
- Consider ending rail systems and pedestrian screens with tapers to avoid abrupt changes.
- Avoid connecting the guardrail to the rail system with through-bolts as the details clutter the appearance of the bridge.
- Avoid setting the outboard face of the rail system flush with deck fascia unless the interface of the rail system and the deck is detailed to address its visual appearance.
- Consider pitching the top of the rail system toward the roadway side where staining is less visible and easier to clean.

Fig. 6-6. Barrier transition provides logical and smooth progression from curb to parapet, Lake St./ Marshall Ave. Bridge, St. Paul/Minneapolis, Minnesota

Fig. 6-7. Fine detail and color of pedestrian railing add to what otherwise might be a mundane ramp, Hennepin Ave. Bridge, Minneapolis, Minnesota

6.1.2 Ornamental Rail Systems

Aside from their primary functional purpose, rail systems perform an important aesthetic role in the appearance of the bridge. Rail systems help finish the visual statement set by the principle aesthetic design factors. To a large extent, they establish the visual character of the bridge. For example, ornate picket railing placed between stone-veneered pilasters is conducive to areas of recreation, areas of historical significance, or areas with a scenic vista; heavy masonry balusters topped with a capstone are quite formal and convey an ambiance of authority. These rail system configurations can be classified as ornamental rail systems.

Ornamental railing systems offer the designer a unique opportunity to develop a significant visual effect for the pedestrian and the highway user alike. Central to the visual design of ornamental rail systems are four factors: the shape, the proportions, the quality of the material, and the color. The combination of these factors determines the visual impression of the rail system to the viewer.

The shape of the rail system should relate to its function and the overall aesthetic design of the bridge. The rail system should also be in proportion to the superstructure. For example, a visually slight ornamental rail system is appropriate for a slender bridge with small substructure units, while a more substantial ornamental rail system would be appropriate for a structure with dominant substructure units. The quality of the material, its finish and construction, becomes particularly conspicuous in a pedestrian situation. An ornamental rail system should be inviting to the touch. Color can be used to draw attention to design components or harmonize with an overall color scheme.

Fig. 6-8. Combination of parapet and light metal pedestrian railing address both functional requirements and appearance, Minneapolis, Minnesota

Fig. 6-9. Use of stone caps, concrete balusters, recessed panels, and picket railing adds to architectural flavor of bridge, St. Paul, Minnesota

Fig. 6-10. Parapet with ornamental railing and complementary lighting produces pronounced character, St. Paul, Minnesota

As with traditional rail systems, the design of ornamental rail systems must address the functional purpose as well as the visual impact of the element. The visual design of ornamental rail systems should reinforce the overall aesthetic plan developed for the structure – the visual goal being to accentuate the visual design without dominating the composition. Designers have several design options to choose from in the design of ornamental rail systems: metal railings (aluminum, steel, cast iron, stainless steel), stone or brick veneer work, surface finishes for concrete, formed impression, and rustication of concrete. These design components may be used in conjunction with parapets, barriers, or balusters.

As with other aspects of aesthetic design, the viewpoint of the observer is important in the design of ornamental rail systems. If the primary viewpoint is from a distance, the main consideration should be put on the fundamental shape of the structure, creating a balance between the main elements of the composition. If the primary viewpoint is close, the detailed shape and texture of the material becomes important.

6.1.3 Pedestrian Screens

Most pedestrian screens are often composed of chain-link fence technology. This type of screen system can be improved on from visual and maintenance points of view. Designers should accept the challenge to develop pedestrian screens that do not clutter and add confusion to the visual appeal of bridges.

The visual appeal of pedestrian screens can be improved by addressing three aspects of the screen design: the configuration, the type of materials, and the color. The configuration should be simple and straight forward with horizontal lines dominant. Materials should be corrosion resistant and low maintenance. Use of alternative fence material, in lieu of chain link, should be considered. Alternative materials include woven wire fabric, metal bars welded in cross pattern, plastic sheeting, expanded metal and metal sheeting with punched holes.

Fig. 6-11. Black screen with black frame provides consistent visual statement that is subordinate to mass and color of parapet

The color and construction of the material should allow the screen to be as transparent as possible. This will tend to make the screen blend into the background, permitting the bridge structure to dominate the visual composition. Use of black or light-colored screens and appurtenances tend to allow the screen to visually fade into the background. Additional guidelines for pedestrian screens placed on bridges are similar to those provided for rail-systems.

Considerations for pedestrian screens should include the following.

- Coordinate the design with overall rail system design such that the post spacing and vertical divisions in the rail system are aligned.
- Use horizontal members that are significantly larger than the vertical members to promote horizontal flow.
- Integrate the ends of the pedestrian screen into the overall design by use of tapers or end blocks.
- Provide simple, compact, corrosion-resistant fittings and connections.

6.2 DETAILS

The overall visual objective should be to make the details as unobtrusive as possible. Details should be simple and consistent with the components of the structure. Simple details are also easily fabricated and usually result in a less expensive structure. Details for splices and connections should be straightforward and easily erected for maximum economy. Nuts and washers should also be placed away from highly visible exterior faces. Simple structural details contribute to the uncluttered appearance of the bridge.

The appearance of a bridge can be unduly diminished by lack of attention to details. Poor details often distract the viewer's attention from the overall composition and concentrate the attention on the detail. Such a detracting detail may be as simple as using through-bolts to connect a guardrail to a rail system. This requires four substantial size bolts to be located on the outboard face of the rail system. The bolts are a different color, material, texture and form than the rail system face. The result is a distraction to the viewer. With well thought-out details, the aesthetic qualities of the bridge do not have to compete with distractions for the viewer's attention.

Expansion joints should be sealed to avoid staining abutments and columns. Concrete sealers or other techniques can be used to minimize surface discoloration. Careful treatment of drains, downspouts, and other appurtenances, such as signs, lighting supports, and utilities, are all things that the designer must carefully detail. An otherwise attractive structure can be spoiled by allowing small flaws or secondary items to catch the eye.

The designer should be aware of all details that will be used for the structure to ensure consistency and compatibility with the visual design. Because signs, signals, lighting, and other utilities are often illustrated on different drawings or other plan sets, designers seldom attempt to look at the accumulation of these elements and how they appear to the public. Each of these items should be addressed early in the design phase of a project. One needs to pay close attention to these concepts during the design phase and monitor them throughout the construction process.

Designers sometimes need to make a special note or statement in the plans or contract specifications in order to get the attention and full cooperation of the field engineers and contractors on these details. Special efforts such as pre-construction conferences may also be appropriate, especially if new or unusual techniques are involved. Field engineers and contractors, if not alerted to the sensitivity of otherwise minor design items, may not realize their importance. Even minor inconsistencies in concrete forming can aesthetically damage a good design. Some common items that may warrant special consideration are rail systems, alignments, surface finishing, line and grade of forms, construction joints, and form liner positioning.

6.3 BRACING

The underside of these bridges will often be prominent because of the height of the bridge, the position of the roadway beneath the bridge, or the location of the bridge. The designer should be aware that the features of the underside will be important factors in influencing people's visual impression of the bridge. The view of wind bracing and diaphragms may be distracting because of the number of members, the different angles at which they are installed, and the competition they offer to the main lines of the structure.

Fig. 6-12. Bottom flange lines dominate view of bridge from below, providing a clean appearance

The designer should attempt to keep the details of the diaphragms and wind bracing simple and consistent along the bridge. A consistent pattern should be developed for wind bracing using as few members as possible, placing all in the same direction. Patterns should not compete with, or contradict, the main lines of the structure. Use of "compact" steel plate girders will require fewer stiffeners and less bracing, with possibly more overall economy.

Considerations for bracing should include the following.

- Eliminate angled bracing if possible.
- Keep all bracing angles the same, relative to the superstructure.
- Use fewer large bracing members rather than many small members.

6.4 BRIDGE APPURTENANCES

This section covers those elements that are mounted on or around the bridge that often have a major effect on the structure's visual appearance. The general theme of this section is to encourage development of appurtenance details that are visually compatible with the architectural themes of the bridge to which they are being applied. The visual quality of the elements needs to be considered along with its utility.

6.4.1 Drain Pipes, Conduits, and Utilities

Fig. 6-13. Drain pipe placed on opposite side of pier from oncoming traffic and follows fundamental shape of pier

The visual objective for the detailing and design of drain pipes, conduits, and utilities should parallel that of detail design. The designer should strive to make these objects as unobtrusive as possible, keep details simple, and keep colors consistent with the bridge structure. Considerations for drains, conduits, and utilities should include the following.

- Keep pipe and conduit systems simple with minimal fittings. Consider the visual design of the bridge when locating and placing the pipe/conduit.
- Conceal conduits and pipes between beams. Avoid placement on the outside of the fascia girder or along the rail system.

- Place drains on the least visible side of piers. Use a configuration that is consistent with the pier shape.
- Color drain pipes and conduits the same color as the structural element on which they are mounted.
- Run exposed drain pipes in lines that are either parallel or at right angles to the main line of the structure.
- Avoid using internal drainage systems and placing pipe drains inside columns due to potential freeze damage.
- Eliminate drainage inlets on bridges where possible.

6.4.2 Signage

Signing and sign structures should be kept off bridges if at all possible. However, there are many situations where the highway layout requires placement of signs on the structure. In these cases the sign, or signs, should be designed as part of the total bridge. Designers should coordinate the bridge design with the Design and Operations Section of the Office of Transportation Engineering to identify potential sign placement and design requirements. Considerations for signs on bridges should include the following.

- When a bridge has more than one sign, the vertical dimensions of the signs should be consistent to promote visual continuity.
- Consider aligning the top of the sign with the top of the railing, and align the bottom of the sign with the bottom of the superstructure for fascia-mounted signs. This objective should not interfere with the function or clarity of the message.
- Consider using internally lit signs where elimination of the external light sources (and associated grating and support) is beneficial.
- Consider painting the back side of the sign and its support elements a color that is compatible with the bridge itself.

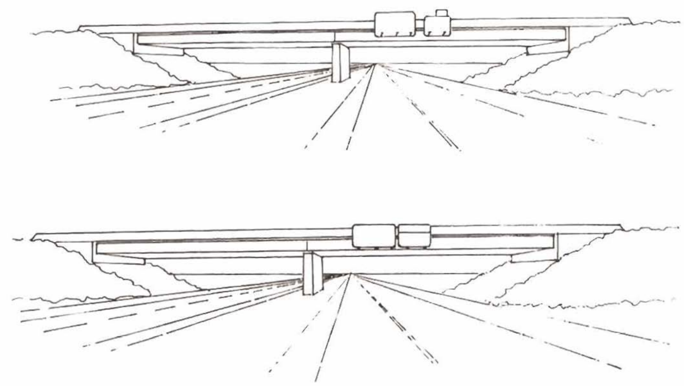


Fig. 6-14. Signs on bridges should ideally be simplified and related to the bridge design

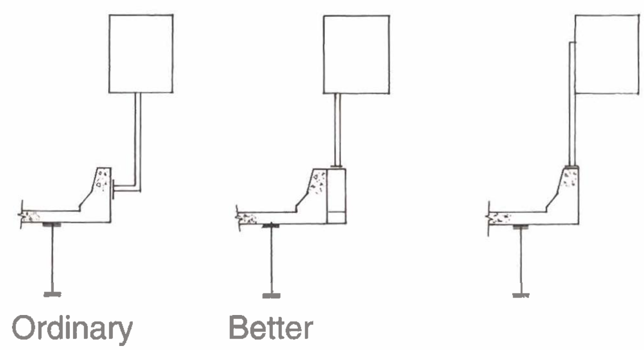


Fig. 6-15. Alternate methods of mounting signs

6.4.3 Lighting

The visual impression of bridges will be influenced by the use or absence of light fixtures, by pole or post shapes, and by the color and location of these elements. As rail systems tend to influence the character of a bridge, lighting tends to punctuate that character.

Illumination of highway structures can be applied for several reasons. The intent may be to provide illumination for the vehicular traffic, river traffic, or for pedestrians. Lighting for pedestrians may be placed on the bridge deck, as well as beneath the bridge, to brighten what would otherwise be an uninviting area.

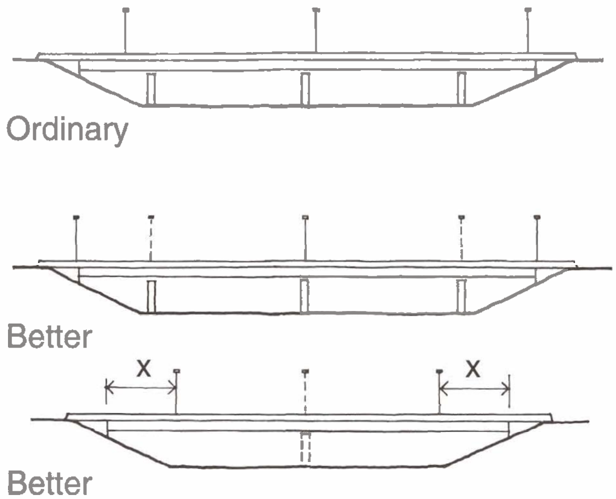


Fig. 6-18. Light pole positioning guidelines

Considerations for lighting should include the following.

- Place light poles in some logical relationship to the structure, e.g., symmetrical to superstructure, over a pier, in sequence with railing posts.
- Coordinate the location of pedestrian and traffic lighting.
- Integrate poles and fixtures with structure type and the rail system.
- Recognize inherent symmetries or other major characteristics of the overall structure, and locate lights accordingly.
- Maintain the horizontal line of the railing with as little interruption as possible. Keep the light pole mounting continuous with the railing and consistent with any ornamental features or construction joints.
- Mount lights under structures in some consistent relationship to the structural elements.
- Recognize and plan for the appearance and location of conduits, junction boxes, ballasts, and so forth early on in the design process. Try to locate these items at inconspicuous areas on the structure.
- Use flood lights on significant forms of the structure, e.g., the tower pylons of a cable-stayed bridge.
- Portray the basic form of the bridge by outlining features with illumination or light to create a silhouette, e.g., stringing lights along the cables of a suspension bridge.

6.5 WALLS

The use of walls on highway projects is often motivated by a need to preserve right-of-way, a need to accommodate grade differences between adjacent roadways, or a need to mitigate noise. These walls can have significant aesthetic effects by virtue of their size and location within the highway corridor. Their influence on the highway environment is controlled to some degree by their height. The taller the wall, the more unnatural it appears and more attention it commands. The number of walls within the corridor also affects the setting. A significant number of walls will have a pronounced effect on the demeanor of the immediate environment.

If the walls within a highway setting are treated with concern for their visual appeal, they can enhance the surroundings by providing continuity, color, and order. If their visual appeal is ignored, they can leave the viewer feeling trapped in a cold and stark concrete jungle.

6.5.1 Retaining Walls

The overall design approach should be to establish the geometry of the walls and then address its surface treatment. As with bridge structures, the physical aspects of walls have a greater bearing on their visual effect than do surface treatments. When establishing the overall wall geometry, the designer should attempt to eliminate or minimize the number of walls, minimize the wall height(s), and avoid abrupt wall terminations or abrupt changes in top-of-wall elevation.

Fig. 6-19. Distance between wall and roadway is maximized to increase drivers' comfort and reduce wall height, making termination of wall logical and gradual

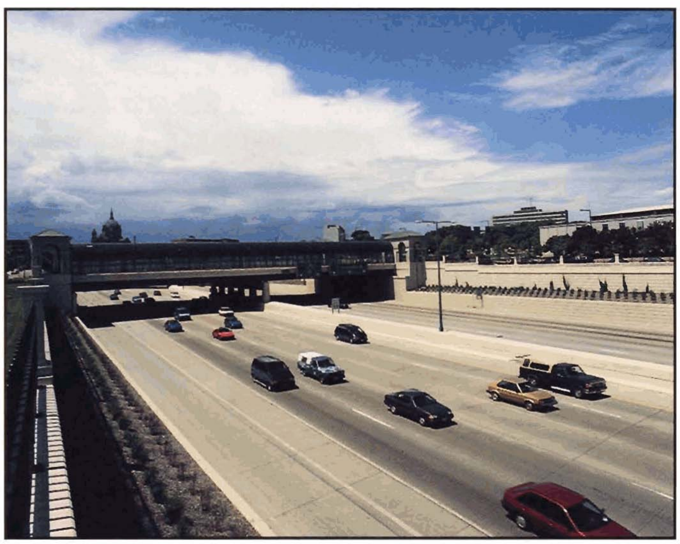


Fig. 6-20. Apparent wall height minimized and surface treatment provided for visual continuity and drivers' comfort

The surface treatment of the walls must be designed and coordinated with other key design structures such as bridges, so that a sense of design continuity is established throughout the highway corridor. Walls may tie into bridge abutments and link various bridge structures together. The bridge and highway designers must coordinate these design elements to ensure compatibility of design, detail, and treatment.

Due to the speed of the moving observer, wall materials and detail on the wall are less important than overall line, form, color, and the relationship of the rail to other elements in the landscape. On the residential side of a rail, detail may be more important, especially to the individuals who lives there year round.

Weep holes are often required to prevent the build-up of hydrostatic forces. The designer should consider the effect of the weep holes on the overall appearance of the walls. Weep holes should not appear to be an afterthought to the wall design, rather they should be integrated into the overall visual scheme.

Considerations for retaining walls should include the following.

- Minimize the height and number of walls.
- Where possible, the top of the wall profile should be developed into a graceful profile. If the top of the wall is to be stepped, it should be stepped in consistent increments without abrupt jumps.
- Where retaining walls and sloped grades are combined to provide grade separation, place the retaining wall at the top of the slope, if possible. This will provide more open space at the roadway level.
- Weep holes for drainage systems should be constructed at a constant height above the ground line and in a consistent manner throughout the surface pattern. Consider the visual consequences of the type of varmint screen used.
- Avoid abrupt terminations to retaining walls. Use alternatives such as turning the wall into the earth.
- Railings and fencing installed on retaining walls should be consistent with or complementary to those found on adjacent bridges.

6.5.2 Noise Walls

By nature of their function, noise walls are usually very large elements that can dominate a visual field. Although many of the visual objectives for retaining walls apply, noise walls need not parallel the roadway alignment to the same degree as retaining walls. Noise walls may follow the irregularities of local drainage or property lines, resulting in an irregular alignment. Noise walls share most of the same visual design objectives as retaining walls. Considerations for noise walls should include the following.

- Noise walls should be aligned so that they relate to topographical features and surrounding communities.
- Alignment and connection to bridges and retaining walls should be well detailed.
- Use of noise walls on bridge structures requires special detailing and consideration of the mass, scale, and proportions of the total visual composition.

6.6 SURFACE TREATMENT

Color and texture are fundamental visual design elements that can be used to develop surface treatments. These visual design elements offer the designer an opportunity to punctuate the overall composition of the bridge form. They can be used to reinforce dominant visual themes, enhance the structure lines, or simply add interest to the structure. The designer can use color and texture to augment or subdue the aesthetic qualities of proportion, order, harmony, and contrast.

The designer has the option of treating surfaces with color or texture, or leaving them in their naturally occurring state. Natural materials and fabricated finishes provide a wide range of colors and textures for use in support of design concepts. Designers have the option of using one of several surface treatments to alter the appearance of structure components. As such, somewhere in the visual design process the question of whether surface treatments should be used needs to be addressed.

Choosing surface treatments, or choosing not to use surface treatments, should take into account the overall visual design theme of the structure. This visual design theme should, in turn, recognize the surrounding site conditions, community characteristics, orientation of the bridge to the natural light, and primary vantage points from which the bridge will be viewed.

6.6.1 Color

Color can be used for aesthetic purposes as well as more pragmatic purposes. On the pragmatic side, bright colors are often used to draw attention and alert the viewer, as with red fire trucks and orange maintenance vehicles. On the aesthetic side, colors are used to summon emotional responses and reinforce visual design themes. Designers can use color application to define, modify, accentuate, or subdue the visual effects of structural elements.

Full-hued reds, yellows, and browns are considered warm colors and tend to emphasize presence, size, and form. Whereas full-hued blues, greens, and purples are considered cool colors and diminish the visual importance of elements. The intensity of colors can be varied from vivid to dull to arouse a different response from the viewer, e.g., a vivid green would be more stimulating than a muted yellow.

Colors are also categorized as light and dark. Lighter colors tend to emphasize because they provide sharp contrast for shadows and provide high definition. Conversely, dark colors subdue the prominence of elements because shadows tend to get lost in the dark color and the lines of the elements are not easily distinguished.

The designer should recognize that colors will appear different at various stages over the life of the project, and at various times of the day and season. This is because colors are perceived differently in the various hues of light, and the color itself will change over time. The ambient light will vary greatly depending on the weather, time of day, and season. Colors react to the intensity and color of the light shown on them. Most color systems will deteriorate and fade with the passage of time. Selection of an applied color that will be compatible with an aging color system can reduce visual distraction of the deteriorating color system.

Color can be used to contrast or harmonize bridge elements within the structure. The selection of color will also affect whether a bridge contrasts or blends in with its environment. Most common bridges are not intended to be the focus of attention. They are more often a background in which other items are viewed or simply a significant part of the environment. As such, the color selection for common bridges should be made with the intention to integrate the structure with its environment. This aspect of the visual design should recognize and complement its setting, community, and historic place in time.

Fig. 6-21. Buff-colored concrete in combination with separate finish colors for railing and structure provides visual interest, Island Canal Bridge, St. Paul, Minnesota

Designers have the option of using accent colors to draw attention to and feature forms of the structure. Accent colors can be any color that is complementary to the dominant color of the object. When used with understanding, color can be used to define, clarify, modify, accentuate, or subdue the visual effects of structural elements or the bridge as a whole.

Harmonious colors seem to belong together and produce pleasing visual effects. The simplest way to achieve color harmony is to select colors that occur most frequently in nature: greens, blues, and browns in varying shades.

Fig. 6-22. Color used to reinforce designers' visual theme, Irene Hixon Whitney Bridge, Minneapolis, Minnesota

Guidelines for the color selection for conventional structures are provided below. The color selection for unconventional structures may be governed by overriding project-specific issues or considerations.

- Color should be used to develop harmony within the structure and between the structure and its setting.

  Full-hued colors are not harmonious with the naturally occurring environment. Use of these colors should be limited to manufactured settings.

- Light colors emphasize presence by producing stronger shadow contrasts. Dark colors diminish visual importance by obscuring shadow lines.

- Hot colors such as reds, oranges, yellows, and intense colors attract attention. Use these colors with discretion.

- The color combination of signs, lights, and railings should be considered in the color selection.

The opportunity to apply color to metal structures is primarily limited to surface coatings. However, weathering steel left in its fabricated finish provides a unique alternative to surface coatings. Weathering steel forms a natural occurring patina that provides an attractive finish and effectively serves as surface coating in certain conditions. The patina is void of any sheen and will change in color from a rusty red-orange to a dark purple-brown with the passage of time. As the formation of the patina is a naturally occurring phenomena, weathering steel is well suited for rustic and informal settings.

Designers need to be aware of the staining potential of the rust-laden runoff water when weathering steel is used. Details and precautions should be employed to prevent staining of substructure units and slope paving. These details and precautions can include sealing of concrete, diverting runoff water, providing drip pans, and using drainage troughs and drip plates. Weathering steel should not be used adjacent to pedestrian traffic because the patina will stain clothes.

Surface coatings for metal bridge components can be produced in virtually any color with varying degrees of luster. Steel coating provides ample opportunity for quality control during application. This results in a dependable barrier between the steel and the environment.

Designers have several methods to choose from when applying color to concrete. Methods commonly available include coloring of the cement paste (integral coloring), staining of cured surface, using exposed colored aggregate, and using surface coatings. Each method produces a distinct visual effect. Surface coatings provide the most color consistency and are readily reproducible for maintenance and patch work.

The colors available with stains and integral colors are centered around reds, blues, light grays, and earth tones. Surface coatings are available in a wide variety of colors from primary colors to light grays. Generally, the light colors, grays and white, retain their initial color and are not sensitive to ultraviolet rays. Reds, blues, and earth tones may change over time depending on their exposure to sunlight. Reddish colors fade quicker, whereas earth tones and blues tend to last longer.

Integral-colored concrete is the most durable method of applying color to concrete. This method can also be the most expensive, depending on availability of the color agent and location of the job site. Quality control is crucial to maintaining a uniform color from batch to batch. The range of colors available for integral-colored concrete tends to be restricted to earth tones such as light gray, tans, and browns, but may include light shades of red, green, and blue.

Concrete stains are available in either transparent or opaque liquids that can be applied to the cured surface of concrete. The stain penetrates the surface to provide insoluble, abrasion-resistant color deposits in the pores of the concrete. Stains will not hide surface defects and may not hide discolorations in the concrete. Concrete stains are available in a full range of colors.

Surface coatings typically consist of an acrylic-latex base and can be used to provide a slight surface texture, as well as color. These coatings are excellent for hiding minor imperfections in the concrete. They require little quality control, and provide a durable, low-cost finish. Surface coatings also provide a simple means to cover graffiti.

6.6.2 Textures and Patterns

Textures help define form through subtle surface variations and shadings. Textures applied in a repeated configuration form a pattern. The designer can use texture to add visual interest and to introduce a human scale to an otherwise enormous object. Designers have several options available to produce texture in concrete. Textures can be produced with veneers, form liners, acid washing (exposed aggregate finish), pneumatic blasting, bush-hammering, mechanical stamping, or special formwork. As with the use of color, the designer should use texture to enhance and add interest to the visual composition of the structure or highway corridor.

Most wall and abutment structures have inherent patterns that the designer has no control over. These inherent patterns are created by the joints between monoliths, tie holes, weep holes, and, to some extent, form lines. Whether applying a texture or leaving the surface as board-form concrete, the relation to and interaction with these inherent patterns must be considered. The details of how the texture or pattern will be treated at the joints need to be worked out and clearly indicated within the construction documents.

Distance and speed alters our perception of texture. When viewed from a distance, fine textures blend into a single tone and appear flat. A similar phenomenon occurs with speed. A stationary person looking at a wall with a vertical-ribbed rustication pattern would recognize the irregularities of the concrete surface. However, traveling at highway speeds, the relief in the concrete would not be discernable. To the traveling viewer the rustication would be perceived as a flat texture. Designers should develop texture that can be seen from a distance of approximately 125 meters where the primary observer will be a motorist.

Surfaces that will be viewed predominantly by pedestrians afford the designer an opportunity to use finer textures and more complicated patterns. Consideration should be given to the context in which the texture/pattern will be viewed. That is, will the viewer be leisurely strolling through a park, waiting for transportation, or walking in downtown?

Wall surfaces are generally parallel to the alignment of the roadway. As such, the walls are viewed from an oblique angle and at a high rate of speed. The oblique view of the surface results in perspective foreshortening of patterns on the wall. That is, the horizontal dimension of the pattern is perceived as compressed when viewed from the oblique. Designers should exaggerate the horizontal dimension of wall patterns to compensate for the perspective foreshortening.

Use of horizontal lines in patterns adjacent to roadways requires special attention. Because of the parallel orientation of walls to roadways, the driver is in a position to see along horizontal lines used in pattern. Any discrepancy in the line, width, or grade of the horizontal line will become immediately obvious to the driver. When horizontal lines are used for patterns or textures, the construction documents should make special mention of the need to maintain proper dimension, line, and grade.

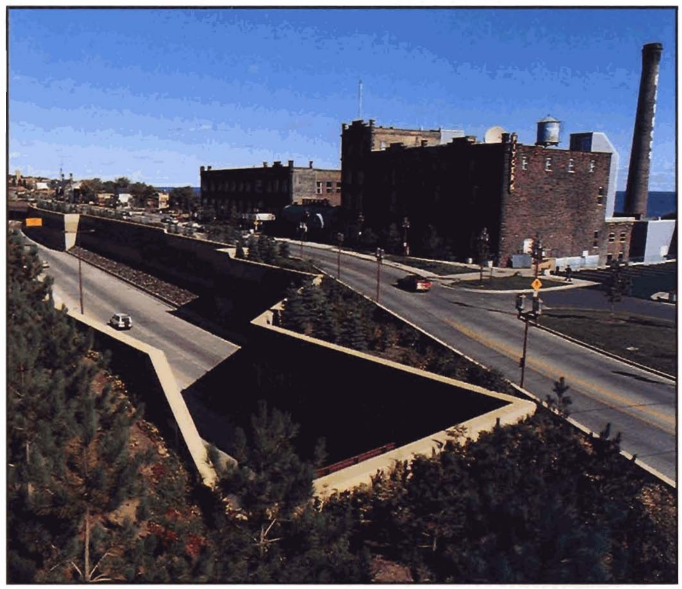


Fig. 6-23. Surface texture provides visual interest and continuity, Duluth, Minnesota

Patterns and textures on concrete flatwork can also be used to reinforce an overall visual design theme. This is particularly applicable to walkways where pedestrians can enjoy the surface treatment. One method of applying pattern to horizontal surfaces is the use of stamped or imprinted concrete. In this process, a metal stamp is used to imprint a pattern in fresh concrete. In other instances, patterns can simply be tooled in the fresh concrete. For these horizontal applications, the alignment of the pattern with adjacent curbs and other elements must be carefully planned. Rectilinear patterns require greater care than random patterns. The joint spacing in the concrete flatwork must be compatible with the concrete pattern. Avoid restricting flatwork patterns to only those portions of the sidewalk on the bridge. The design should have a visual connection to approaches and adjoining structures.

Patterns and textures can be composed of many shapes and techniques. In formal settings, horizontal and vertical rustication can be used to form rectangles that are visually reminiscent of stone blocks. Rectangular raised and recessed panels also work well with formal settings. Vertical ribs or striations, either formed or with a fractured finish, have been successfully used on contemporary visual themes. Acid wash provides a fine texture appropriate for pedestrian application. Commercial form liners can also be used to develop intricate patterns such as: rough cut timber, split face blocks, ribbed designs, rough aggregate designs, and board and batten designs. Custom form liners can be developed to incorporate murals into concrete.

Fig. 6-24. Recess rib rustication and host city icon provide pedestrians and drivers with visual interest, Duluth, Minnesota

Fig. 6-25. Formliner used to create detailed sculpture in bridge parapet, Crookston, Minnesota

Considerations for textures and patterns should include the following.

- Recognize and plan for the pattern created by the construction joints, tie holes, and weep holes.
- Develop architectural studies to ascertain visual sequence of pattern/texture at roadway speed and pedestrian scale.
- Make the pattern elements large enough to be read at distances and driving speeds if the pattern will be seen primarily from the roadway. Use 100 mm as a minimum dimension.
- Textures and patterns viewed predominantly by pedestrians can be finer and more complicated.
- Any specific design must be sufficiently long enough to compensate for perspective foreshortening.
- Minimize the use of horizontal lines in patterns and textures. When horizontal lines are required, call for special attention to their construction in the contract documents.
- Consider use of patterns and textures on horizontal surfaces in areas where pedestrian traffic is high.

The level of illumination for river navigation, pedestrian, and traffic applications has standards that must be met. The standards essentially govern the minimum acceptable level of illumination and the amount of contrast between areas of high light intensity and low light intensity. These parameters are affected by the mounting height of the light source, intensity of the light source, diffusion of the light, and spacing of the lights. Designers should ensure close coordination with the Design and Operations Section of the Office of Traffic Engineer for codified illumination requirements.

When considering illumination, designers must recognize the scale of lighting. Lighting for pedestrians can be effectively accomplished with recessed lights placed from deck level to waist level. Pedestrian lighting can also be post mounted. When using post-mounted lighting for pedestrians, restrict the mounting height to a range of 2.4 to 4.6 meters. This will effectively decrease the scale of the lighting and minimize the difference between light intensity levels. Conversely, the lighting scale and design requirement of lighting for traffic applications dictate a mounting height range from 9 to 12 meters.

The location of the light pole relative to the bridge components is an important design element to consider. The vertical line of the illumination posts can serve as an effective accent when viewed against the strong horizontal lines of the bridge's superstructure. Designers should consider the light and post shape along with the relative position of the light posts to the rail system and the light distribution. Ideally, light posts should be located over piers, or at equal spaces between piers or other substantial visual elements. The designer should coordinate the location of the roadway lighting and pedestrian lighting with those developing the overall lighting plan.

Lighting can also be used exclusively for architectural treatment. This architectural lighting may illuminate the structure itself or mimic functional lighting. Architectural lighting will affect the appearance of the bridge during daylight hours by virtue of the light fixtures and poles used. Designers should select poles and fixtures that complement the overall visual design of the bridge and rail system in particular.

Fig. 6-16. Combination of lighting techniques used for traffic and pedestrian benefit, as well as for architectural treatment, Hennepin Avenue Bridge, Minneapolis, Minnesota

Historical structures and those bridges with particular symbolic importance, because of their relation to the community or environment, may warrant architectural lighting to define the bridge form during the evening hours. The structure may be illuminated to define the structure form and to highlight elements and surface textures. This type of lighting is especially effective for river crossings. When considering illumination of significant bridges, designs should attempt to either flood the significant elements of the bridge with light or outline the bridge in lights to create a silhouette. Architectural lighting of the structure form should be considered for Level A bridge projects and may be appropriate for some Level B projects.

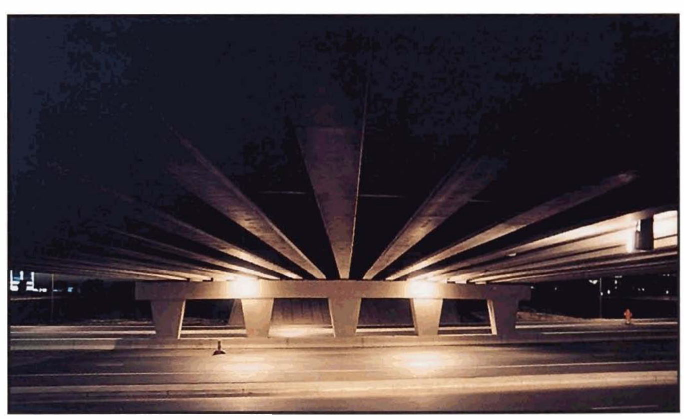


Fig. 6-17. Lighting provided beneath structure increases drivers' comfort level

6.6.3 Veneers

A veneer is a material facade applied for aesthetic purposes that has no structural function. Veneers can be used to add texture, pattern, and color to either simulate construction from a specific material or simply to enhance the appearance of the structure. Veneers used on bridges are typically made from cut stone, fieldstone, brick, cast stone, and, to a lessor extent, pre-cast concrete panels.

Veneers are best suited for use on substructure units, walls, and railings where the material properties and structural requirements are compatible. They should not be used on main supporting superstructure elements (beams and girders) to mask or conceal the function of the elements. The fundamental elements of the bridge must present an honest response to the structural task at hand. For this same reason, if a veneer is used on a railing, it should be used so that the support provided by the girder is clearly demonstrated.

Fig. 6-26. Simulated cut stone pattern and coloring on pier shaft, Bloomington Ferry Bridge, Bloomington, Minnesota

Concrete veneers can be produced to simulate brick, adobe, and a wide variety of rock patterns. The surface of the veneer can be formed with a thin concrete shell (or cast integral with structural concrete). Once the shell is placed, it is backfilled with grout, and its surface is painted to achieve the desired effect. This product can be easily adapted to simulate a wide range of conditions including site-specific naturally occurring rock formations, specific rock types, or particular patterns of stone layout. The appearance of the product is convincing. It has been successfully used to make transitions between natural rock formations and structural concrete in a highway environment.

Veneer can also be used on walkways where patterns and textures are desired. This level of detail is appropriate where high visibility and pedestrian traffic is present. The veneer materials in this instance are pavers made from concrete, fired clay, ceramic, or stone. Pavers can be used in decorative inset panels that add to the character or style of a bridge. To promote continuity, it is important to carry such treatment through the bridge approaches as well as on the bridge.

Fig. 6-27. Application of stone veneer and stone paver in a pedestrian plaza

Fig. 6-28. Brick pavers used for walkway paving, Robert St. Bridge, Crookston, Minnesota

6.7 LANDSCAPING

Proper landscaping helps integrate the structure into the site and neighboring community or environment. Selective planting and thinning can be used to enhance the visual quality of a structure and the highway right-of-way by framing the view, or by emphasizing or screening certain elements in the visual field. Landscaping can be a more economical and effective way to add visual richness and interest to a design than special surface finishes or materials.

Well-designed landscaping not only enhances a large, plain abutment or wall, but also effectively reduces its visual mass. Trees, shrubs, ground covers, and vines must be properly located to blend the functional and the aesthetic aspects. Plants should be avoided that will later grow up to obscure essential elements of the structural form or function.

Plants can serve functional requirements too, such as screening oncoming headlights when used in medians and at interchanges. They can also provide optical guidance or delineation to direct motion or clarify changes in speed and direction. For example, at exit ramps or unexpected curves, the roadway's turning can be defined by a string massing of shrubs and/or trees. Plantings can also be used to reduce maintenance and prevent erosion of steep slopes. Where drifting snow or blowing dust are problems, plantings may be considered living fences to reduce maintenance costs and increase driver safety. Dense shrub plantings may also be employed as crash buffers to slow down or absorb the impact of errant vehicles.

AESTHETIC DESIGN GUIDELINES *for* BRIDGE CATEGORIES

Fig. 7-1. Gate house to John Ireland Boulevard Bridge adjacent to Minnesota History Center, St. Paul, Minnesota

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"The word beauty is used reservedly as it does not fully explain the aesthetic perception. A better word is experimental, as it encompasses not only the object but also the viewer."

William Zuk

7.0 INTRODUCTION

All bridges have an aesthetic or visual effect. Whether or not the engineer thinks about this visual impression, people see it, and they react to what they see. People tend to recognize this in larger bridges because they have a greater visually impact and often receive greater aesthetic consideration. However, smaller bridges, viewed together or in sequence, can have a greater total effect within a highway corridor.

Aesthetic guidelines for specific categories are not separate and distinct from guidelines previously presented. Rather, these guidelines simply place an emphasis on certain aesthetic principles to best suit the application. Often, a given structure will not fall neatly within a particular category, but will cross over into other categories. Designers should evaluate the conditions presented and apply the guidelines that are most appropriate with the overall goal of developing a solution that satisfies the functional as well as the visual requirements.

7.1 CORRIDOR BRIDGES AND STRUCTURES

Continuity of appearance within individual structures and the environment as a whole is particularly important in the presentation of corridor structures and the landscape of the highway. The aesthetic goal is to carry a consistent visual theme throughout the corridor. Bridges within a corridor are often viewed in quick succession. As such, designers should consider the physical and visual relation of bridges to one another. The visual display of the collective group of highway structures must be taken into account.

Because of confined space that typifies many corridors, bridges must often compete with other highway structures for the viewers' attention. The aesthetic goal should be to minimize the visual confusion as much as possible. Consideration should be given to the signage requirements of the roadway beneath, the lighting requirements, and the urban and rural enhancements surrounding the corridor.

Those situations where a significant portion of a roadway is being reconstructed or a whole new roadway is being constructed, designers have a unique opportunity to define a uniform overall visual theme. In these instances, project-specific architectural and aesthetic guidelines should be developed. The architectural guidelines should address secondary aesthetic design factors to provide common treatment for various elements such as wall surface treatment, rail shape and surface treatments, structure presentation, and signage, along with other visual aspects that influence corridor appearance. The objective for developing project-specific architectural and aesthetic guidelines is to simplify and enhance the travelers' view, improve the appearance of the highway corridor, and establish continuity throughout the highway corridor.

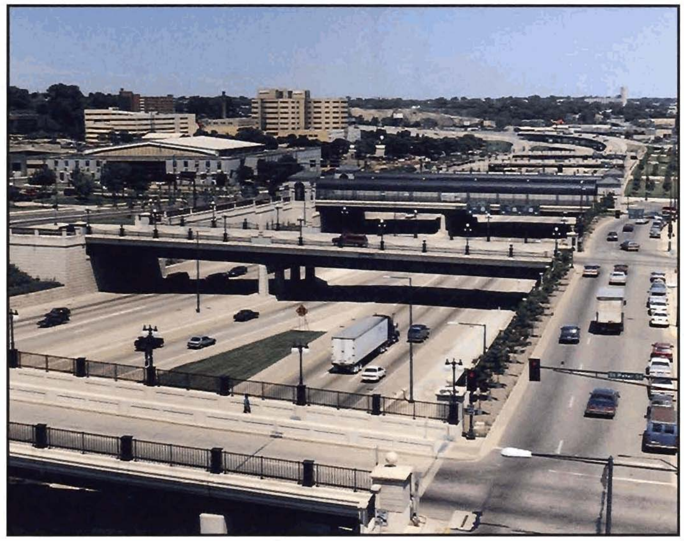

Fig. 7-1. Continuity of appearance achieved in visual treatment of a corridor, Capital Approach Area, St. Paul, Minnesota

When project-specific architectural and aesthetic guidelines have been developed, decisions regarding several secondary aesthetic design factors will have been taken out of the hands of the individual bridge designer. However, simple application of predetermined architectural treatment does not ensure a pleasant bridge form. The individual bridge designer must still make decisions regarding primary aesthetic design factors. These primary aesthetic decisions are those that dominate the visual statement of the bridge. As such, the designer must continue to address the visual aspects of functional clarity, scale and proportion, order and balance, line and mass, and continuity.

7.1.1 Grade Separation Crossings

Grade separation structures are usually short- to medium-span structures that are viewed in their entirety. Therefore, it is important that they are kept simple, with simple shapes, minimal changes in materials, and with all elements in clear relationship to one another.

This type of bridge is primarily viewed by people traveling at high speeds along the lower roadway at a distance of 90 to 250 meters. At this distance, the elevation view of the structure is the only image clearly visible. The silhouette of the structure will register first as the viewer approaches the bridge. At this stage, the functional clarity of the structure will disclose itself through line and shape. As the viewer approaches, color and texture will be revealed, bringing scale and proportion into play. The image resulting from the traveler approaching the bridge is primarily determined by the elevation features of the structure.

To enhance the elevation features of the bridge, the designer should concentrate on orchestrating bridge components that contribute to the elevation view. Consider optimizing primary aesthetic design factors to enhance the functional clarity, scale and proportion, continuity, and order and balance with the following elements:

- Fascia girder
- Rails
- Pier shape in elevation
- Abutment wing walls
- Voids between bridge elements
- Rail terminations
- Superstructure form
- Structure setting and environment

7.1.2 Interchanges

Interchange structures are obviously a form of grade separation crossing. As such, the guidelines outlined previously apply. In addition, the special challenges must be addressed due to their inherent complexity. The goal of the designer should be to make the function of the structure as simple as possible. The function of the structure will be readily apparent when the lines and appurtenances are clear and graceful.

Diamond and cloverleaf interchanges usually have single or paired structures that are highway overcrossings. The visual treatment of the paired structures should follow that of single structures with the exception that the structures should be considered simultaneously when evaluating the principle aesthetic design factors. Directional interchanges with multi-span ramps are more complex and have features similar to viaducts. The most important visual aspect of interchange ramps and viaducts is the overall flow of the highway itself.

Fig. 7-2. Bridge width conforms to junction of ramp geometry

Considerations for interchanges should include the following.

- Keep the horizontal and vertical geometry as smooth as possible with long curves.
- Keep the form, depth, and continuity of the structure continuous with smooth curves and tapers.
- Keep overhangs at a maximum to emphasize horizontal continuity and minimize pier width.
- Integrate any aesthetic and architectural design guidelines developed for the highway corridor.

7.1.3 Pedestrian Bridges

Pedestrian bridges are often thought of as insignificant because of their relatively small size. However, these structures are important to the visual makeup of the highway environment or neighboring community, in part because they are something of an anomaly.

Motorists are accustomed to encountering vehicular bridges, so when this variation crosses the roadway it draws attention.

Pedestrian bridges offer the designer an uncommon opportunity to develop the optimum structure presentation because vehicular containment railings are not required. As such, the structure can be made to appear slender. Pedestrian bridges should be designed as light and graceful structures reflecting their loading and usage. They look best when the superstructure is kept thin and the lines of the structure flow continuously over the supports and into the ramp or stair sections.

If stairs are to be part of the design, the designer must use ingenuity to integrate them smoothly into the overall design flow. Ramp and stair sections should be aligned to creatively link with the community pedestrian circulation patterns.

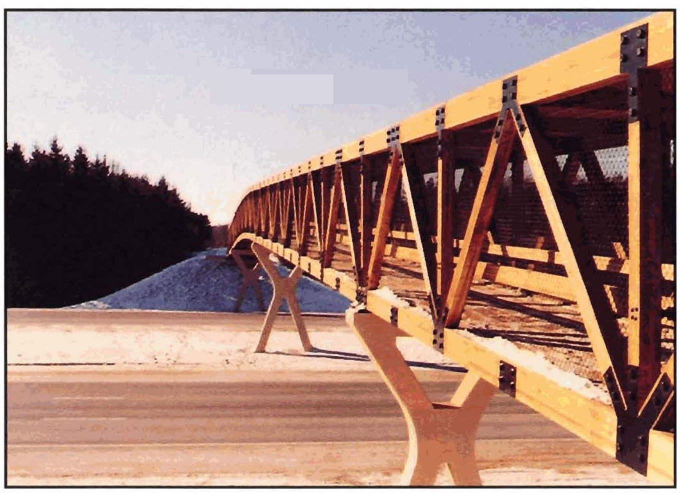

Fig. 7-3. Pedestrian bridge designed to reflect its surrounding environment, Collegeville, Minnesota

The designer should be aware of the viewers' ability to discover the visual details, character, and quality of the structure. On a pedestrian bridge, for example, viewers are more aware of scale and detail than on a vehicular river crossing because of the rate of travel. Intricate texture patterns and refined handrail details would be appropriate on a pedestrian bridge, whereas they would often go unnoticed on a highway bridge.

The recognition and perception of detailed designs also affords an opportunity to relate the visual design of the structure to the cultural aspects of the community. The design may incorporate a particular graphic of local significance as well as other community statements.

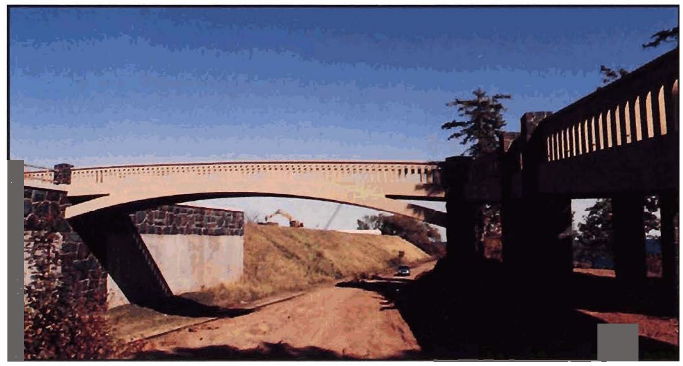

Fig. 7-4. Delicate railing and slender structure depth enhances the graceful appearance of the bridge, Duluth, Minnesota

The approach structure for pedestrian bridges often pose obstacles to the continuity of the visual design. The obstacles may result from different structure depths and materials used for the main spans and the approach structures, and the need to satisfy the accessibility requirements of the Americans with Disabilities Act (ADA).

Because of the significantly different span lengths between the main spans and approaches, a utilitarian design may suggest that different materials and structure depths be used for the respective spans. The result can be a discontinuity in appearance of the total visual composition. Designers should attempt to use consistent materials on the main spans and approach structures. If significant changes in the depth of the adjacent spans are necessary, designers should explore methods to mitigate the visual disruption. These methods may include orientation of the approach structures at a 90 degree angle to the main span, use of a substantial pier at the ends of the main span to visually separate the two structures, or replacing the approach structure with a ramp supported on fill.

The accessibility requirements of the ADA dictate the use of ramps of substantial length and level landings within the ramps. For pedestrian bridges crossing over roadways, these ADA compliant ramps often reach 100 meters or more. The approach ramps can often dominate the visual composition of the structure and should receive the same attention to aesthetics as the bridge itself. It is important that the pedestrian bridge and its approaches be treated with a consistent visual theme. Designers may have the options of using "switch-back" ramps if right-of-way is limited or a single direction ramp of substantial length. Generally, aesthetics, maintenance, and economy will be improved if the approach ramps can be placed on fill rather than on a structure.

The following guidelines are recommended for pedestrian bridges.

- Integrate the ramps and stairs into the basic structural form.
- Consider the adjacent community environment and pedestrian circulation patterns.
- Keep the bridge light in appearance.
- Avoid concrete railings unless it is also the supporting girder.
- Try to incorporate lighting into the structure to avoid poles and mounts.
- Pay particular attention to scale and detail.
- Simplify substructure units for ramps and stairs. An open, light structural design is preferred.

7.2 MAJOR RIVER CROSSINGS/LANDMARK STRUCTURES

Major river crossings and landmark bridge structures can be among highway travelers' more memorable driving experiences of a journey. They create singular or repeated enclosures, open up wide vistas, and frame views through their structural shape. They may appear as simple, understated, and elegant testimonials to good design and engineering. They may appear as monumental landmarks, provide scenic views, and/or identify the image of a city.

Major river crossings have a greater individual effect than other bridges owing to their large size, dramatic location, and carrying capacity. Their effect as landmarks can be significantly enhanced by their aesthetic qualities. Carefully designed, they can produce a visual reaction in us that becomes engraved on our collective memories, so that they become instant symbols of their community. They then can enhance their environment, increase civic pride, and provide an emotional lift to those who see them daily.

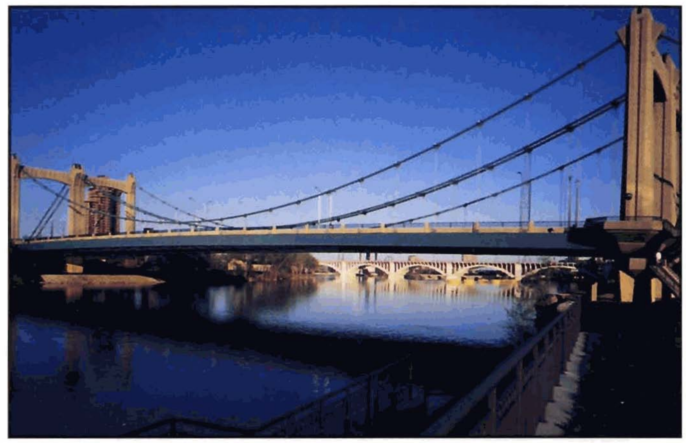

Fig. 7-5. Bridge symbolizes the gateway to Minneapolis. The bridge type recalls its historic predecessor at the site of the first bridge crossing of the Mississippi River, Hennepin Avenue Bridge, Minneapolis, Minnesota

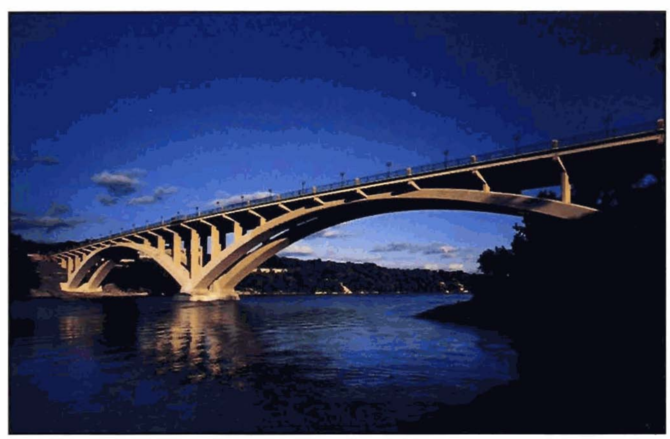

Fig. 7-6. Color and visual treatment reflects natural limestone bluffs and historic setting, respectively, Lake Street/Marshall Avenue, St. Paul and Minneapolis, Minnesota

Fig. 7-7. Length and prominence of interstate bridge creates regional landmark, Bong Bridge, Duluth, Minnesota

The visual design of major river crossings and landmark structures will necessarily need to consider site-specific information. The design of these bridges must reflect the community, city, or region. Public input and consensus is paramount. Designers must dedicate a substantial effort to the design and execution of details, as the legacy of these structures is carried on for decades.

7.3 HISTORICAL BRIDGES

As civil works projects, bridges face a greater preservation problem than their building counterparts. Bridges are born of utilitarian transportation needs. They are often integrally woven into the historic and cultural fabric of the community and state. Their preservation as historic structures is dependent on contemporary engineering issues that usually have little relation to history.

In the recent past, engineers have become more aware of the condition of older bridges. The ability of bridges to serve their intended purpose and today's transportation needs may be brought to question by inspections or traffic concerns. Their deficiency is most often the consequence of inadequate structural capacity, resulting in the posting of load limits. In other cases, old bridges, which may have adequate load-carrying capacity, are deficient because of poor approach alignment, inadequate clearances, or narrow decks. The terms structural deficiency and functional obsolescence have been coined to describe these two categories of deficiency.

Also coming to the forefront is a greater awareness of historic preservation. Historic preservation is being championed in the name of fulfilling a combination of social, economical, psychological, and intellectual needs – needs that are subjective and not easily quantified. The benefits of preservation include recognition of past achievements in the industrial era, the art of craftsmanship, and a deeper understanding of our origins. Preservation of old bridges engenders cultural awareness in a time of rapid change and increasing cultural homogeneity. Current practice differentiates between old bridges and historic bridges. To qualify as a historical structure, a bridge must be at least 50 years in age and be of historical significance. The instrument used to recognize historic properties is the National Register of Historic Places. Determination of eligibility for inclusion in this list of historic properties is based on criteria specified by the Keeper of the National Register of Historic Places.

Consideration of eligibility for inclusion on the list of historic properties is initiated at the state level within the Minnesota State Historical Society under the direction of the State Historical Preservation Officer (SHPO). The SHPO's judgement is then forwarded to federal agencies for concurrence or deliberation. When the state and the federal agencies reach concurrence regarding the significance of a particular property, the property is then listed in the National Register of Historic Places. Conversely, if no historic significance is found, it is then considered only an old bridge.

The overall objective of preservation legislation is to prevent intentional or uninformed adverse effect to historic structures without first considering alternatives that either avoid or mitigate the detrimental effects. Typically, when bridge designers get involved with a historic bridge, the feasibility of continued use of the bridge is already being examined. Fundamental to the preservation and continued use of historic bridges are three criteria: 1) that the governing authority can be convinced the structure is safe; 2) that the restored bridge will be capable of meeting the functional transportation needs of the overall transportation system; and 3) that the elements of historic significance will be preserved, rehabilitated, and protected as is feasible in recognition of historic value.

When considering extending the use of historic bridges, a defined hierarchy of actions should be considered in their appropriate order. Central to this hierarchy is the basic premise that restoration of the bridge should modify the structure as little as possible. These actions are listed below in order of application.

- Identify, retain, and preserve the historic structure (recognition of the historic nature and proactive maintenance).
- Protect and maintain the historic structure (repairs of the historic features as well as functional elements).
- Repair as necessary (rehabilitation).
- Replace as necessary.

If minor deterioration of a historic bridge exists, repair of the historic features is the appropriate action. When the deterioration of the bridge is extensive, or the bridge fails to meet historic properties criteria, rehabilitation should be considered. Rehabilitation is defined as the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property that are significant to its historic, architectural, and cultural values.

Whether considering preservation (minor repairs or maintenance) or rehabilitation, the historical character of the property must be respected. Efforts should be made to preserve the historical aspects of the bridge in a reasonable manner, taking into consideration the economic and technical feasibility. Guidance that can be considered basic to the treatment of historic bridge projects is listed below.

- Recognize the bridge as a physical record of its time, place, and intended use. Avoid changes that create a false sense of historical development such as adding conjectural features or architectural elements.

  Recognize that historic bridges have often been modified during the life of the structure. These modifications have likely acquired historic significance in their own right and should be respected as such.
- Preserve distinctive features and construction techniques that characterize the historic bridge.
- Salvage and repair, rather than replace, deteriorated historic features to the extent allowed by economic and technical feasibility. Where severity of deterioration requires replacement of distinctive features, the new feature should match the old in design, color, texture, and other visual qualities, and where possible, material. Replacement of missing features should be substantiated by documentary, physical, or pictorial evidence.
- Clean the surface, if appropriate, with the gentlest means possible.
- Differentiate new work from the old work. New construction or alterations should not destroy historic elements that characterize the property. The new work should be compatible with the mass, scale, proportion, and architectural features to preserve the historic integrity of the property.

This section deals with various aspects of the preservation and rehabilitation of historical bridges. The information provided in this section is provided for guidance and consideration. Unless stated otherwise, the information presented herein should not be construed as codified regulations nor statutory standards.

Fig. 7-8. Photograph of bridge after its initial construction, Anoka/Champlin Bridge, Minnesota

Fig. 7-9. Rendering of historic structure to be widened, historic integrity of original construction preserved, Anoka/Champlin Bridge, Minnesota

7.4 PARALLEL BRIDGES AND MODIFICATIONS

As traffic demands increase, the pressure to increase traffic capacity across a bridge increases proportionately. In these situations, designers have the options of replacing the existing structure with a new structure that has greater traffic capacity, widening the existing structure, or adding a new bridge parallel to the existing one. Aesthetics rarely dictate the selection of these alternatives. If the structure is to be replaced, the aesthetic guidelines previously mentioned can be applied without exception. If the structure is to be widened, respecting and emulating the initial visual design aspects of the bridge will likely be most fitting. The addition of a parallel structure presents the most challenging alternative from an aesthetic standpoint.

Fig. 7-10. Bridge widening – newly constructed piers adjacent to initial construction emulate the visual design of the initial design

If a parallel structure is to be added, the most desirable solution from an aesthetic standpoint is to replicate the existing structure. However, replication of the existing bridge is not always feasible because of economics and changes in technologies, standards, and material. This situation poses dramatic aesthetic challenges. Designers should strive to fashion the parallel structure to be visually consistent and complementary to the existing bridge.

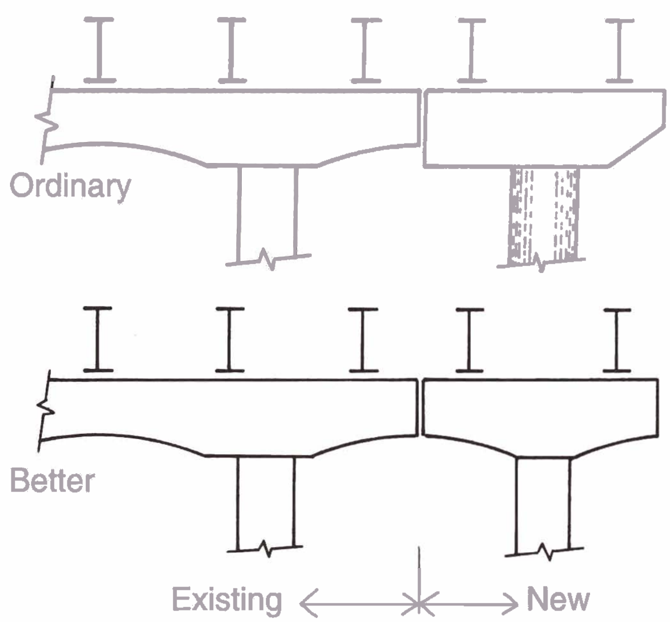

Fig. 7-11. Match new construction characteristics to existing construction characteristics when widening bridges

The designer should look first to replicating the existing structure type. The structure type is one of the most identifying elements of the bridge. When the structure type is replicated, the fundamental aspect of consistency can easily be incorporated into the visual design. Replication, as it is intended to indicate here, does not necessarily mean reuse of the plans of the existing bridge. Replication may include mimicking built-up truss members with rolled sections or mirroring pinned connections with rigid connections. The goal is to replicate the existing structure type with contemporary technology.

When replication of the existing structure type is not feasible, the designer should concentrate on maintaining the visual theme of the existing structure. The challenge is to evaluate each site or corridor situation and determine the best way to blend existing structures with the new or parallel structure. In this instance, the first step is to review the existing structure to identify features that are consistent with the guidelines found in previous sections. The desirable features can then be the basis of common details, common proportions, and common structural systems that can be used in both the parallel and existing structures. Color is another simple and obvious way to link the two structures. Application of similar colors to the existing and new bridge will visually connect both structures.

The mixing of old and new does not readily follow hard and fast guidelines. Each situation requires careful architectural and engineering studies and analysis to be successful.

Considerations for parallel bridges should include the following:

- Maintain a consistent visual theme.
- Replicate the existing structure type to the extent possible.
- Match profile, and parallel the horizontal alignment.
- Feature and complement the existing bridge. The new parallel bridge should be designed to simply compliment rather than compete with the old structure. Use only simple color, shapes, and details on the parallel bridge that reflect characteristics of the old.
- When circumstances require a different structure type, look for compatible structures whose lines and shapes do not clash with the existing structure's lines and shapes.

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