Bridge Aesthetics Sourcebook

Practical Ideas for Short and Medium Span Bridges

Draft, March 2009

TRB

Bridge Aesthetics Sourcebook

Practical Ideas for Short and Medium Span Bridges

This Sourcebook presents guidelines for improving the appearance of short- to medium-span bridges (those with spans up to about 300 feet). These structures constitute the great majority of bridges and are often referred to as "workhorse" bridges. The Sourcebook begins by explaining why it is **necessary** for engineers to consider bridge aesthetics. It then provides practical, easy-to-apply ideas for design engineers to use in developing elegant designs for the typical bridges on which they work every day.

This Sourcebook has been prepared by the Subcommittee on Bridge Aesthetics (AFF10(2)) of the Transportation Research Board (TRB). The group is a subcommittee of TRB's General Structures Committee (AFF10). Full credits may be found at the end of the Sourcebook.

This is the initial DRAFT of the Sourcebook. It has been prepared for presentation to the Bridge Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO) at its May 2008 meeting. A final version of this Sourcebook will be published after the receipt of comments from the AASHTO Bridge Subcommittee.

The Subcommittee also operates a companion interactive website at **www.bridgeaesthetics.org**. The website presents discussions of Icon Bridges which have entered the general culture as symbols of achievement and/or geographic areas, case studies of particularly successful Featured Projects, Insights from prominent bridge designers and a Forum that encourages individual practitioners to interact with each other on questions of bridge aesthetics.

Table of Contents

A. Why Consider Aesthetics? 5

B. How to Consider Aesthetics 9

1. Understand the Goals and the Site *9*
2. Develop a Design Intention/Vision *15*
3. Do a Conceptual Engineering Study *16*
4. Proceed to Detailed Analysis and Design *18*

C. Design Guidelines 19

1. Horizontal and Vertical Geometry *19*
2. Superstructure Type *21*
3. Pier/Support Placement and Span Arrangements *22*
4. Abutment Placement and Height *24*
5. Superstructure Shape (including parapets, overhangs and railings) *25*
6. Pier Shape *28*
7. Abutment Shape *29*
8. Color *30*
9. Texture, Ornamentation and Details *32*
10. Lighting, Signing and Landscaping *34*

D. Background Information 37

1. Fundamentals *37*
2. Context Sensitive Design/Context Sensitive Solutions and How to Achieve Them *46*
3. Community and Stakeholder Involvement *48*
4. Practical Tips When Historic Bridges or Historic Settings are Involved *51*
5. Working with Architects, Landscape Architects and Artists *54*
6. Bridge Aesthetics and Cost *55*

E. Example Bridges 59

F. Bibliography 65

It so happens that the work which is likely to be our most durable monument, and to convey some knowledge of us to the most remote posterity, is a work of bare utility; not a shrine, not a fortress, not a palace but a bridge.

*— **Montgomery Schuyler**, 1883, writing about John Roebling's Brooklyn Bridge*

A.

Why Consider Aesthetics?

The public is becoming ever more aware of the appearance of bridges and the effects they have in their communities. We need to respond to that concern. We can't just worry about the structure and leave the aesthetics to someone else. Every structural decision is an aesthetic decision. If a decision affects the size, shape, color or surface texture of a visible part of the bridge, it affects how people will feel about the bridge. For the same reason we would not build a bridge that is unsafe, we should not build one that is ugly. To ignore aesthetics is irresponsible.

Frequent Objections to Considering Aesthetics:

It automatically adds cost.

Most agency planners immediately associate bridge aesthetics with increased design and construction costs and additional construction time. While this is frequently the case, it is not always so. Whether it is so and the degree to which it is so varies widely depending on region of the country, owner preferences and practices, contractor capabilities, span length, size of project, community aspirations and other project specifics. If increased cost is involved, the relevant question is, does the aesthetic improvement justify the additional cost? The designer's obligation, as always, is to seek the best combination of efficiency, economy and elegance.

See Section D, Background Information, for more on costs.

Figure A.1– Often simply paying attention to proportions and details can result in an attractive bridge with no increase in cost. Canyon Creek Bridge, Anchorage, Alaska.

People can't agree on what looks better.

This is also not true. People have agreed for centuries on which paintings look better, which symphonies sound better and which buildings are more attractive. A consensus has existed since the nineteenth century on which bridges look better and why. That consensus is embodied in this Sourcebook.

Figure A.2 – The aesthetic quality of Robert Maillert's Salginatobel Bridge was recognized by New York's Museum of Modern Art in 1949 and by many others since.

My client/boss won't let me.

Give your client/boss this Sourcebook.

I don't know how.

Read this Sourcebook.

What's the goal here?

The goal of this Sourcebook is to make every bridge an efficient, economical and elegant feature in its community and environment by giving meaningful visual expression to loads, equilibrium and forces.

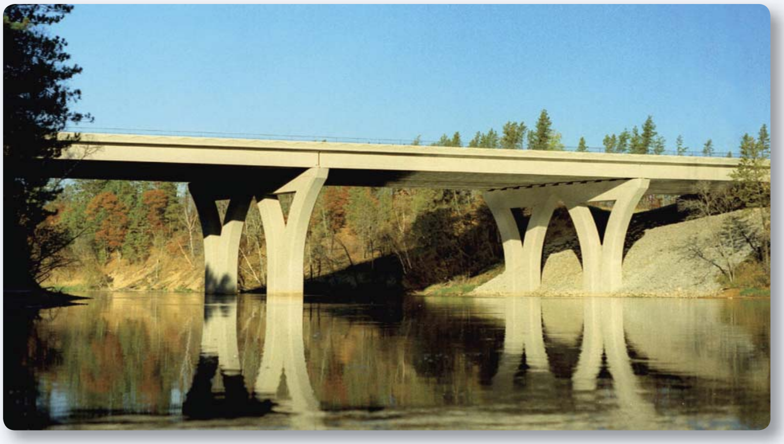


Figure A.3 – An elegant feature in its environment. Brainerd Bypass over the Mississippi River, Brainerd, Minnesota.

Keys to Success

The shapes and sizes of the structural members themselves dominate people's impressions of a bridge. They are the largest elements of the bridge, therefore the first elements people see as they approach and the most strongly remembered. It is impossible to correct the appearance of a poorly proportioned or detailed structure by the application of "aesthetic treatments," though many have tried. There is no substitute for correctly proportioning and sizing structural members. With that in mind, the consensus on bridge aesthetics over the last century and a half can be boiled down to these basic criteria:

- Simplicity
- Good proportions with an emphasis on thinness
- Clear demonstration of how the structure works
- Fits its context /surroundings

Figure A.4 – Simplicity and thinness are often enough. I-95 over Pulaski Highway, Baltimore, Maryland.

Only after all of that is right, think about surface textures and ornamentation.

Aesthetics, like every other field of endeavor, has its own terminology. See the Fundamentals section in Background Information for more on the use of words.

B.

How to Consider Aesthetics

Bridges have more than just transportation functions. They also function socially, visually and symbolically as significant elements in their communities and environments. Every project will be different and will possess its own unique characteristics. Nevertheless, there will be some commonality in the steps the engineer can apply in considering aesthetic bridge design. Following these steps will help ensure a successful bridge that its owner and community will be proud of.

1. Understand the Goals and the Site

Before a designer can start on the bridge itself, he or she must understand what the bridge is expected to accomplish, functionally as part of a transportation system and socially, visually and symbolically as part of a living community and environment. The designer must have an idea of all of the criteria that the structure must meet and all of the concerns that will act on the structure. In recent years, the Federal Highway Administration (FHWA) and many other transportation agencies have recognized that this is a broad task, requiring the coordination of many, often competing, interests. This process has been given the name **Context Sensitive Design.**

See the Background Information section for how to use Context Sensitive Design techniques to address all of the concerns involved in a project.

Figure B.1– Community uses under a bridge may be more important than transportation uses. 17th Street Causeway, Ft. Lauderdale, Florida.

The Site

The bridge site is the most important feature that will influence the configuration and hence the aesthetic design of a bridge. Bridges designed to work with and complement a site will be both functionally and aesthetically successful.

Tip: Go to the site at different times of day, at night and in as many different seasons as possible. There is no substitute for first-hand familiarity with the bridge site.

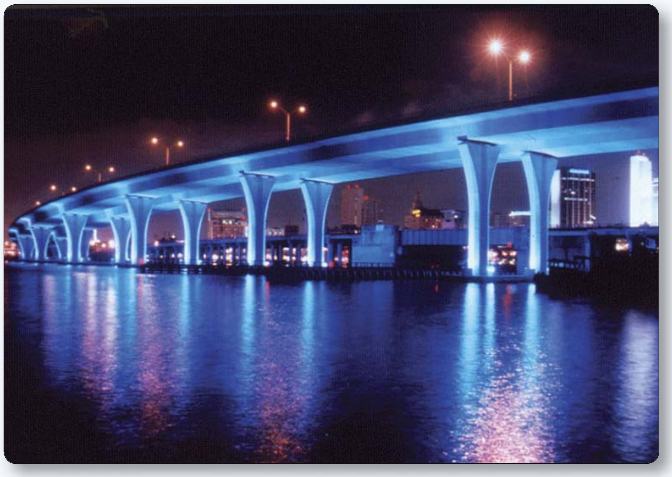


Figure B.2 – Sometimes the appearance at night is as important as during the daytime. Broadway Bridge, Miami, Florida.

- What features does the bridge traverse? Bridges over canyons or deep cuts will require a structural type that may be inappropriate for a highway crossing.

Figure B.3 – Rock foundations permit arch bridges. Reichenau Bridge, Switzerland.

- What are the widths and design speeds of the roadways being carried or traversed by the bridge?
- What types of traffic will the bridge be expected to carry or traverse? Bridges that carry pedestrian traffic will require appurtenances scaled to people more than a bridge that carries only interstate highway traffic.

Figure B.4 – Having pedestrians on a bridge suggests the addition of overlooks. Upper Middle Road over 16 Mile Creek, Oakville, Ontario.

- Are there clearance envelope requirements that can affect the layout of the bridge?

Figure B.5 – Marine channels and riverbank uses often affect bridge clearance requirements. Deutsch Bahn Railroad over Humbolthaven, Berlin, Germany.

- Is there a type of geology or in-situ soil conditions that will favor a certain type of foundation or substructure layout?
- Are you replacing an existing bridge? Is it historic? If so, is a formal historic review process in place? What are its results?

See the Background Information section for more information about historic review processes.

The Context

A structure in an urban setting will have different requirements than one in more rural locations, especially if there will be pedestrians nearby or below. The bridge should fit into its surroundings.

What is the nature of nearby land uses? Buildings? A bridge in an industrial area may warrant a different level of aesthetic design than a bridge located in a park or public place. Adjacent buildings and structures might lend existing architectural features that can be echoed in the bridge.

Figure B.6 – Nearby land uses must be considered. Clearwater Memorial Causeway, Clearwater, Florida.

- Are nearby land uses historic or is the area historic? Is a formal historic review process in place? What are its results?
- What are nearby environmental features? Will they affect the bridge in some way?
- What is the visual environment? From which viewpoints will the bridge be seen? By whom? How will any of this change with the season or time of day? Because of their size and conspicuous placement, bridges are often seen as structures that define a community. They can even be centerpieces around which a community will be built. The viewpoints from which the bridge will be seen and the view sheds that are affected by the bridge will be important.

Tip: Take lots of photos, and study them.

- How will the topography influence the bridge layout? Some examples are:
    - A high profile crossing a canyon or deep valley or a side hill alignment that is visible from a distance.

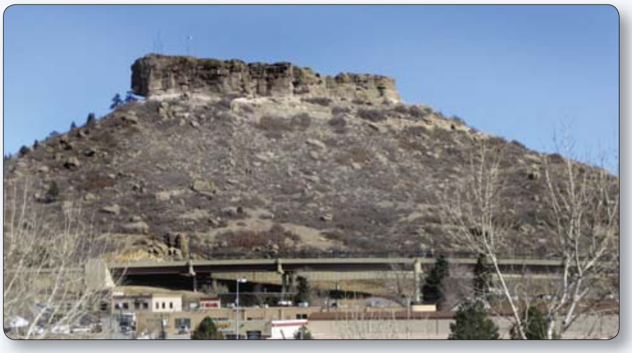


Figure B.7 – The roadway profile for this bridge needed to provide for clearance over a railroad track and made the bridge prominent in relation to the tops of buildings in the surrounding town. Skillful use of color blended this bridge into its surroundings. Perry Street Bridge, Castle Rock, Colorado.

-
    - A depressed highway section passing under a bridge.

Figure B.8 – This community entry is in a depressed roadway section and passes under a bridge. The use of massive abutments combines with the roadway side slopes to form a gateway. Meadows Parkway Railroad Overpass, Castle Rock, Colorado.

- A bridge located at the top of a crest curve on a ridgeline which frames views of the distant landscape.
- A flat coastal plane with minimal ground relief or open water. Bridges in this environment are often seen from a distance and in silhouette. The overall composition of forms may be the most defining visual image.

- Is the bridge part of a larger project, an interchange or corridor? Will the bridge have to follow a previously established theme?

Figure B.9 – Albuquerque's Big I interchange has a theme covering MSE walls, standard details and colors developed with community input.

The Community and Other Stakeholders

In every project, there are influences outside the control of the engineer which may affect the design and configuration of a bridge. Potential stakeholders include communities, elected officials, businesses, public agencies and the people that will live with the bridge after it is constructed.

Tip: Involve all concerned parties from the very beginning, before putting pencil to paper. The process will run more smoothly and the final result will address the most strongly held desires of the community and meet with their approval. See the Background Information section for more on effective community involvement.

- Are there communities, businesses or individuals nearby who are concerned about the bridge? What are their concerns?
- What is the community's attitude toward the bridge? Some communities see themselves as historic enclaves and view a bridge as a chance to restate local architectural traditions.

Other communities present themselves as forward-looking, stepping confidently into the future. These communities will be interested in a state-of-the-art bridge that embodies their aspirations.

- Are there other agencies that will review or comment on the bridge? What are their roles and opinions?
- Will an artist, architect or landscape architect be involved in the project?

See the Background Information section for tips on working with these professionals.

Owner Requirements

Owner requirements are most commonly applied by way of the owner's design standards and policies. The designer needs to recognize that, because every bridge is unique, some of the standards and policies may not completely apply to this particular project, and the owner should be made aware of that.

- Is there a previous feasibility study, Environmental Assessment, Environmental Impact Study or other document that will direct the design? What commitments have been made pursuant to those studies?
- Is there a formal project need statement that defines what the intended result of the project is?

Tip: The project need statement should be referred to periodically so that scope creep is avoided and the design remains focused.

- Does the owner have existing aesthetic design guidelines? Are they appropriate for this bridge?
- Does the client have a department or bureau that deals with landscape, urban design and bridge aesthetic design issues? Will they be involved in this project? What are their opinions?
- What are the cost limitations that have to be considered when developing the bridge aesthetic design recommendations?

Tip: An aesthetically successful bridge design will most often result when the engineer produces an economical design that expresses the function of the bridge and does not put the primary emphasis on ornamentation.

2. Develop a Design Intention/Vision

Make a written list of all of the factors that will influence the design of the bridge in their order of importance. Get comments from all involved parties and make appropriate revisions. Get it approved by the owner. This will be the basis of all future design work.

3. Do a Conceptual Engineering Study

Conceptual Engineering is the stage when all of the plausible options, and some not so plausible, are examined at a rough level of precision, with consideration of the design intent, various materials, size and form of major members, constructability, project cost, life cycle economics and appearance. The most promising ideas are then taken to greater levels of refinement. Solutions will emerge that fit the requirements of the site and that are roughly equivalent in terms of structural efficiency and economics. These solutions can then be worked to best appeal to the aesthetic sensibilities of the designer, the owner and the public.

This phase is too often short-circuited by an assumption that a standard bridge that has worked well at another location will work well here. That often means hammering a square peg into a round hole, resulting in a suboptimal bridge and unnecessary construction cost that far outweighs the cost of Conceptual Engineering. Every bridge deserves a design; everyday bridges require the application of engineering arts to the same level as do large bridges. Settling on a standard bridge type before fully understanding its requirements and opportunities shortchanges both the bridge and the public.

Figure B.10 – A Conceptual Engineering Study for the Seattle LRT viaduct produced a design that both reduced cost and improved appearance compared to a standard design.

Involve All Stakeholders in Identifying Options

Communities and review agencies will have opinions about what types of bridges are appropriate. Testing their ideas in the Conceptual Engineering phase will avoid the need to go back and look at their options later when they object that their ideas are not being considered. It will also encourage their support of the final decision. It may even result in the adoption of a superior but previously unconsidered bridge type.

Figure B.11 – Sometimes the best response to an unconventional problem is an unconventional solution. Interchange on Route A35 near Basel, Switzerland.

Test Promising Options with 3D Views Taken from the Important Viewpoints

Even seasoned design professionals have a hard time anticipating all of the visual implications of a design from 2D engineering drawings. Non-professionals sometimes have an even harder time.

Include drawings made at night and in various seasons, especially in northern locations where snow is on the ground for a large part of the year.

Tip: Most CAD software has 3D modules that make this quick and easy to do. The best approach is to place 3D drawings developed in CAD over photos taken from the most important vantage points.

Figure B.12 – Showing how a proposed bridge will affect an existing marina. Proposed crossing of the St. Croix River, Stillwater, Minnesota.

Evaluate Promising Options for Constructability, Maintainability and Costs

Through the generation and review of multiple alternatives, the process will narrow down to the concept that best satisfies efficiency, economy and elegance while still achieving the design vision. The product of Conceptual Engineering is the Type, Size and Location report.

Tip: Make sure all involved stakeholders know all of the implications of the alternatives, including comparative costs. That will facilitate their support of the final decision.

Select the concept that best integrates efficiency, economy and elegance while achieving the design vision.

4. Proceed to Detailed Analysis and Design

The next section of this Sourcebook provides practical steps in the detailed design of aesthetically pleasing bridges.

C.

Design Guidelines

The Ten Determinants of Appearance

How people react to an object depends on what they see and the order in which they see it. This means the largest parts of the bridge – the superstructure, piers and abutments – have the greatest impact. Surface characteristics (color/texture) come next, then details. Therefore, design decisions should be approached in the following order of importance.

1. Horizontal and Vertical Geometry

Before there is a concept for a bridge, the roadway geometry creates a ribbon in space that can be either attractive or unattractive. The geometry establishes the basic lines of the structure, to which all else must react. A graceful geometry will go a long way toward fostering a successful bridge, while an awkward or kinked geometry will be very difficult to overcome.

> The structural engineer must work interactively with the project highway engineers during development of the project geometry to make a suitable allowance for structure depth and define features that would enhance or detract from the overall bridge appearance. A proactive approach is highly recommended since it is extremely difficult to change the project geometry during later stages.
>
> As a guideline, the more visually challenging geometrics are also more difficult and expensive to construct, and they may result in a questionable product.

Profile grades relative to surrounding topography as well as variations in grade over the length of a bridge are major influences on how a bridge is perceived. Examples include:

- Many urban grade separations or viaducts may have minimal clearance above grade and may be perceived by the community as barriers or tunnels.

Figure C.1 – Wide bridges that are relatively close to grade often create visual barriers. In this case, use of post-tensioned caps increased the transparency of the substructure when viewed from an oblique angle. I-25 over Broadway Viaduct, Denver, Colorado.

- At the opposite extreme, the profile grade of an urban highway may extend upward past the horizon line and raise concerns related to blocking the viewshed.

In addition to the profile grade, other aspects of project geometry that influence bridge aesthetics are:

- Sag curves on the bridge alignment result in both visual and drainage problems. Consider using a slight crest vertical curve on bridges wherever possible, particularly on longer bridges as it often provides visual interest.
- Skew angle with the alignment of roadways and other crossed features often require difficult pier configurations that are oblique to the fascia, and can create a visually complex or disharmonious bridge elevation.
- Constant deck widths are preferable, but variable deck widths over the length of a bridge are often required, particularly at ramp terminals or intersection transitions.
- A bridge that is completely on a curve or tangent is more visually consistent than a bridge that contains transitions from tangent to curved alignments.
- Superelevation transitions over the length of a bridge can result in discordant variations in the perception of the bridge profile and complicate the bridge geometry.

Figure C.2 – This bridge has a reverse superelevation between the abutments. The effect of this deck geometry is that the bridge appears to be twisted, drooping between supports, and varies in depth. It is doubtful that this is the aesthetic effect the designer intended. Ramp bridge at I-25 and I-225 Interchange, Denver, Colorado.

2. Superstructure Type

The superstructure type defines the structural system used to support the bridge self-weight and applied loads. It can be an arch, girder, rigid frame, truss or cable-supported type structure. The most memorable aspect of the structure is determined when the overall shape of the structural members is established.

- Multiple girder systems, such as steel plate or box girders, prestressed concrete girders and concrete box girders, are common structural systems for everyday bridges.
- Arches or rigid frames are occasionally used in situations where visual features, atypical site conditions or project requirements make their use appropriate. These are sometimes used for workhorse bridges.
- Cable-supported bridges are often used in special situations where visual impact is important or where site conditions require a long span solution. These are very infrequently used for workhorse bridges.

Each structure type has optimum span-to-depth ratios, cross-sectional shapes, details and use limitations, which have aesthetic implications. The primary visual consideration related to structure type is structure depth.

- Generally, thinner structures with longer spans are more visually transparent and pleasing than deeper structures or structures with shorter spans.
- The apparent depth of a bridge is the combined depth of the girder, deck slab and edge railing. If this dimension becomes too large, the bridge may appear bulky and more of a barrier than a crossing.

Some guidelines to consider include:

- Continuous multi-span structures are typically shallower than simple span structures. In the case of single point interchanges, this may be helpful in reducing the impression of massiveness.
- Haunched girders can be very effective in reducing the midspan structure depth and providing a more visually interesting opening beneath the structure. In addition, the haunched girder profile often provides an interesting visual rhythm on multi-span bridges.

Figure C.3 – This bridge utilizes a haunched girder design with battered abutments to create an attractive span. The center median pier was eliminated to frame the view beyond the bridge and provide a gateway opening into the adjacent development. College Road over Route US 1, Princeton, New Jersey.

- Rigid frame bridge structures create continuity with substructures and may be appropriate for single- or two-span bridges. They may also be combined with haunching to provide a shallow arch opening beneath the bridge.
- Slant leg piers or delta frames may be suitable for providing continuity with supports and creating geometric openings beneath a bridge. This approach may be particularly attractive at the crest of a vertical curved alignment to frame the view.

Consistency is important in the selection of an appropriate structure type.

- Use of different structure types over the length of a bridge should be avoided as it often interrupts the visual line created by the superstructure and is contrary to developing a sense of unity and integrity.
- It is preferable to use the same depth of girder for the entire bridge length and not change girder depths based on the length of each individual span.
- When a series of bridges is seen as a group, such as an interchange or a corridor, it is preferable to use the same structure type.

Figure C.4 – This multi-level system interchange uses a common superstructure type to visually unify a complex geometry. I-25 and I-70 Interchange, Denver, Colorado.

3. Pier/Support Placement and Span Arrangements

Most bridges are linear frameworks of relatively slender columns and girders. Depending on the position of the observer, a bridge may be perceived as a transparent silhouette or as a collection of massive structural forms.

Pier placement establishes not only the points at which the structure contacts the topography but also the size and shape of the openings framed by piers and superstructure. The success of the visual relationship between the structure and its surrounding topography will depend heavily on the apparent logic of the pier placement.

The visual character of the bridge site has an influence on the structure layout and span arrangement. In rural landscapes with little visual evidence of development, the bridge design may respond to the site by one of the following approaches:

- Strong long-span sculptural elements that contrast with, but do not ldominate, the landscape.

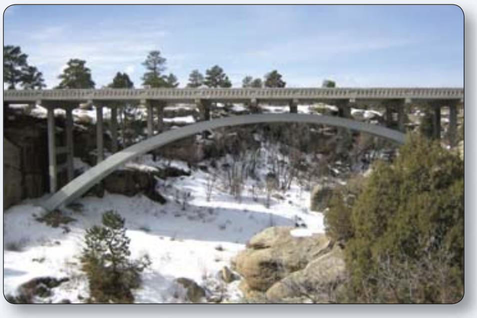


Figure C.5 – This deck arch completely spans the canyon floor and is highly transparent. The bridge and the site are complementary. State Highway 83 Bridge over Castlewood Canyon, Colorado.

- Slender elements that minimize the silhouette and are as transparent as possible may be preferable to reduce the visual impact of the project.

Figure C.6 – The substructure for this high level crossing with slender piers is virtually transparent. Meadows Parkway over Plum Creek, Castle Rock, Colorado.

While each bridge site is unique, many guidelines have been developed to consider the relationship of the span layout to the site:

- Examine the ratio of the span to vertical clearance or height. It may be appropriate to hold this ratio constant throughout the bridge. As the vertical clearance diminishes going away from the main span of the bridge, smaller side spans may be warranted. In general, the span should be greater than the height.

- Longer spans require deeper superstructures, which can have a major visual impact. This is particularly true for bridges with minimal underclearance or long span single point interchange bridges.
- Examine the fit of more classic approaches to structure composition and proportioning. An odd number of spans may be more preferable with the center span longer than the other spans and may also provide a more optimum structure design.
- Depending on the site topography, it may be appropriate to vary the span length with the height above grade.

4. Abutment Placement and Height

Abutment placement and height determine how a bridge begins and ends and, for shorter bridges, how the structure is framed. The abutment placement also establishes the shape of the end-span opening, which can have a significant influence on what can be seen beyond the structure and how well the structure relates to adjoining uses.

- An abutment is the location where a bridge touches the ground and the transparency of the structure transitions to the mass of the surrounding walls or topography.
- Abutments may have an important symbolic function, as these are the points where travelers begin and end their passage over a bridge. This is particularly true when pedestrian traffic crosses a bridge.
- Abutments frame the landscape or cityscape behind the bridge much like a picture frame defines the view of the picture it encloses.
- Depending on the underclearance and superstructure width, spaces under bridges may be very dark even during daytime. Security or maintenance considerations may influence abutment type selection.

Abutment types and visual considerations include:

- Stub-type or flow-through end bent abutments are located at the top of an approach embankment or at the top of a cut slope. From a visual perspective, the spaces adjacent to stub abutments are often slivers that are dark and distant to the observer. This may not be desirable on bridges where security or maintenance considerations may discourage the creation of spaces that are not easily viewed from a distance.
- Mid-height abutments are typically located within the limits of the side slopes and have a vertical surface whose height is a significant percentage of the overall bridge opening. This abutment type may better frame the view beyond the bridge and be more suitable for use on bridges in close proximity to the public, such as over recreational trails.

Figure C.7 – This mid-height abutment with a six-foot front face height eliminates the "sliver" silhouette of a stub abutment with a minimal abutment face height. E-470 standard bridge abutment, Denver, Colorado.

- Full-height abutments extend from the ground line to the bottom of the superstructure. They are typically more massive than other abutment types and often create a very strong definition of the bridge ends. This may be desirable for gateway bridges or for locations where framing the view of the background is important. They may also provide for improved security beneath urban bridges.

Figure C.8 – This full-height abutment strongly defines the ends of the bridge and acts as a gateway. BNSF Railroad over Meadows Parkway, Castle Rock, Colorado.

5. Superstructure Shape (including parapets, overhangs and railings)

The superstructure shape establishes the form of the structural members, including deck overhangs, parapets and railings. The superstructure can be shaped to respond to the forces on it, and the shapes of these elements and the shadows they cast will determine the intrinsic interest of the structure.

A bridge's form and details can strongly define the shadows it casts and hence influence the appearance of the structure. The overhang dimension between the edge of the bridge deck and the girder fascia can range between two extremes:

- A long overhang can create a deep shadow. When used in conjunction with a thin deck slab line and a relatively transparent barrier, the bridge is often perceived as being slender and lighter.

Figure C.9 – The shadow of the long deck overhang and relatively transparent barrier creates strong horizontal lines on this bridge. The superstructure appears to be very slender. I-25 over Woodman Road, Colorado Springs, Colorado.

- Short or non-existent overhang dimensions typically result in a massive appearance due to the combined depth of the structural components at one unbroken surface. The overall effect is to appear as a perforated wall as opposed to a series of horizontal planes.

The exterior girder fascia can be a major visual design consideration. Guidelines for fascia girders include the following:

- On curved alignments, it is preferable to use curved girders with constant overhangs. Chorded girders result in a variable overhang and shadow line. They also interrupt the lines of the bridge.
- Fascia surfaces should be continuous, even in the case of simple span girders made continuous. This can be achieved by extending the pier diaphragms to the fascia line.
- In some instances inclined fascia surfaces may be preferable to vertical fascia surfaces.

Railings and parapets may be among the most visually prominent elements of a bridge. They are located at the highest point, can be visible from a distance, and are the bridge components that are closest in proximity to drivers and pedestrians. From a cost perspective, modifications to railings and parapets are often less expensive than modifications to girders or other bridge components.

Guidelines for railings and parapets include the following:

- Railings may be preferable to a standard concrete parapet to visually lighten a structure by reducing the concrete edge height and improving views of the surrounding landscape from the driver's perspective.

Figure C.10 – This crash tested railing is relatively transparent.

- Parapets and railings are safety-tested components and their structural integrity must never be compromised in the name of aesthetics. The designer must also be mindful that articulating a parapet or railing can have the unintended consequence of creating snag points, which can be hazardous to vehicular traffic.
- While parapets are typically solid concrete surfaces, their exterior face presents an opportunity for surface articulation. The use of horizontal rustications, textured surfaces, color or other aesthetic enhancements may be appropriate to consider.

Figure C.11 – This deep barrier relief on a reconstructed concrete arch bridge is visually compatible with the original concrete barrier. State Highway 83 Bridge over Castlewood Canyon, Colorado.

- Fences attached to parapets have been used to create interesting silhouettes and to provide unique visual identities.

Figure C.12 – Decorative fencing was utilized on this bridge over I-80 in Davis, California to create a community gateway. A simple arched pipe attachment to the fence echoed the relief on the exterior parapet face. The strong silhouette of the fencing is memorable, yet relatively inexpensive to construct.

It may be appropriate to consider the underside of the bridge or soffit as a ceiling in the following situations:

- Bridges over pedestrian traffic or recreational trails will be readily visible due to the relatively slow travel speed and close proximity of the observers.
- Bridges seen primarily from below and at a distance, including: high-level urban viaducts, multilevel interchange ramps and bridges located at the top of crest curves, will also be visible.

In these cases, consider the following:

- Investigate a structure type that has a relatively simple or continuous soffit. Box girder type bridges may be preferable for use due to their wide soffit widths.
- Alternatives to standard bracing systems for multi-girder cross sections may be appropriate to consider.

- Wider girder spacing may be preferable in simplifying the soffit shape, introducing more reflected daylight onto the deck slab soffit and creating the impression of a higher ceiling beneath the bridge.

6. Pier Shape

The pier shape defines the form and details of the piers. From many viewpoints, particularly at oblique angles to the structure, the shapes of the piers will be a major influence on the impression created.

The majority of workhorse bridge piers are structural frames consisting of circular or rectangular columns with a cap beam, which supports the superstructure girders. Typically, the exterior columns are inset from the fascia girder for reasons of structural efficiency, and the cantilevered portions of a cap beam are often tapered to reduce the depth and mass at the ends.

When considering the layout of the pier shape, there are many configurations that can be used to add interest to the structure. Some of these alternatives include:

- Columns can have hexagonal or octagonal column cross sections with multiple surface planes, elliptical cross sections or more complex cross section geometry.
- Linearly taper the column cross section dimensions over the column height or use curved flares at the column capitals.
- Place the exterior columns at the outside face of the cap and eliminate the cap cantilevers to emphasize the vertical lines of the columns.

Figure C.13 – Columns have been placed at the outside edges of the pier cap, which emphasizes the vertical lines of the substructure. Similar corner details at the abutments strongly frame the bridge opening. Hiawatha Avenue over State Route 55, Minneapolis, Minnesota.

- Variable depth cap beams or beams with arched or haunched soffits between columns provide visual interest.
- Integral cap piers are within the plane of the superstructure. While this pier type is commonly used for concrete box girder bridges, it is also feasible for use on other bridge types, such as steel plate girders. From a practical perspective, this pier type has been used to accommodate vertical clearance issues that would not have been possible with drop caps.
- Inverted T cap piers have a relatively small projection below the superstructure soffit. This cap type provides a similar appearance

to integral cap piers, and they have been used widely for prestressed concrete girder bridges. A variation of this cap type is a solid pier cap with dapped end girders.

- Wall type piers are continuous planar structures that may or may not have openings or end profiles to provide visual interest.

Aside from shape and form, there are other major parameters, which can have a large influence on pier aesthetics, including: pier height, structure width and skew angle.

- Taller piers are typically more slender and result in a more transparent substructure. Shorter piers may require more columns to lessen the cap beam depth. Depending on the structure orientation, light may penetrate the interior of bridges with taller piers far more than for bridges with shorter piers.
- Narrower piers may use a single “hammerhead” cap with a single column, which increases their transparency. Wider piers may require two or more columns, which reduces their transparency, especially when viewed from an oblique angle.
- Highly skewed piers may be unavoidable and often result in a pier layout with multiple columns as is required on wider bridges. The overall visual effect may be more of a colonnade than a span.

7. Abutment Shape

Abutments may become visually massive structures or secondary structures, depending on the nature of the grading at the bridge ends and the bridge layout geometry. Abutment shapes are typically more visually important on shorter bridges than on longer bridges, since an observer is more likely to view a short bridge in its entirety. From viewpoints near the ends of longer structures, the shape and detail of the abutment will also be important. For structures involving pedestrians, the provisions made for them at the ends of the bridge can be among the most memorable aspects of the structure.

Alternative abutment shapes include:

- Wrap around abutments allow the approach embankment side slopes to extend under the ends of the superstructure, and they typically have short abutment walls on the top of the slope. This minimalist configuration can result in an abutment that has little visual relationship to the superstructure and supporting embankment.
- Massive abutments have tall continuous faces, which may be vertical or battered either inward or outward. Strong slab-like forms sharply define the bridge ends, often giving it a monumental appearance or a distinct contrast with the surrounding landscape.

Figure C.14 – This haunched Steel box girder bridge carrying 20th Street over the South Platte River in Denver, Colorado was designed as a gateway structure. The battered faces and rusticated surfaces of the full-height abutments add interest to this structure.

- Terraced abutments consist of a series of walls or stepped elements that soften the ends of the bridge and merge it with the landscape. They may also serve as planters for landscaping.

Figure C.15 – Terracing and plantings are used to visually soften the bridge ends on this crossing over US 36 in Broomfield, Colorado.

- Articulated abutments have complex geometry and may consist of a series of layered or textured surfaces to break up the scale of an otherwise massive structure.

Figure C.16 – Pilasters and offset wall planes are used to break up the retaining wall surface and strongly define the ends of the bridge. This bridge is in a town park, and a monumental image was desired. Perry Street Bridge, Castle Rock, Colorado.

8. Color

Colors have a long history of application on bridges due to their large visual impact with a correspondingly low cost relative to that associated with other bridge features and treatments. The colors of uncoated structural materials as well as coated elements and details need to be considered. Color, or lack thereof, will influence the effect of all the decisions that have gone before. It provides an economical vehicle to add an additional level of interest.

Strategies in using color include the following:

- Integrate the bridge into the surrounding landscape.

Figure C.17 – An excellent application of color was used to blend this slant leg frame concrete bridge into the high desert landscape. I-25 over State Route 599, Santa Fe, New Mexico.

- Provide for a strong bridge identity by visually contrasting the bridge with its surroundings. This may be particularly appropriate in the case of sites with little vegetation where the bridge can be viewed from a distance.
- Identify the bridge with a geographic region or culture through the use of colors that will form this association. For example, New Mexico has a tradition of coloring bridge surfaces to relate to a distinct local culture.

The use of color can be very subjective. Some approaches that have been used include:

- Very light colors may be hard to distinguish especially in direct sunlight.
- Darker colors will fade over time and any flaking will be more noticeable.
- Light colors help to emphasize shadows and provide contrast.
- Bright red, yellow and brown colors tend to emphasize the presence of size and form.
- Light blue and green colors are less bold and tend to diminish the visual importance.
- Reversing the intensity of color can reverse the effect.

Tip: Color choices are complex decisions requiring specialized technical knowledge and refined visual sensibility. This field has developed as a

consulting specialty of its own. Architects and artists get assistance in this area, and engineers can too.

9. Texture, Ornamentation and Details

Texture, ornamentation and details are elements that can add visual interest and emphasis. Structural elements, such as stiffeners and bearings, can serve this function. Indeed, traditional systems of architectural ornament started from a desire to visually emphasize points where force is transferred, such as from beam to column through an ornamental capital. Patterns of grooves or insets and similar details are other examples.

Surface Texture

Formliners and other types of surface texturing can be used to create patterns, add visual interest and introduce subtle surface variations and shading, which in turn soften or reduce the scale or mass of abutments, piers and walls.

There are a variety of formliners available. Some mimic other materials, while others have more abstract or geometric designs. Consider the following when specifying formliners:

- When simulating another material, such as stone or brick, formliners should be made as realistic as possible. Use color in addition to texture to assist in the simulation.
- When using formliners to simulate another material, avoid suggesting a material that would not be utilized in that application. For example, stone texturing on a cantilevered pier cap surface creates disharmony since a stone cantilever would not be stable if constructed.
- When a geometric pattern or texture is used, consider its relationship to the overall bridge composition. The parts must relate to the whole.
- Care should be exercised in the use of formliners for girder fascias or parapet exterior faces. Inappropriate use may disrupt the superstructure lines.

Texturing can also be achieved through rustication grooves, form strips, varying surface profiles, veneers, bush-hammering, mechanical stamping or acid washing.

A few guidelines for execution of texturing include the following:

- The use of textures needs to be closely monitored, since poor detailing or construction can severely affect the appearance.
- Depth of recess should be greater when viewed from a distance with consideration of how sunlight/shading will affect the appearance.
- The use of horizontal lines in patterns may require special attention to avoid conflict with the roadway and bridge profile, which are rarely level.
- Consider the observer’s perspective. When texture is viewed up close the relief will appear deeper and the pattern may appear more complicated.

- Consider the speed and position of the observer. Finely textured surfaces on a rural freeway bridge may not be perceptible.
- Keep it simple.

Ornamentation

While attitudes regarding the appropriateness of ornamentation in bridge design have varied over time, some best practices have evolved.

- Avoid using false structure as ornament. Aside from requiring additional costs to construct and maintain, adding false structure will rarely improve a design and is often viewed as extraneous clutter.

Figure C.18 – A variety of monumental decorative treatments have been added to this interstate overpass to disguise a standard-design bridge and attempt to make it compatible with a nearby brick factory and associated workers' housing historic district. Treatments like this should be avoided.

- Don't use ornament as "make up" to disguise an inappropriate design. The form and composition of an inappropriately designed bridge can rarely be improved by applying ornament.
- If ornament is appropriate, use it sparingly. Less is generally better than more.

" In bridge building…to overload a structure or any part thereof with ornaments... would be to suppress or disguise the main members and to exhibit an unbecoming wastefulness. The plain or elaborate character of an entire structure must not be contradicted by any of its parts. "

J.B. Johnson, 1912

Bridge Drainage

Conveyance of bridge drainage is a design consideration that often has a major visual impact on bridge appearance. If it is ignored, the consequences of having downspouts and other exposed bridge plumbing can seriously damage the appearance of a bridge.

Figure C.19 – This drainage system and pier geometry clash with an otherwise attractive overall aesthetic scheme. Union Pacific Railroad Bridge over I-25, Castle Rock, Colorado.

- Work with the roadway engineers to identify potential drainage issues before the project geometry is set. If the bridge length is relatively short, investigate conveying drainage off of the bridge without downspouts.
- If downspouts will be required, investigate their visual impact at the time the deck cross section is developed. Avoid embedded piping as this very often becomes a maintenance issue.

10. Lighting, Signing and Landscaping

Though not actually part of the structural system, these elements can have great influence on the aesthetic impression a bridge makes.

Lighting

Bridge lighting must be sensitive to motorists, pedestrians, boaters and other users. It should be selected and located to enhance and highlight the structure, yet minimize glare and unnecessary distraction. The lighting must respond appropriately to the context, both in terms of surrounding structures and environmental conditions. Considerations of wildlife and light pollution in the night sky concerns should be weighed together with those of aesthetics.

Figure C.20 – The Hathaway Bridge is located in Panama City, Florida. The structure is a variable depth segment bridge built in balanced cantilever. The pier-up lighting illuminates the piers and the underside of the superstructure. The designers chose to light the piers on either side of the navigation channel and only the ends of the side piers.

Luminaire selection and placement as well as the color of the lighting can detract from or strengthen any of the visual design elements discussed earlier. Lighting choices should be based on a clear design concept and be supported by facts.

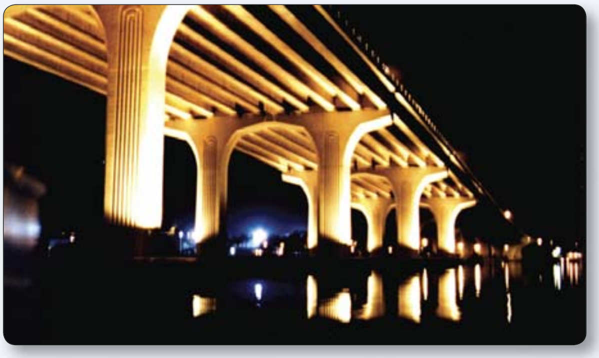


Figure C.21 – The Merrill Barber Bridge is located in Vero Beach, Florida. The pier flood lighting consists of high pressure sodium type fixtures that are mounted 12' above the waterline pile caps. The lighting illuminates the piers and the bottom-side of the superstructure.

At night, color is perceived differently depending upon the type of light source used for roadway, signage, security or aesthetic lighting. There are two ways in which lighting affects color : the actual color (or color temperature) of the light source and the way the light source renders the color of the object it illuminates.

- The yellow-orange tone of the traditional high pressure sodium source used for roadways and other transportation lighting makes many hues look grey or muddy and reduces the ability to recognize color.
- Metal halide is a much whiter light source, from the same "family" of light sources as high pressure sodium (high intensity discharge), and can be a more appropriate selection when aesthetics and color are important. Metal halide is often available in more than one color temperature, so the lamp can be selected with emphasis on either the site or the bridge itself.

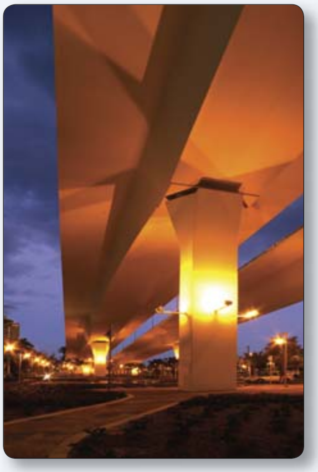


Figure C.22 – The S.E. 17th Street Causeway Bridge is located in Ft. Lauderdale Florida. The approach spans are variable depth segmental built in balanced cantilever. The feature lighting was installed on the approach spans as well as the bascule span. The fixtures illuminate the pier columns and the bottom of the superstructure.

When designed with care and sensitivity, lighting can create a strong image of a bridge that can be appreciated by all.

Tip: Aesthetic lighting design requires specialized technical knowledge and refined visual sensibility. It is a consulting specialty of its own. Engineers should consider including such specialists when developing an aesthetic lighting design.

Signing

There are two types of signs mounted on bridges. The first and most common is where the bridge itself is used as a support for a sign serving the underpassing roadway. The second is when a sign structure is erected on a bridge to serve the bridge's own roadway. This is often necessary on long viaducts and ramps. In both situations the sign usually blocks and/or complicates the lines of the bridge itself. The result is rarely attractive. Thus, the most desirable option is to keep signing off bridges. Saddling a bridge with an ugly sign or sign structure defeats the purpose of creating an attractive aesthetic bridge design. The first goal should be to seek alternate locations for signs away from bridges. This will inevitably mean more specialized structures for the signs themselves.

- When a bridge-mounted sign is required for the underpassing roadway, fit the sign into the overall design. Align the top of the sign with the top of the parapet, railing, or pedestrian fence, and align the bottom of the sign with the bottom of the superstructure.

  This will avoid having the projection of the sign disrupting the lines and silhouette of the bridge.
- Whether they are located on or off the bridge, sign structures look best when they are simple. These structures should be cleanly designed, relying on a few large members rather than truss work. It is hard to get simpler than a structure made of a single curved tube. Even the simplest trussed sign structure counts as three elements: the two posts and the truss, and that doesn't even include all of the individual members of the truss. Structures using two tubes with Virendiehl bracing can be designed to carry signs too large for a single tube.
- Design connections for sign structures on bridges as a logical extension of the structural members of the bridge. When a sign structure must be mounted on a bridge, the connection should be made so that the sign structure looks like it belongs there and not like a slapped-on afterthought.

Landscaping

Landscaping is defined here to include planted areas and hardscape: stone, brick, or concrete paving, often colored and/or patterned, used primarily for erosion control or pedestrian circulation. Landscaping should enhance an already attractive structure. It should not be relied upon to cover up an embarrassment or hide some unfortunate detail. Conversely, it should not be allowed to grow up to hide some important feature that is crucial to the visual form of the bridge. Landscaping can be a more economical and effective way to add richness and interest to a design rather than special surface finishes or materials. For example, a large, plain concrete abutment can be effectively enhanced by well-chosen landscaping.

D.

Background Information

1. Fundamentals

Aesthetic reactions are created by the eye and brain at the moment an entity is seen. The aesthetic value of a bridge is realized subconsciously – it is not created by words. Thus words cannot completely reflect the phenomena that we are trying to describe and evaluate. Nevertheless, words are a necessary part of our communication and are often used to describe or explain an aesthetic reaction after it has occurred. In order to use words to communicate about aesthetics, we need a commonly understood terminology. The following terms are borrowed from other visual design fields and applied to bridge and highway design.

a. Visual Characteristics

To be able to talk about an object, it is helpful to have names to describe its visual characteristics.

Line

A line is a direct link between two points, either real or implied. The strongest lines on a highway are created by the pavement edges. Other prominent lines are created by railings, girders, piers, abutments and the top edges of retaining walls and noise walls.

Figure D.1a – Our aesthetic reaction to this bridge is strongly influenced by the attractiveness of its parallel curvilinear lines.

Figure D.1b – The lines of this decorative pattern criss-cross the parapet overhang line and muddy the clarity of the structure.

Shape

Shape is the outline of a two-dimensional surface with spatial directions of height and width.

Figure D.2 – The haunch gives the girder a more interesting and attractive shape than a girder with parallel edges. It also indicates how the girder works structurally; it makes the girder deepest over the pier where the moments are the highest. I-81, Virginia.

Form

Form is the three-dimensional array of an object, adding depth to its height and width. 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, relationship to adjacent structures and its relationship to the space or sets of spaces that create its environment.

Figure D.3 – The three-dimensional form of a bridge is a result of the interaction of all its solid elements. Proposal for the Rich Street Bridge, Columbus, Ohio.

Color

Color can be applied to define, clarify, modify, accentuate or subdue the visual effects of structural elements. Warm colors (yellows and reds) tend to emphasize the presence and size of elements, whereas cool colors (blues and greens) diminish the visual importance of the elements to which they are applied.

Colors are perceived differently at different locations, at different times of the day and at different seasons of the year because of the changes in light conditions created by changes in sun position and atmospheric conditions.

Colors are also influenced by the background against which they are seen, and their appropriateness is often judged in terms of their fit with their background. Background is particularly important for most highway color selections because the highway element is almost always a very small part of a much larger scene, the colors of which are outside the designer's control.

Figure D.4 – A well-chosen green can help a bridge fit a wooded background. This example would be improved by choosing a green closer in hue to the foliage behind it. I-83, Maryland.

Texture

Texture refers to patterned or unpatterned roughness on the surface of objects. Texture helps define form through 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 retaining walls. Distance and motion alter the perception of texture. When viewed from a distance or at high speeds, fine textures blend into a single tone and appear flat. Generally the greater the distance, the higher the observer's speed or the larger the object to which it is applied, the coarser or larger the texture must be.

Figure D.5 – Using form liner patterns to create texture on an abutment wall. Scotch Road over I-95, New Jersey.

Shade and Shadow

Shade and shadow are important in areas of comparative darkness caused by the interception of light by intervening parts of the bridge or another nearby object. Shadow is the term usually used when the intervening object can easily be identified. The shadow that the deck overhang of a girder bridge casts on the outside girder can be a very strong component of the appearance of the bridge.

Figure D.6 – Shades and shadows help to visually define the bridges of the Big I Interchange, Albuquerque, New Mexico.

Reflections

Images of a bridge visible in the water below can be a very important part of the impression made by a bridge. Reflections of light from the ground below or other nearby objects can also help illuminate the underside of a bridge and influence our impression of it.

Figure D.7 – The importance of reflections. Branch Brook Lake, Newark, New Jersey.

b. Visual Qualities

Visual qualities result from the arrangement of the visible elements of an object and are used to evaluate a visual composition. Visual qualities are intangible; they are perceived characteristics that exist only in the mind of the evaluator.

Order

Order is the arrangement of design elements so that each element has a clear place and function with no visual confusion.

This bridge is a confusion of girders and piers – it is hard to tell what supports what.

The repetitive pier shapes and continuous girder depth give this bridge a sense of order.

Figure D.8. – Comparing disorder and order.

Proportion

Proportion is a method of creating a sense of order by assigning appropriate relative sizes to the various elements. The goal is appropriate proportions between the various parts of a structure – comparing its height, width and depth; comparing solids and voids; and comparing areas of sunlight and shadow.

Figure D.9 – The proportions of this bridge, the large depth at the abutments compared to the depth at the crown, give it a very slender appearance. Ottawa, Canada.

Proportion can suggest the order of significance of the elements or the role played by the elements in a structure. Their relative size classifies some as performing principal functions and others as performing secondary functions. For example, a slender column suggests a light load-carrying function, whereas a thick column suggests the opposite.

There can also be proportional degrees of surface texture and color.

Rhythm

Rhythm is a method of creating a sense of order by repeating similar elements in, on or around a structure. When these elements create a natural flow that is satisfying to the eye, rhythm is created. 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.

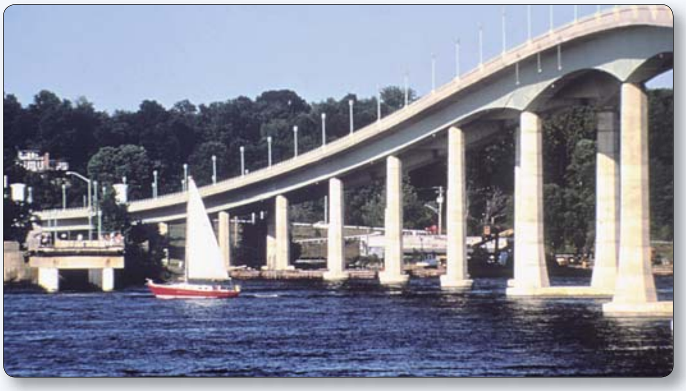


Figure D.10 – The larger main span creates a variation in the major rhythm of the piers, while the light posts create a consistent minor rhythm. Severn River Bridge (U.S. Naval Academy Bridge), Annapolis, Maryland.

Harmony

Harmony means that elements of a design have visual similarity. The relationship must be complementary. If planes or lines in a design have more dissimilar characteristics than they have similar characteristics, they are not likely to be perceived as harmonious.

The shapes of these piers are similar, and thus harmonious, even though their sizes are different. I-95, Cheverly, Maryland.

The differences in shape between the hexagonal elements of the retaining wall and the rectangular elements of the noise wall, differences which are reinforced by the color contrast, make this an inharmonious composition. I-295, Trenton, New Jersey.

Figure D.11 – Comparing harmony and disharmony.

Balance

Visual balance is the perceived equilibrium of design elements around an axis or focal point. It can mean a physical balance or it may refer to the equilibrium of abstract elements, such as areas of strong color or visual mass.

Figure D.12 – Freeway compositions work best when they are balanced about the median centerline. Avery Road over US 33, Dublin, Ohio.

Contrast

Contrast relieves the monotony of simple harmony by complementing the characteristics of some design elements with their opposites. This adds a heightened awareness of each other. Contrast often takes the form of dramatic differences in color or light and shadow.

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

Figure D.13 – Contrast in color brings out the arched vertical profile of this overpass. Pennsylvania Turnpike near Somerset.

Scale

Scale refers to the size relationship among various features of the highway and between the highway and its surroundings. Since most 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.

Highways have a larger scale because they are built for vehicles moving at high rates of speed. Highway elements such as piers or girders can be very large but appear “in scale” with the highway environment. Conflicts in scale become apparent when highway elements become part of a pedestrian environment or adjoining buildings. Ways must then be found to reduce the apparent size of the highway element so that it fits into the smaller scale environment.

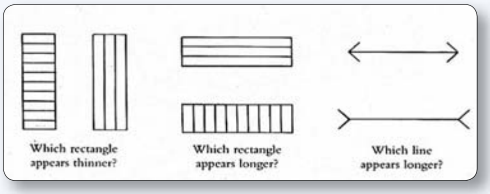
Highway bridges are very large elements, even when compared to city buildings. I-5, San Diego, California.

The overwhelming size of a typical highway element becomes clear when it is inserted into a pedestrian environment.

Figure D.14 – Highway scale.

Illusion

What people perceive is not always what is really there. Our vision is susceptible to manipulation and illusion. Designers can use illusion to improve the appearance of an element. For example, placing a series of vertical grooves on a column will make it appear thinner.



Some common visual illusions that can assist with highway design.

The slanted lines of the abutments create the illusion that the girder is longer, and thus thinner, than it really is. I-70, Denver, Colorado.

Figure D.15 – The uses of visual illusion.

Unity

Unity provides the observer with a sense of wholeness. This is generated by some central or dominating perception in the composition. It encompasses the positive application of all the other qualities, and it refers to the combined effects of all other aesthetic qualities applied simultaneously. Unity denotes the full resolution of the site and the project, where all elements are in accord, thus producing an undivided total effect.

Figure D.16 – The arch provides a central feature, reinforced by its strong color, that ties together both the man-made and natural features of this scene. I-70, Frederick, Maryland.

2. Context Sensitive Design/Context Sensitive Solutions and How to Achieve Them

Context Sensitive Design (CSD) is a process through which practitioners can apply techniques and considerations that will help shape a transportation project and yield design solutions which best serve the needs of the community. These types of solutions, having been developed through a process that takes into account input from sources other than traditional AASHTO design specifications and agency design manuals, are called variously Context Sensitive Design (CSD) and Context Sensitive Solutions (CSS). While many practitioners have been applying CSD/CSS principles for years, the topic was first formally described at the *Thinking Beyond the Pavement Conference* in Maryland in 1998.

The purpose of CSD/CSS is to (1) recognize that transportation projects have to be appropriate for the transportation need they are designed to address, (2) consider the context in which they will be constructed and (3) incorporate input from an interdisciplinary team comprised of project stakeholders. In this way, the resulting project will be one of excellence and have the support of the community and project stakeholders.

Figure D.17 – This graceful arch located in Branch Brook Park, Newark, New Jersey accommodates multiple transportation needs and reflects the geometry of its environment and companion pedestrian bridge.

The findings of the *Thinking Beyond the Pavement Conference* are summarized in the following two lists:

The CSD/CSS Product: Qualities of Excellence in Transportation Design:

- The project satisfies the purpose and needs as agreed to by a full range of stakeholders. This agreement is forged in the earliest phase of the project and amended as warranted as the project develops.
- The project is a safe facility for both the user and the community.

- The project is in harmony with the community, and it preserves environmental, scenic, aesthetic, historic and natural resource values of the area (that is, it exhibits context sensitive design).
- The project exceeds the expectations of both designers and stakeholders and achieves a level of excellence in people's minds.
- The project involves efficient and effective use of the resources (including time, budget and community) of all involved parties.
- The project is designed and built with minimal disruption to the community.
- The project is seen as having added lasting value to the community.

Figure D.18 – This stress ribbon bridge located in Freiburg, Germany provides a much-needed pedestrian crossing over a busy street. The bridge exhibits an excellent, economical design and has become a noteworthy structure in the community.

The CSD/CSS Process: Characteristics of the Process That Yield Excellence:

- Communication with all stakeholders is open, honest, early and continuous.
- A multidisciplinary team is established early, with disciplines based on the needs of the specific project and with the inclusion of the public.
- A full range of stakeholders is involved with transportation officials in the scoping phase.
- The purposes of the project are clearly defined, and consensus on the scope is forged before proceeding.
- The highway development process is tailored to meet the circumstances. This process should examine multiple alternatives that will result in a consensus of approach methods.
- A commitment to the process from top agency officials and local leaders is secured.

- The public involvement process, which includes informal meetings, is tailored to the project.
- The landscape, the community and valued resources are understood before engineering design is started. A full range of tools for communication about project alternatives is used (such as visualization).

FHWA and most state DOT's have recognized the importance of this approach to project development. In addition to guidelines available at the local level, FHWA has its own website **http://www.fhwa.dot.gov/csd/** and has sponsored the development of a separate CSD/CSS website, which can be accessed at **http://www.contextsensitivesolutions.org/.** These websites contain extensive treatment of CSS/CSD, and the reader is encouraged to visit them for additional information.

3. Community and Stakeholder Involvement

A citizen participation process is a mutual educational process between the engineers and the citizens. The engineers are educating the citizens about reasonable bridge types, costs and other implications for the site in question, and the citizens are educating the engineers about community concerns, perceptions and values for the site in question. Like any educational process, it must begin with a willingness on the part of the *educatees* to listen to and understand the *educators*. The best way for both groups to get to this point is through face-to-face dialogue and recognition of the resulting trust that will be produced.

Here are some practical tips for a successful citizens participation process:

1. **Create opportunities for mutual education by the citizens and the engineers.** The two groups need opportunities to develop a face-to-face relationship and discuss general topics of mutual interest before being faced with the stress of decision making on the project itself. A valuable technique is a joint field visit to the project site. The citizens will be on familiar ground. Indeed, they will know more about some aspects of the site than the engineers do. This puts them on a more equal footing with the engineers and makes them more receptive to comments from the engineers about the structural possibilities at the site.

2. **Before putting pencil to paper, encourage citizen participation in developing the bridge alternates to be studied.** Citizens will come to the process with a general idea or vision as to what they think the bridge should look like. It is very important for the engineers to understand what these visions are and to address them at an early stage. They may in fact be impractical; however, such ideas can be addressed in general terms in the first round of alternative evaluation. The impracticality, whether it be cost or structure, can be addressed at this early stage before too much time or money has been spent. If all of the citizen visions are not addressed at the beginning, their sponsors will not be able to let go of them. They will continue to raise their ideas, and the whole process may be disrupted or delayed.

Including the citizens in the development of alternatives from the very beginning increases the likelihood that they will possess a sense of ownership about the final result, avoiding the need for a later stop and restart. Of course, it is always possible that the citizens will come up with something that the engineers had not imagined. This possibility has to be recognized and encouraged.

3. **Develop enough alternatives to cover all of the possibilities.**
The alternatives selection process should start with a minimum of four technically appropriate alternatives. These concepts should have already been through a conceptual engineering phase and be technically sound, economical and efficient solutions that meet the needs and constraints of the site and can be further advanced at a minimum of risk. This will give citizens a full range of the possibilities and provide for further education of the citizens and the engineers as to their mutual areas of concern.

A frequent error is to take community opinion too literally. Communities tend to ask for what they are familiar with, often a copy of the bridge that they had before, thereby missing the opportunity for a new and even better solution. It is up to the designer to let them know what all of the options are **before** they make up their minds. His or her role is like that of the trumpeter in a jazz band. By their applause, the audience influences what the band plays, but it is still the musician that blows the horn.

4. **Present all alternatives in three-dimensional form, showing the bridge in its actual setting.** Without good 3D images, everyone involved will form a different mental image of what the bridge will look like. The result is endless arguments over differences in individual impressions, none of which are accurate.

The techniques that are available to resolve this problem, such as three-dimensional CAD-based drawings over photographs, are now commonly available at a reasonable cost and should be used liberally.

Figure D.19 – 3D-computer rendering over a site photo used as part of a successful citizens participation process. Veterans Memorial Bridge over the Missouri River, Bismarck, North Dakota.

5. **Fully disclose all technical and non-technical information, including cost, budget and cost sharing.** If the citizens are to be full participants in the decision-making process, they need to have access to all of the information. The major engineering constraints and cost implications need to be explained. Citizens are taxpayers; faced with realistic and

credible information about cost, they will, in most cases, draw the logical conclusion. However, their logic may not be the same as the engineer's. Citizens may consider it logical, in view of the importance they attach to the bridge, to spend some of their money on features added for their contribution to the appearance of the structure, and they have a perfect right to do so.

Such decisions are often complicated by policy-level considerations about the responsibilities of the different levels of government for the various features of the bridge. For example, the state transportation department might be willing to pay for the major features of the bridge but not for a nonstandard ornamental railing. These issues can be anticipated in advance and should be sorted out among the governmental decision-makers before the community involvement process begins. The community should have a clear understanding from the beginning about which pocket various costs will come from and what the budget limitations of the project are.

6. **Provide multiple iterations of review and narrowing of alternatives.** Some concerns may not be aroused until a proposal reaches the table. The process needs to allow for incorporation of these ideas, with revision, extension and reevaluation of the possibilities in a second or even third round of review.

   Multiple rounds of review also allow for the deferral of details to the later rounds of review. There is no need for the basic decisions about structural type to get hung up at the beginning because of debates about railing details.

7. **Make a presentation to an elected or appointed body and/or to the larger public for ratification and approval.** Even with the best citizen participation process there may remain a disgruntled minority who feel that their views have not been appropriately heard or reflected in the final decision. In order to forestall the later derailment of the process by this group, the selected alternative should be a given a formal review process during which the formal commitment of the appropriate decision-making body or elected officials is received. This will make it more difficult and less likely for those individuals to change their minds at a later date should other objections surface.

A community participation process conducted along these lines makes possible reasoned debate based on a common vision of what the new bridge should look like. While time-consuming in terms of labor-hours, the process may well save both labor-hours and calendar time by resolving issues in an orderly and timely manner, rather than through an endless series of contentious hearings and redesigns. Best of all, the process will result in a clear and specific mandate for the appearance of the new bridge.

More information on community participation may be found at **http://www.fhwa.dot.gov/environment/pubinv2.htm,** FHWA's community participation website, and at **http://www.fhwa.dot.gov/reports/pittd/cover.htm,** a publication on Public Involvement Techniques for Transportation Decision-making by FHWA and FTA.

4. Practical Tips When Historic Bridges or Historic Settings are Involved

The approach to replacing an individually historic bridge or a bridge located in historic districts is no different than any other design. The same principles and guidelines that underlie good aesthetic design should be used. In fact, the ten guidelines for design, with their emphasis on using massing, size, scale and character of the setting to guide design of an appropriate and appealing bridge, provides exactly the same approach that National Park Service guidance has promoted since the early 1980s when *The Secretary of the Interior's Standards for Rehabilitation* was first issued. The National Park Service guidance, in the form of ten standards that outline how to work on historic properties, was developed for buildings, but they proved so practical and broadly applicable that they are now applied to all types of properties, including roads and bridges.

Contrary to the all-too-common practice of taking a standard design-bridge and applying conjectural historic decoration and then calling it compatible, the *Standards* call for the use contemporary design that clearly differentiates new construction from the old. Nowhere do the *Standards* say that new work has to mimic the old. To the contrary, they state that "changes that create a false sense of historical development shall not be undertaken." The 1983 version of the *Standards* direct that "contemporary design for alterations and additions ... shall not be discouraged when such alterations and additions ... are compatible with the size, scale, color, material, and character of the property, neighborhood or environment." Unless the new design is going to be a faithful reproduction of what is being replaced, which is rarely the case, national preservation guidance for working with historic resources calls for using contemporary design that is compatible with the historic context, not modern bridges decorated to look like something old.

The Secretary of the Interior's Standards for Rehabilitation and *Treatment of Historic Properties* are further explained at **http://www.nps.gov/history/tps/standguide/.** This user-friendly website explains application of both the standards and the treatments.

When historic bridges were built, they were usually examples of then-current technology, and this time-honored practice should still be used to develop pleasing examples of current technology that blend with their setting. In historic districts, where often ordinary bridges are "historic" not in their own right but because they are located within the district boundary and were built within its period of significance, it is often scale, shape and railing design that are the most important considerations affecting whether the new bridge is compatible, not applied decoration. All-too-often decorative treatments that try to make the new bridge something that it is not are used to make the new bridge "aesthetic" and thus an acceptable replacement for the historic bridge. Decoration intended to disguise the structural functionality of a new bridge should not be used.

Figure D.20 – This box beam bridge, which relies on applied decoration instead of good aesthetic design for its appearance, illustrates what can happen when historic context is not understood. Built in an area where native stone is not common and thus not used for bridge superstructures and parapets, this bridge, with its retarditaire detailing, ignores the fact that the steel stringer historic bridge it replaced was a straight-forward example of up-to-date technology when it was built in 1914. The result is a pretentious design that is not compatible with the actual history and character of the proto-industrial 19th and early-20th century town. Designs like this should be avoided.

The bridge engineer should understand how historic materials and finishes were applied before using them as a treatment on a new bridge. They should be used only when plausible and appropriate for the setting. For instance, form lines imitating stone should be used only where stone is an indigenous material and in a manner that is structurally appropriate, like for load-bearing abutments. Stone-like finishes are not appropriate for railings on cantilevered deck sections where there is no logical means of support. Likewise, the open balustrade railing was an urban bridge feature, which means that using a contemporary version like the popular Texas railing should be limited to urban bridges, not on those in rural areas or wooded areas.

Contemporary designs that are compatible and quietly blend with their historic settings should be used rather than applying decoration that creates a false sense of history. The goal should be to let the historic resources dominate, not the new feature.

Figure D.21 – This steel stringer bridge reflects how not understanding aesthetic design, history of bridge-building technology, historical significance, and The Secretary of the Interior's Standards resulted in a cluttered design and a false sense of history. The applied decoration to an otherwise appealing bridge was required by the state historic preservation officer to mitigate an adverse effect on a historic district where land was taken for a short section of roadway. The stone-veneered substructure is not an appropriate pairing with a two-span continuous stringer bridge, and it mimics the real stone masonry that dominates adjacent historic resources. The textured concrete skirt disguises the structural functionality of the superstructure, and the Texas railing is not appropriate for the rural setting and the rustic manipulated landscape the bridge abuts. A simpler design would have been more appropriate and successful at this site.

It is important to understand why a property is historic and to use that information to guide the new designs. The sources of significance are many, from associative and architectural to technological and city planning, and the source of significance will define the important aspect that should be picked up in the new design. In historic districts, the scale is often the most significant feature.

Figure D.22 – This new bridge was designed to be a faithful reproduction of the handsome but severely deteriorated 1912 arch bridge that was a significant feature in the National Register-listed Iuka Ravine Historic District. The decision to accurately simulate the previous bridge and provide the required budget was based on the strong desire to preserve the period character of the manipulated landscape. In this instance, reproducing the past is an acceptable approach. Indianola Avenue over Iuka Ravine Historic District, Columbus, Ohio.

Figure D.23 – The balustrade design also satisfies current safety standards.

5. Working with Architects, Landscape Architects and Artists

In the Introduction section of this Sourcebook, we noted that engineers must accept concern for appearance as an integral part of bridge engineering. Gifted engineers working without the assistance of architects, artists or other visual professionals have produced masterpieces. Thus, it is not necessary for all bridge design teams to include visual professionals. The engineer should seek to develop his or her skills to meet this requirement. However, for reasons of time or personal inclination, this is not always possible. Accordingly, engineers have often sought the advice of other visual professionals – experts in aesthetics who are consulted in the same way as experts in soils, traffic and wind. Many memorable bridges illustrate the potential success of this approach if done well; the Golden Gate Bridge is just one example.

Such collaboration does not relieve the engineer of the responsibility to be knowledgeable about aesthetics. As the leader of the design team, he or she remains responsible for the final result. Many over-decorated and expensive failures have been created when the collaboration was done poorly or when someone other than the engineer took over the lead role. The visual professional's role should be as aesthetics advisor and critic, making comments and suggestions for the engineer's consideration. A landscape architect, urban designer, architect or artist can have a positive impact as an aesthetic advisor and critic, but the engineer must have the last word.

Figure D.24 – This bridge was the result of a successful collaboration between an engineer and architect. Clearwater Memorial Causeway, Clearwater, Florida.

If their involvement is to be successful, the engineer must be sure that his or her advisors understand the basic issues involved in bridge design. Most visual professionals are used to dealing with buildings and their immediate surroundings, but bridges are significantly different than buildings. Appearance is a matter of perception, and the perceptions of people in and around buildings are different than their perceptions around bridges. People in and around buildings are walking, standing, sitting or even lying down. Most people viewing bridges are moving at 30 to 70 miles per hour and view the bridge through the windows of an automobile. Their perceptions are significantly altered in ways that are not immediately obvious. Bridges are also often larger than buildings; thus they are seen from greater distances and have a greater impact on the landscape and the people around them. Small elements which are important at the scale of a building, such as bricks, can become visually lost when applied to a bridge. Few landscape architects, urban designers, architects or artists have the training, experience or perspective to work effectively in this field without taking the time to understand these issues.

Effectively working with other visual professionals also requires that the engineer develop sufficient knowledge about aesthetics and sufficient self-confidence to recognize valuable ideas and reject inappropriate ideas. Engineers are sometimes handicapped in this process because they are used to making decisions based on calculations and tests that seem to result in just one answer. But most engineers realize that, for any given situation, there will be many concepts that will satisfy analysis and economy. The designer's goal must be to choose the one that best fits the situation, a decision that can often be made on the grounds of aesthetics.

Some have observed that the public seems to more readily accept bridges designed by teams that include architects, urban designers or landscape architects than those that are not. People may feel that more of their goals will be met when such professionals are involved, in part because most people in these professions are skilled at responding to community concerns. Unfortunately, engineers have a reputation for being insensitive to community wishes, due in part to many engineers' inability to speak clearly and knowledgeably in this area. The engineer needs to have the vocabulary and knowledge to remain the project's spokesman to the client and community groups, even concerning aesthetic ideas. Gaining the vocabulary and knowledge to respond to a community's aesthetic concerns allows an engineer to fulfill the leadership role and retain the community's confidence.

Finally, given that the engineer retains the final responsibility for the design, the most accurate way of referring to a consulting visual professional is as "aesthetic advisor."

6. Bridge Aesthetics and Cost

Design and construction of short and medium span bridges in the early 21st century is, generally speaking, in a relatively static and highly optimized condition. Girder bridges primarily made from structural steel, reinforced concrete and prestressed concrete have been the dominant bridge form for about the last 100 years. This type of bridge is the most cost efficient and quickly-built structure for the great majority of spans constructed around the world. Other forms, which are usually considered more attractive, typically only become economical for spans greater than those needed for workhorse bridges. For example, cable-stayed bridges are usually the most economical bridge type in the 700 foot to 2000 foot range and suspension bridges become the only viable structure for spans greater than about 2000 feet. The only other significant aesthetically pleasing forms—the arch, and to a lesser extent, the truss—are today rarely the most economical bridge solution for any span length.

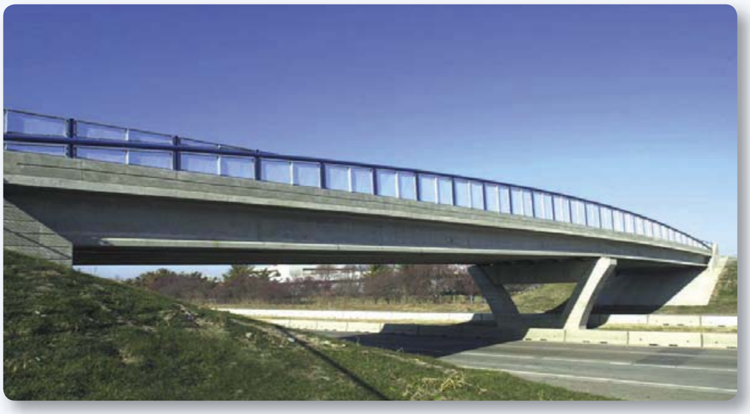


Figure D.25 – Developing better standard details for the I-235 Reconstruction in Des Moines, Iowa resulted in a whole series of more attractive bridges without a major increase in cost.

The girder bridge, be it a post-tensioned cast-in-place box, pre-tensioned I-girder, steel rolled section or welded plate girder, has become the most common type of structural system for several reasons. Ductile, high-strength tensile materials developed in the last century in the form of prestressing strands and structural steel allow for thin and efficient flexural members of constant depth that can provide a large clearance envelope. Big, rectangular openings are required underneath most bridges whether it is to allow for the passage of vehicles or flooded rivers. Girder bridges are also easily adapted to the demands of roadway geometry. Roadway designers can create curved, flared or skewed roadways without worry as girders can be curved, splayed and adjusted for length with relative ease.

Multi-girder bridges consisting entirely of pre-manufactured individual girders have become the principle structural system in many regions of the country. Bridge beams are economically mass-produced in either steel or concrete and can be easily deepened and lengthened to fit the required span. Additionally, multi-girder bridges are easily built in stages, which make them ideal replacement structures for existing bridges. The independent, self-supporting nature of these line elements allows for them to be placed adjacent to an existing bridge in nearly any required structure width—all while traffic is maintained on the old bridge. Finally, and increasingly more importantly, multi-girder bridges can be constructed rapidly because the pre-manufactured concrete and steel girders can be placed with little or no falsework.

None of the non-girder bridge types can claim all of these advantages. Therefore it is likely that the girder bridge will remain the dominant form until some new technological breakthrough occurs. Meanwhile, most of the technical progress in short- and medium-span girder bridges will likely come in the form of even more optimized shapes, details and production methods of these various types of girders. As a result, it is likely that least-cost bridge solutions will result in a continuation of the same general bridge architecture.

Nevertheless, there are opportunities to achieve superb aesthetics in bridge design. With the advent of prestressing in the U.S., some states' Departments of Transportation have made a commitment to building elegant, cast-in-place concrete box girder bridges and have found these structures very economical in their circumstances. They are frequently placed on sculptural piers that are in visual harmony with the superstructure. With these and other types of girder bridges, there continues to be architectural opportunities involving the refinement of individual elements. As discussed in the Design Guidelines section, careful design of secondary elements such as piers, abutments, lighting standards and railings can improve the appearance of simple girder bridges without much increase in overall cost. Smooth-sided, prefabricated concrete or steel tub girders can improve the aesthetics of multi-girder bridges, but they are usually somewhat more expensive than I-girders.

There will also continue to be opportunities for least-cost construction to occur in conjunction with excellent bridge architecture in special situations. For short spans (up to about 40 feet) precast concrete arches can be economical. Unusual site conditions, special purpose structures (e.g. light rail bridges and pedestrian bridges) or extremely long, multi-span projects can make creative one-off designs economical. For example, concrete segmental bridges, while typically classified as girder bridges (an exception is when they are incorporated into cable-stayed structures), can offer opportunities for whole-width box girders not otherwise economically viable in most parts of the country. In congested urban areas, their above-ground delivery and construction methods may make them a realistic choice for large projects.

Of course long spans are almost always visually appealing and are routinely built by least-cost methods. By virtue of their size, rarity and opportunity for the utilization of other, more-elegant forms, they easily captivate the viewer. However, opportunity for economical aesthetics also exists for spans longer than those employed in routine overpass and creek crossings but shorter than those usually employing unusual structural forms. As a general guideline, in the 200 foot to 700 foot range, steel and concrete girder bridges can be made less expensive and at the same time made more attractive by varying the section depth. The bottom soffits of such haunched girders can be gracefully curved so the cross section is deeper at the piers and thinner at mid-span.

The most significant opportunity for improved bridge aesthetics may be in the philosophical shift in community values that has begun to occur in the last few decades.

Around the globe, cities and towns are re-awakening to the notion that certain high-profile bridges can have a tremendous, positive social impact. Structures in some locales can become essential artistic statements that define the ideals and values of the people who will live with them for many decades.

No longer is it just the unsightly bridge that is unacceptable to some communities, but the finely-proportioned, if unspectacular, girder bridge is increasingly being rejected. When their opinions are solicited, residents frequently favor much more impressive arch and cable structures. Moreover, some communities are even dismissing traditional arch and cable proposals for more daring and contemporary variations of these forms. This is frequently seen in the design of pedestrian bridges where the engineer is liberated from the severe restrictions of the highway geometric plane, overhead clearance criteria and robust traffic railings. However, using such variations for vehicular bridges is particularly challenging for the engineer, who is forced to meet accepted highway design criteria while utilizing structurally or functionally inefficient systems.

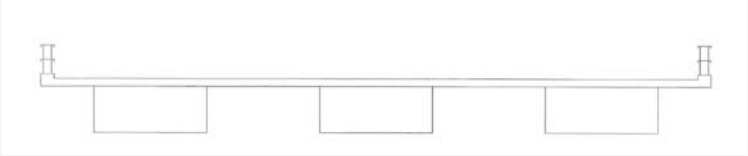
Needless to say, the cost increase of these bridges is more than just a little. A seemingly simple shift towards a cast-in-place box girder bridge in a region of the country that relies on inexpensive manufactured girders can double the cost. The use of non-girder bridge types for short- and medium-span bridges can easily increase the cost four- or five-fold. It is not unheard of for some dramatic and structurally extravagant arch or cable structures to cost ten times more than simple girder bridges. Only the future will tell how long this new philosophy will endure. It seems likely, however, that the balance point between aesthetics and cost will continue to change with the shifting fortunes, economic conditions and values of individual communities.

E.

Example Bridges

Genesee Mountain Interchange (1972)

Location	I-70, Colorado
Client	Colorado DOT
Designer	Colorado DOT
Maximum Span Length	180 Feet
Total Area	10,900 SF
Cost	N/A



This graceful bridge is the ideal structure for its locale. As motorists travel west out of Denver on I-70, this bridge on the crest of a hill frames their first view of the spectacular Rocky Mountains. The center bent, typical of overpass structures, was purposely eliminated in order to open the view. As a result, only three essential architectural elements remain – the girders, the abutments and the railings.

The superstructure consists of three steel box girders. The designers utilized a haunched profile which adds grace to the structure. In order to achieve a shallow depth at midspan, full moment connections were required at the abutments. However, the tall abutments do more than just provide a tremendous vertical force couple; they also increase the view opening with angular shapes and provide elegant pedestals on which to support the girders. The open railing visually lightens the superstructure and enhances its long slender shape. The combination of the angular abutments with the slender, haunched superstructure energizes the composition and invites the motorist to the mountains beyond.

NB81 Direct Connector over I35 (2007)

Location	Hillsboro, Texas
Client	Texas DOT
Designer	Arcadis, Houston, Texas (Lead) and Texas DOT – Bridge Division (Substructure Concept and Design)
Maximum Span Length	135 Feet
Total Area	11, 500 SF
Cost	$117/SF

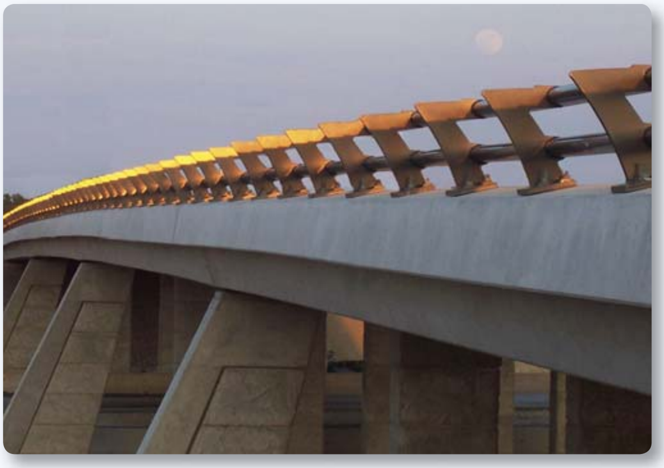
This modest underpass is an architecturally appropriate structure for an interstate highway. The four-span structure has a girder depth of just 50 inches. The appearance is dominated by the strong horizontal lines of the superstructure created by the use of various materials. The dark weathering steel girders create a thin continuous band running the entire length of the bridge. The contrasting concrete deck and parapet keep the entire composition thin. A light perforated railing adds visual interest and introduces a third material – galvanized steel.

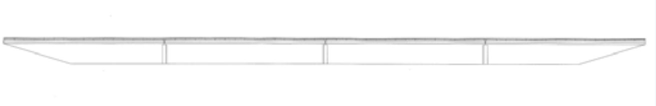
The light superstructure is important for maintaining good proportion. Because of limitations for cross section with of the lower roadway, the columns were limited in width to just 3 feet. Frequently, narrow columns can be visually overpowered by deep concrete beams and tall, solid railings. The proportions were improved by adding mass to the columns in the transverse direction. The columns are 4'- 4" wide at the top and increase in width as they descend. Because of varying cap cross-slope and undulating terrain, each column base has a different width, but the maximum is approximately 7'- 6". This mass is also needed to meet the new, stringent LRFD requirements for vehicular impact.

The bent design itself adds subtle contrast to the simple, ordered superstructure. The slightly curved cap soffit and sloped columns ground the structure while adding a touch of daring. Shallow reveals at the top of the columns articulate the cap and hide the construction joints. Visual perspectives are enhanced by the 6-degree horizontal curve and 43-degree skew in combination with the splayed columns. To keep the bents stain-free, small tabs were welded to the exterior girder bottom flanges which prevent water from moving along the girder and reaching the bents. As an additional measure, the exterior girder bridge bearings rest on stainless steel drip pans.

Loop 340 over I35 (2007)

Location	Waco, Texas
Client	Texas DOT
Designer	Texas DOT Bridge Division (Lead) and Structural Engineering Associates (Beam Concept and Beam Design)
Maximum Span Length	115 feet
Total Area	Two bridges at 22,200 SF (ea.) and two bridges at 26,800 SF (ea.)
Cost	$86/SF





Unique replacement structures needed to be built quickly with minimal disruption to interstate traffic. Furthermore, the spans required lengthening without increasing the structure depth. The result was a new type of girder, the Pre-Topped U-Beam, which has a span-to-depth ratio of 46 (36 if the composite slab is included). The beams were pre-assembled near the bridge, and composite slabs were cast with gaps at the midpoints between girders. After setting the beam/slab elements at the bridge site, long and narrow (16") closure joints were quickly cast in place.

The sloped beam web and distinctive curb and railing dominate the aesthetic appearance. The exterior girder is located close to the edge of slab so that it is rarely in shadow, and the rail curb is exaggerated vertically and severely undercut to create a strong horizontal band. The striking railing is also new; this is the first-ever use of the T77, which has been successfully crash-tested to TL-3 standards. A metallic automotive paint was chosen to contrast the matte concrete appearance and heighten the stylized post shapes.

The rather widely-spaced beams allowed for the possibility of eliminating the bent caps. Removing this element and setting the beams directly on columns also accelerated construction but unfortunately required two additional columns per bent line. Eliminating the bent cap, while not often possible with routine bridges, also enhances the overall appearance as the eye can naturally follow the longitudinal girder line without the interruption of this jarring transverse element.

The exterior columns are inclined to impart architectural vitality to the composition by repeating the slanted structural motif, while increasing the mass to withstand vehicular impacts. The horizontal striations on one side allude to the resulting compressive forces on the interior face, and the smooth uninterrupted exterior face emphasizes the need to withstand continuous tensile forces along the entire outer surface.

F.

Bibliography

Bridge Aesthetics References

Bill, M. *Robert Maillart: Bridges and Constructions*. 3 ed. Trans. by W.P.M. Keatinge Clay. New York: Praeger, 1969.

Billington, David P. *The Tower and the Bridge*. New York: Basic Books, 1983.

Billington, D.P. *The Art of Structural Design: A Swiss Legacy.* New Haven: Yale University Press, 2003.

Billington, D. P. *Robert Maillart's Bridges*. Princeton: Princeton University Press, 1979.

Billington, D. P. *Robert Maillart: Builder, Designer, and Artist*. Cambridge, New York, and Melbourne: Cambridge University Press, 1997.

Buckland, P. G. "The Inherent Beauty of Cable-Stayed Bridges". In *Esthetics in Concrete Bridge Design*. Detroit: American Concrete Institute, 1990.

Figg, Eugene C. "Public Involvement Creates Revolutionary Bridge Design". In *Proceedings of the International Bridge Conference*. Pittsburgh: Engineers Society of Western Pennsylvania, 2001.

Finley, R. Craig. "Five fundamentals of bridge design". *CE News* 13 (August 2001): 48-49.

Gauvreau, P. "Innovation and Aesthetics in Bridge Engineering". *Canadian Civil Engineer 23.5* (Winter 2006-2007): 10-12, 2007.

Gauvreau, P. "Engineering and Urban Design: Who Leads Whom?" *1st CSCE Specialty Conference on Infrastructure Technologies, Management and Policy.* Montreal: Canadian Society for Civil Engineering, 2005.

Gauvreau, P. "The Three Myths of Bridge Aesthetics". *In Developments in Short and Medium Span Bridge Engineering 2002,* pp. 49-56. Ed. P. H. Brett, N. Banthia, and P. G. Buckland. Montreal: Canadian Society for Civil Engineering, 2002.

Giedion, Siegfried. *Space, Time, and Architecture*. Cambridge, Mass.: Harvard University Press, 1952.

Gottemoeller, Frederick. *Bridgescape: The Art of Designing Bridges.* New York: John Wiley & Sons, 1998.

Leonhardt, F. *Bridges: Aesthetics and Design*, 308 pp., Deutsche Verlags-Anstalt (MIT Press, Cambridge, Massachusetts), 1982.

Mock, Elizabeth B. *The Architecture of Bridges*. New York: The Museum of Modern Art, 1949.

Salvadori, M.G. *The Message of Structure, Engineering and the Humanities*, pp 190-205, Ed. James H. Schaub and Sheila K. Dickison, John Wiley & Sons, New York, New York, 1982.

Sullivan, Louis. *Kindergarten Chats*. New York: Wittenborn, Schultz, Inc, 1947.

Torroja, E. *The Beauty of Structures, Philosophy of Structures*, pp 268-289, University of California Press, Berkeley, California, 1958.

Zuk, William. "A Rating Index for Bridge Aesthetics". *Concrete International 17* (August 1995): 45-47.

Links to Publications Available Online

Innovation and Aesthetics in Bridge Engineering. Gauvreau, P. 2007.

Engineering and Urban Design: Who Leads Whom? Gauvreau, P. 2005.

The Three Myths of Bridge Aesthetics. Gauvreau, P. 2002.

Links to Informative Webpages & Sites

CASE STUDY: Central Susquehanna Valley Thruway Gateway Project (Pennsylvania)
http://www.seda-cog.org/seda_cog/lib/seda_cog/Crc/bridge_case_studies.pdf

Iowa DOT Bridge Aesthetics Webpage
http://www.dot.state.ia.us/bridge/aesthetics.htm

Corus Company – Bridge Aesthetics Webpage
http://www.corusconstruction.com/en/reference/teaching_resources/architectural_studio_reference/design/bridges/bridge_aesthetics

Links to Transportation Agency & State DOT Manuals

Alberta, Canada
http://www.infratrans.gov.ab.ca/INFTRA_Content/docType30/Production/AesStudy0405.pdf

Australia (New South Wales)
http://www.rta.nsw.gov.au/publicationsstatisticsforms/downloads/bridge_aesthetics.pdf

Massachusetts Highway Department , Bridge Manual, Section 2.2
http://www.mhd.state.ma.us/downloads/bridge/CHAPTER%202%202005.pdf

New York State DOT, Bridge Manual, Section 23
https://www.nysdot.gov/portal/page/portal/divisions/engineering/structures/repository/manuals/brman_4th_edition/section23_4-06.pdf

Credits for Sourcebook on Bridge Aesthetics and Companion Web Site

Task Force Leader	Frederick Gottemoeller

Sourcebook

Why Consider Aesthetics?	Frederick Gottemoeller
How To Consider Aesthetics	Frederick Gottemoeller Joseph Showers Eric Yermack
Design Guidelines	Joseph Showers David Traini Faith Baum Eric Yermack
Background Information	Frederick Gottemoeller Mary McCahon Robert Shulock Dean Van Landuyt Eric Yermack
Example Bridges	Dean Van Landuyt
Bibliography	Tom Morreale
Review and Comment	Faith Baum Alan Matejowsky Mary McCahon Mary Ann Nabor Robert Shulock Bryan Spangler Dale Thomas
Editing	Ken Wilson Eric Yermack
Graphic Design/Art Direction	Chitttrat Amawttana (Gail), Oregon DOT

www.bridgeaesthetics.org

Home/Introduction	Geoffrey H. Goldberg
Icon Bridges	Ken Wilson
Featured Project	Richard Beaupre Juan Sobrino
Insights from Practitioners	Bob Healy
Fundamentals	Frederick Gottemoeller
Design Competitions	Future
Bibliography	Tom Morreale
Contacts and Links	Geoffrey H. Goldberg
Events	Geoffrey H. Goldberg
Webmaster	Geoffrey H. Goldberg

Photo Credits

To be supplied in the Final Edition

Bridge Aesthetics Sourcebook

Practical Ideas for Short and Medium Span Bridges

Draft, March 2009

TRB