AESTHETIC DESIGNS FOR SHORT TO MEDIUM SPAN CONCRETE BRIDGES

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EXPANDED ABSTRACT

INTRODUCTION

A term, which has gained popularity and importance within the transportation industry, during recent times, is Context Sensitive Solutions (CSS), also referred to as Context Sensitive Design or Thinking Beyond the Pavement. CSS is defined by the FHWA as *"a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources, while maintaining safety and mobility.* The involvement of the project's stakeholders, in a CSS process, occurs early in the project timeline and continues through the construction phase. A CSS process promises to deliver many benefits to an agency, for example, effective and timely decisions, gaining public trust and support, building positive relationships with resource agencies, delivering safe, aesthetic, and financially feasible project solutions, while improving the overall project delivery process.

The Federal Lands Highway (FLH) is responsible for the engineering and construction of aesthetic, safe and environmentally sensitive roads and bridges on some of the nations most beautiful lands, the Nations Parks. The FLH project development process is a good example of an efficient CSS process, one that considers the total context within which a transportation project will exist and which seeks to involve all stakeholders early and continually, through all phases of a project. An aesthetic structure, one that fits its physical setting, is a key requirement for any structure located within a National Park. The FLH Bridge Office has a successful history of engineering bridges that are aesthetic and that fit their physical setting while preserving scenic, historic, and environmental resources.

OBJECTIVE

The term aesthetic is a subjective one, individuals do not always agree on what defines aesthetics. While there are no formulas used to design an aesthetic bridge, careful consideration of size, proportion, color and materials used, during the preliminary engineering phase, can result in a structure, which a majority would agree is pleasing to look at, i.e. aesthetic. This presentation will focus on the FLH Bridge Office's aesthetic design practice for short to medium span concrete structures, several of which have received awards.

The presentation will discuss key factors considered during preliminary engineering, general principles applied, and the tools used to present proposals to client agencies and the public.

FLH PRELIMINARY BRIDGE DESIGN PROCESS

Prior to the beginning of any engineering on a new bridge project, a project Scoping Trip is held. FLH's representatives from the applicable disciplines (e.g. environment, Geotech, construction, etc) and all resource agency stakeholders attend the Scoping Trip. The site is evaluated, and the transportation facility function, environmental factors, safety considerations, client preferences and requirements are discussed and decisions made regarding the future bridge.

After the Scoping Trip Report is finalized, the Project Development branch designs the entire project's horizontal and vertical alignments (including the structure's alignment). The designed alignments consist of long continuous curves and tangents, rather than short discontinuous segments. During the design of the project's alignment, the Project Development branch coordinates with the Bridge branch to ensure that a reasonable bridge alignment is designed.

Once the Bridge branch receives the project alignment and topography information, preliminary engineering begins and ends with the development of a Typical Section & Layout (TS&L) drawing. For some projects several bridge alternatives are developed. This phase of a bridge project is the most important phase, since decisions made during this phase define 90% of the structure's final appearance, its aesthetic value. It is interesting to note that this phase on average accounts for only 10% of the final engineering cost of a bridge project.

The bridge TS&L is sent to the owner agency for review and approval. As part of the project development process Public Meetings are held to present the project's scope, its purpose and function. The Public Meeting's purpose is to educate, solicit feedback and suggestions for improvement, and to ultimately gain buy-in from the majority of the stakeholders. Examples of various groups that attend the public meeting are the general public, environmental groups, special interest organizations, local politicians etc. The majority of the attendees lack a familiarity with the engineering of transportation facilities; therefore, computer generated renderings of the bridge are used, i.e. visualization tools. Renderings present the viewer with an accurate snapshot of the completed site, prior to any construction beginning. Bridge visualizations are also helpful to the owner agency, since it quickly alerts them to areas were they may want a different treatment than that proposed.

BRIDGE TYPE, SHAPE, AND SIZE

The structural type and size of the structure selected, during the preliminary engineering phase is dependant on the proposed function of the bridge, i.e. pedestrian, vehicular, or rail

and the site location and topography. The site's topography delineates the bridge's length and height. During this layout phase it is important that the engineer consider some basic factors, which when treated correctly result in an attractive structure, without a significant increase to construction cost. These factors are the keys to success, and include:

- **Appropriate Structure Type**- the type selected should fit its environment
- **Appropriate Structure Size**- the size of the structure should be in harmony with its environment
- **Structural Simplicity** - the structure's overall shape represents what is intuitively considered the flow of forces/stress
- **Horizontal Continuity** - the structure maximizes the continuity of horizontal lines
- **Harmony** - the structure maintains a uniform shape for the majority of bridge elements
- **Slenderness** - appropriate depth to span ratios are used from a structural as well as aesthetic perspective

There exists a fallacy that the construction cost of a bridge significantly increases by taking into consideration aesthetics; however good decisions made with respect to the above list only increase a bridge's cost by approximately 2% - 5% (higher percent for longer bridge spans), not a significant increase.

STRUCTURAL AND AESTHETIC CONSIDERATIONS

Once the overall shape of the bridge is defined (length, width, and height), the engineer is faced with another set of factors he/she must make decisions on, factors, which significantly contribute to the final aesthetic value. A bridge designer's training and natural tendency is to focus on a structure's functional purpose, e.g. structural capacity and safety performance, and unfortunately, at times, views aesthetics, environment and cultural resources as external factors. The FLH CSS process requires that the bridge preliminary engineering consist of structural analysis and design that is partnered with an aesthetic value evaluation. Therefore, as the structural analysis is performed the following bridge related items are evaluated using aesthetic criteria, in addition to the structural:

- Number of spans and their proportion to each other
- Superstructure type, shape, and material
- Pier type and shape
- Proportion of a pier's height to its neighboring piers
- Abutment and Wingwall type and shape
- Bridge rail type
- Surface color and texture treatments

The length of a span is driven by what the structure must cross, requirements for vertical and horizontal clearances, foundation constraints, environmental restrictions, which are

functional and structural factors. In addition to these factors, the aesthetic driven designer considers the following recommendations:

- Minimize the number of substructure units
- Use odd number of spans which is considered more visually pleasing
- Emphasize the structure's horizontal proportions by maximizing the span to structure depth ratio
- Maintain a constant span to structure depth ratio throughout the length of the structure, i.e. span lengths decrease proportional as the bridges vertical clearance decreases
- Use span variations which visually make sense, for example use equal spans lengths for deep valleys, varying span lengths for shallow valleys

The type of superstructure (girder in most cases) selected should optimally allow for a continuous structure, one that is free of joints, and which visually provides uninterrupted lines. The type selected should also maintain structural economy and durability.

Selection of a girder should also consider its slenderness ratio, defined by the span length to girder depth, the more slender the better; however designers are cautioned from making a beam appear too slender, which could give the viewer a sense of insecurity about the structures stability. The use of shadow can contribute to making a girder appear shallower than it is thereby making it appear more slender. An example where shadow reduces the visual appearance of the girder depth is the use of a cantilever deck/overhang, which places the exterior girder in shadow.

The aesthetic selection of a pier type and shape takes into consideration the bridge's geometry and superstructure shape. For narrow bridges it is generally agreed that a single shaft or wall visually looks the best. The aesthetic treatment of short piers provides more of a challenge to the designer, than tall slender piers. The use of short hammerhead type piers should be avoided, and the use of inverted trapezoidal shapes are recommended to give the pier a slender appearance. Tall piers provide the designer numerous aesthetic options. The following recommendations are presented- use simple continuous vertical shapes, accentuate the piers verticality, taper the pier shape in a vertical direction, and visually integrate the pier and pier cap.

The placement of the abutment should provide the approaching traveler with an open feeling and visually give the appearance that the abutment is of an appropriate size to carry the structure. A general guideline is to expose a minimum height of abutment breast wall equal to one-half of the girder depth. Engineers are cautioned against creating a visually dominant abutment, a guideline is to expose a maximum height of breast wall equal to one-third of the bridge vertical clearance or nearest pier's exposed height.

The treatment of the abutment's embankment slope and material can provide the viewer with several visual experiences. The flatter the embankment slope the smaller the abutment will appear, a recommendation for an embankment slope is 1:2 or less. The use of concrete

paving for an embankment nicely relates the embankment to the structure; however if this effect is not desired then the use of rubble, stone or grass relates the embankment to the landscaping.
The bridge rail treatment impacts the appearance of the bridge as well as the view of the surroundings off of the bridge. A caution to the designer is that the bridge parapet/rail adds to the visual appearance of the depth of the exterior fascia, thereby reducing the perceived slenderness. To minimize this effect one can break the perceived parapet depth by using multiple horizontal lines, for example the use of a drip grove line, or using an open rail system. To elongate the visual length of the bridge, the bridge rail may be continued past the abutments.

CONCLUSION

There is a new emphasis on Context Sensitive Solutions (CSS) within the transportation industry. On bridge projects CSS may be easily attained through the careful evaluation of the project's context, consideration of stakeholders requirements and needs, and effective structure type selection, during the Preliminary Engineering phase. Design decisions, made during the preliminary engineering phase, strive to create a bridge that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources, while maintaining safety and mobility. The term aesthetic is a subjective one, since individuals do not always agree on what defines aesthetics. While there are no formulas used to design an aesthetic bridge, careful consideration of size, proportion, color and materials for the various bridge elements, during the preliminary engineering phase, will result in what a majority considers an aesthetic structure. The use of visualization tools such, as computer 3-D renderings are an important part of an aesthetic design process. The snapshot which these renderings provide facilitates the publics understanding of the project. They are also extremely helpful during the evaluation of several bridge alternatives. Therefore, the careful consideration of bridge size, proportion, color and materials does not add to the engineering cost and yields a visually pleasing structure, more importantly it does not significantly increase the construction cost.

Keywords: Aesthetic, Color, Context Sensitive Solutions, Federal Lands Highway, Material, Proportion, Size, Shape, Visualization Tools