# BRIDGE ARCHITECTURE OF THE 21st CENTURY
# A BRIDGE ARCHITECT'S PERSPECTIVE

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## ABSTRACT

*The 21st century brings a new paradigm in bridge architecture. New projects have increasing costs, fixed budgets, and public scrutiny. At the same time community involvement grows. This leads to principles of bridge architecture different from those of the last 50 years.*

*This paper will propose three principles of bridge architecture. These three concepts may guide designers: 'Cost controls aesthetics', 'hierarchy of elements' and 'green over gray'.*

*The concepts of this discussion apply to standard small or medium sized bridges. Long span bridges are beyond the scope of this paper.*

**KEY WORDS:** Context Sensitive Design, Metaphorical Design, Mechanical Design, Cost Controls Aesthetics, Hierarchy of Elements, Green over Gray

## INTRODUCTION

The 21st century requires a new paradigm in bridge architecture. Projects have increased costs, fixed budgets, and public scrutiny. At the same time community involvement grows.

The nineteenth century's Louis Sullivan brought 'form follows function' philosophies. According to David Billington the twentieth century's Robert Maillart brought 'function follows form'[1]. What guidance do we have for the 21st century?

This paper will propose three new principles of bridge architecture different from those of the last 50 years. 'Cost controls aesthetics', 'hierarchy of elements' and 'green over gray' are suggested contemporary guides for designers. Each project may have a mixture of each principle.

## CIRCUMSTANCES AROUND 21ST CENTURY BRIDGE ARCHITECTURE

### COMPETITION AND ADVANCES IN BRIDGE DESIGN

During the 19th century the greatest works of engineering where built under the lowest cost options. [1]Design competitions were the common means of project delivery. The competition leads to great advances in bridge engineering.

Today many new projects have fixed budgets and public scrutiny. Since structures are often the largest cost items in highway projects, they are strategic targets for savings.

This was different in previous decades. Then cost overruns may have taken up by deferring other projects into the future, to make up for cost over runs. Today projects are more strictly budgeted. Contrast this with previous century's where private enterprise funded projects and had greater flexibility.

In *The Tower and the Bridge* David Billington [1] documents the significance of competitions in the history of bridge design. "Although there is little tradition in the United States for design competitions in structure, such a tradition is firmly rooted elsewhere, with results that are both politically and aesthetically spectacular. Switzerland has the longest and most intensive tradition of bridge design competitions, and it is no coincidence that, by nearly common consent, the greatest bridge designers of the twentieth century were Swiss: Robert Maillart (1872-1940), who designed in concrete, and Othmar Ammann (1879-1965), designer of the George Washington and Verrazano bridges who designed in steel."

The current lack of competition may have slowed progress in the art of bridge design. Today when environmental mitigation requires higher visual quality, engineers often merely offer 'signature bridges' in miniature. These replicas of the past have not

advanced bridge engineering in any meaningful way. Therefore a new paradigm is required.

HUMAN ASPECTS

Understanding what the traveling public responds to is essential in creating new principles. The public cares little about abstract priniciples of minimalist architecture. Terms such as Sullivan's 'form-follows-function' or even Billington's 'function-follows-form' have limited appeal to people. However observe a public meeting and watch as people respond positively to high quality richly detailed elements.

Studies reveal three levels in the way we perceive our environment. These are the visceral, reflective and behavioral levels. The visceral level is satisfied by safe looking elements such as formidable abutments or strong looking superstructures. The second and third levels are the behavioral and reflective. These levels of perception are complex and require pleasing and culturally satisfying designs.[2]

Additionally high visual quality is the measure of a great society. As the University of Durham's Ash Amin points out"the Greco-Roman city would have measured its worth through its capacity to embellish the built environment, project its power and develop the deliberative, political and creative energies of some of its citizens."[3]Additionally Tom Wolfe writes of the United States in *From Bauhaus to Our House*. "Has there ever been a place on earth where so many people of wealth and power have paid for and put up with so architecture they detested…?"[4] Clearly we need new guidance in architecture as well as bridge design.

CONTEXT SENSITIVE DESIGN

The principle of 'green over gray' is supported by Washington State Department of Transportation (WSDOT) policy.[5] Before expensive concrete surface treatments are considered, WSDOT uses less expensive landscape plantings. Green spaces are far easier to justify than expensive architectural features. The aesthetic response is humane and creates an enduring connection to nature.

Across the United States regional communities compete for workforce based on lifestyle opportunities. Increasingly, what attracts people "are abundant high-quality amenities and experiences, an openness to diversity of all kinds, and above all else the opportunity to validate their identities as creative people."[6] Green spaces help provide this quality in transportation structures.

## RECOMMENDATIONS

THREE PRINCIPLES OF 21ST CENTURY BRIDGE ARCHITECTURE

The circumstances of cost constraints, public scrutiny, fixed budgets and community involvement leads to three principles of 21st century bridge design.

1ST Principle: Cost Controls Aesthetics.

The primary application of 'cost controls aesthetic' is to select the least cost superstructure option. These savings can then be shifted to create high quality amenities. The structural sections may be a mix of precast I sections, precast trapezoidal boxes, cast-in-place boxes or voided slabs. The aesthetic requires other elements to visually dominate the superstructure.

Superstructures should be the same with respect to constant depth and deck overhang. Regional trends in fabrication methods should be a determining factor in deciding superstructure types.

The first principle focuses on superstructure elements, since substructure types are typically dependent on soil conditions, and difficult to realize cost savings.

2nd Principle: Hierarchy of Elements.

The primary application of the 'hierarchy of elements' is to design columns, crossbeams and abutments to be visually dominant. Substructures should become visually dominant to superstructures. Conversely, superstructures should be visually subordinate elements.

Dominant elements feature high quality contextual, human scale and culturally significant details. These features have traditionally been called ornament in the past. Recognize that ornament is a highly effective visual element and if used tastefully can be very well received by the public.

3rd Principle: Green over Gray

The application of 'green over gray' requires designers choose green designs (landscape plantings) over gray designs (concrete). The term 'green over gray' is both literal and figurative. The use of landscape greenery is cost effective and well received by the public.

The principle recommends obscuring substructures, and differences in superstructure types with plantings. Designers should choose ivy and other wall coverings before more expensive architectural wall treatments.

## CASE STUDIES

The following case studies demonstrate the three principles. For simplicity, each project demonstrates only a single principle. In practice, final designs are an amalgam of principles.

## 1st PRINCIPLE: COST CONTROLS AESTHETICS

The case studies demonstrate that lower overall costs result from choosing the least cost superstructure type. Savings in cost allow embellishments that would not be possible with higher cost superstructure alternatives.

### I5 Lynnwood Pedestrian Bridge

Preliminary designs of the pedestrian bridge where a steel truss. The truss is as shown in figure 1.

Figure 1. Steel Truss Pedestrian Bridge proved beyond budget. [7]

During review it was suggested a precast prestressed concrete superstructure be used with fence details to replicate the truss. Note that the depth of the voided slab prestressed girders is equivalent to the steel truss floor deck system. Therefore elevation views of either superstructure option are equivalent. See Figure 2.

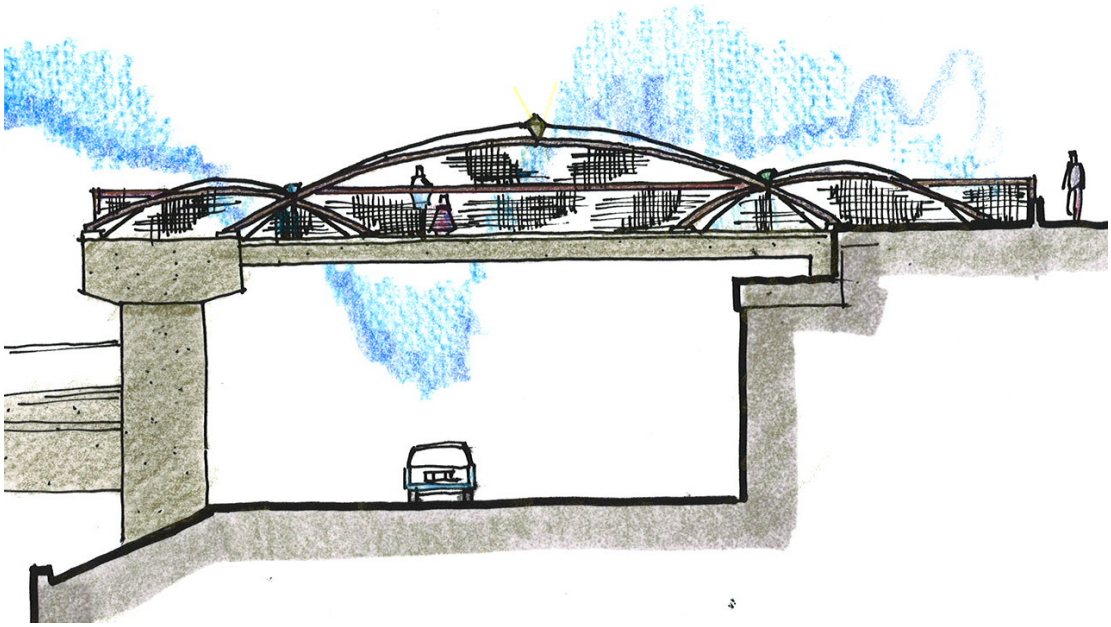

Figure 2. Prestressed girder bridge with faux truss railing was more cost effective than steel truss.

Not only is the prestressed concrete superstructure less expensive initially, but also the long-term costs are less. Maintenance costs are essentially zero for prestressed superstructures. Notice that the fence creates a convincing truss-like appearance since the faux arch terminates at the spring line.

SR 520 Evergreen Point Floating Bridge Arch Option

Context Sensitive Design methods indicated a strong preference for an arch bridge on the pontoons of the floating bridge. Through the context sensitive design process, the public desired that the sites water waves be symbolized with arches.

Community members analogized rolling waves with arches. The design represents a growing trend in bridge architecture which may be called metaphorical design. In this approach designers assign symbolic meaning to components. The bridges iconic imagery overshadows the structural utility.

Figure 3 shows an early pencil sketch of a precast concrete arch superstructure on the floating bridge pontoon. However recall that arches are most naturally sited in deep canyon crossings with rock foundations to resist thrust. Due to structural inefficiency the arches where estimated at hundreds of thousands of dollars in additional cost and where abandoned.

Figure 4 shows the 3D computer model to demonstrate the ‘forest of arches’ that result from the design. In this case the reality of the metaphorical imagery created an undesirable and confusing array of curves. Additionally the views of the bridge from shore are at such a distance that any attempt at detailing is not noticeable.

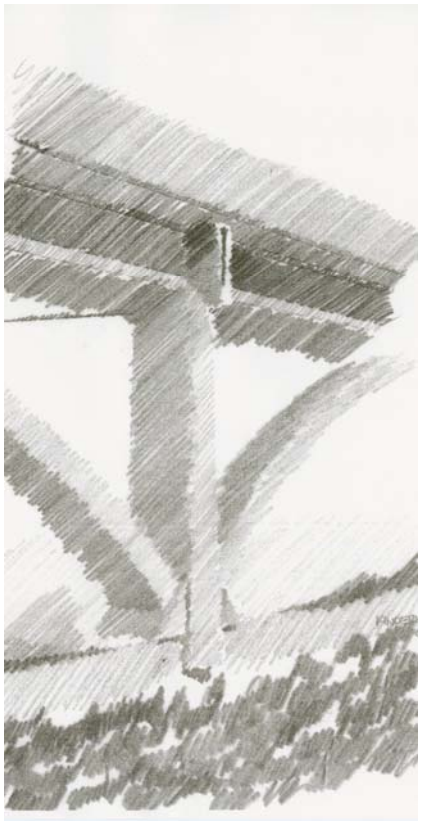

Figure 3. Metaphorical design of arches on pontoon superstructure.

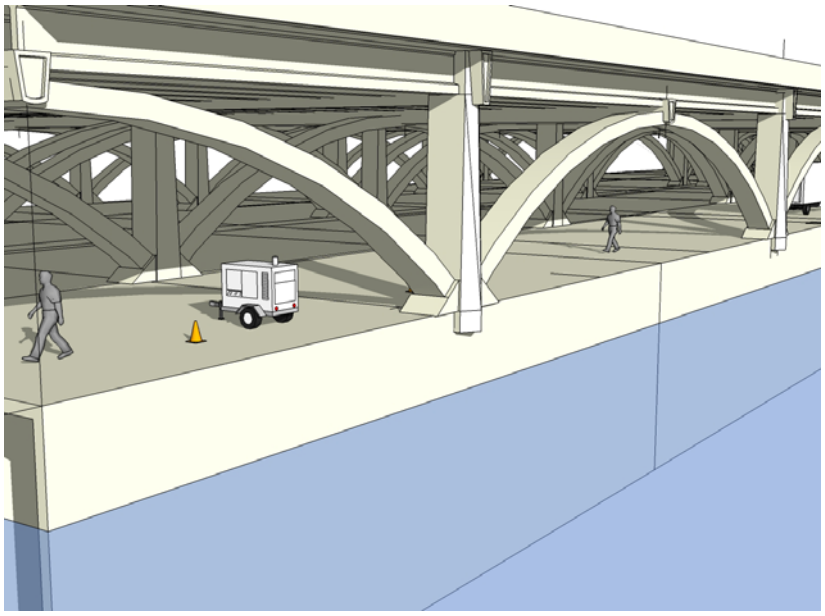

Figure 4. 3D model of metaphorical design arches on pontoon superstructure.
The design proved too expensive.

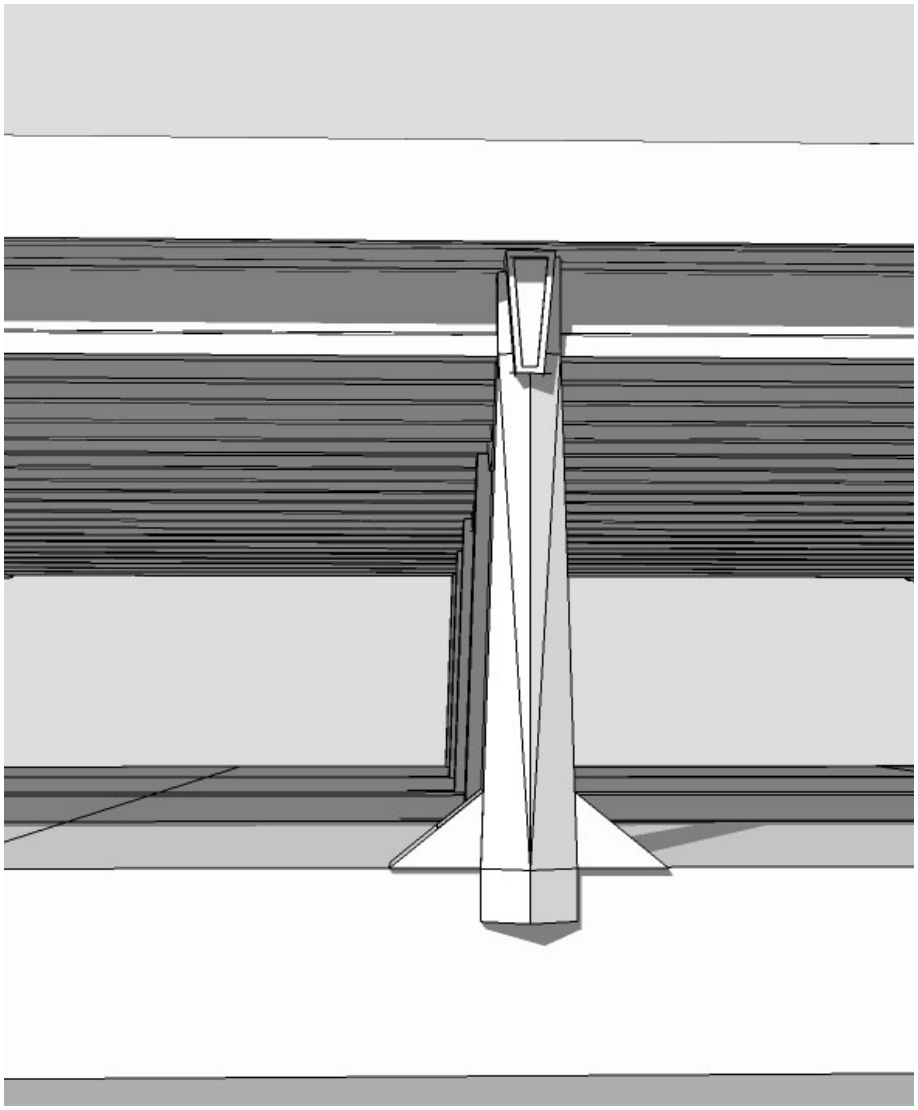

Figure 5. Cost effective trabeated design of pontoon superstructure.

Figure 5 shows the final design of a cost effective trabeated post and beam structural system. The keystone and faceted column are simple classic elements. They may be precast and add little to the cost or weight of the floating bridge. This design may be termed a mechanical design, influenced more by structural constraints than metaphor, iconic imagery or symbolism.

In the case studies the final designs were based solely on structural efficiency and cost. The aesthetic treatment was given high value but followed only after the low cost option was chosen.

CASE STUDIES: 2ND PRINCIPLE: HEIRACHY OF ELEMENTS

The superstructure elements are visually subordinate to the dramatic substructure and parapets in these designs. Cost effective prismatic prestressed girders are embellished with contextual, locally meaningful motifs.

SR 395 North Spokane Corridor

Figure 6. Barrier details override the importance of the superstructure elements.

In Figure 6, the fractured basalt barrier and retaining wall finishes are accomplished with low cost concrete formliners and coloring. The color and texture draw the eye away from the superstructure type. Therefore the superstructure is visually subordinate and may be low cost.

Figure 7. Abutment details overshadow the superstructure type.

Figure 7 further demonstrates the value of dominant substructure elements. In this image the sun medallion has icon value and dominates the abutment, further removing emphasis and importance of the superstructure type.

I 405 Canyon Park Park & Ride

WSDOT embraced FHWA's context sensitive design principles by executive order in 2006. Since then corridor themes have been created under the guidance of aesthetic design committees. Local transit carrier Sound Transit built the pedestrian bridge with WSDOT Context Sensitive Architectural guidelines.

Washington State recognizes the importance of context sensitive design as a project development tool. In order to bring projects in on time and within budget communities must have their voices heard. "To accomplish a vision of context sensitive design requires an understanding of community values and the tools to help achieve those values by project managers, public involvement personnel, and senior and executive level managers and administrators." [8]

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Figure 8. Column details are visually dominant over the superstructure.

In Figure 7 the cost effective superstructure is visually subordinate to the highly detailed column elements.

Figure 9. Canopy and barrier details make the superstructure less visually important.

In Figure 8 the superstructure was chosen based on engineering requirements only. However a lengthy public involvement process resulted in collecting community values and tailoring the designs to the individual area. The state flower, the rhododendron, can be seen in the column shape. And superstructure colors to symbolize the 'evergreen state' give local meaning to the design. Color, organic column shapes, classic 1950's Interstate barrier details and pedestrian canopy all deemphasize the superstructure type.

The principle of hierarchy of elements resulted in lower overall costs and higher visual quality. While the principles of Context Sensitive Design brought the project in on budget with minimal investment.

CASE STUDY: 3RD PRINIPLE: GREEN OVER GRAY

The principle of green over gray is shown in the following two examples. Emphasizing landscape greenery is well received by the public.

"Starting with 'green' and moving to 'gray' means looking at opportunities for improvement starting with natural elements like vegetation and earthen/topographical features (also referred to as 'green' features). That continuum extends through more intrusive placement of structures ('gray' features' that fit the communities scale." [9]

The term 'green' is not to be confused with the contemporary jargon referring to eco-friendly details. The term is to be taken literally where designers first look toward landscaping before ornamental concrete. Note that as the transportation infrastructure community considers global warming, it's important to consider the long term maintenance costs associated watering and replanting. These costs can outstrip any savings from 'green over gray' construction. Therefore planting must be self sustaining local flora.

I 90 Hyak to Easton Snow Shed Portal Design Concept

The I 90 Hyak to Easton Project is a multibillion dollar mega-project in Washington state. Environmental standards require mitigation with high quality aesthetics.

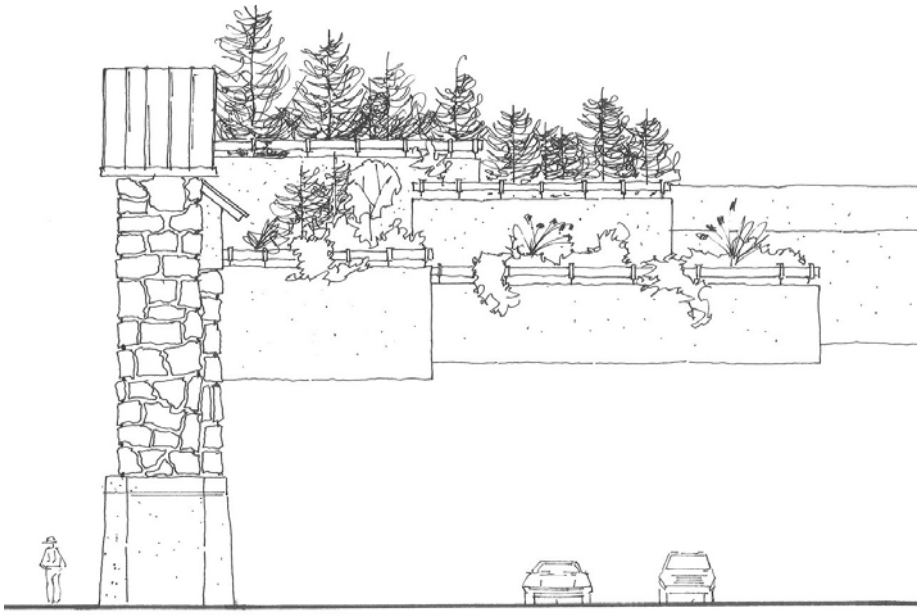

Figure 10. Landscaped snow shed portal design concept demonstrates ‘green over gray.’

In figure 9, landscape planters are preferred over ornamental concrete surface treatments. These are amenities that communities have come to expect of contemporary transportation projects.

In figure 10, the Seattle Freeway Park is a nationally recognized example of the principles of green over gray. Here the greenery of ivy softens and humanizes the freeway. Washington states Mercer Island I90 corridor is another successful project. The state has multiple other designs in progress using landscaped ‘lids.’

Figure 11. Landscaped lid portal

## CONCLUSIONS

The 21st century requires a new paradigm in bridge architecture. Projects have increasing costs, fixed budgets, and public scrutiny. At the same time community involvement grows.

This leads to new principles of bridge architecture, for short to medium span bridges, which are different from those of the last 50 years. 'Cost controls aesthetics', 'hierarchy of elements' and 'green over gray' are three contemporary principles to guide designers. The concepts may be viewed singly, but in practice are best used as an amalgam to create the optimum design.

The application of 'cost controls aesthetic' is to select the least cost superstructure option. These savings can be shifted to create high quality amenities. The aesthetic requires other elements to visually dominate the superstructure.

The primary application of the 'hierarchy of elements' is to design columns, crossbeams and abutments to be visually dominant. Substructures should become visually dominant to superstructures. Conversely, superstructures should be visually subordinate elements.

Starting with 'green' and moving to 'gray' means looking at opportunities for improvement starting with natural elements like vegetation and earthen/topographical features.

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