

ESTHETICS IN CONCRETE BRIDGE DESIGN

EDITORS:
STEWART C. WATSON
M.K. HURD

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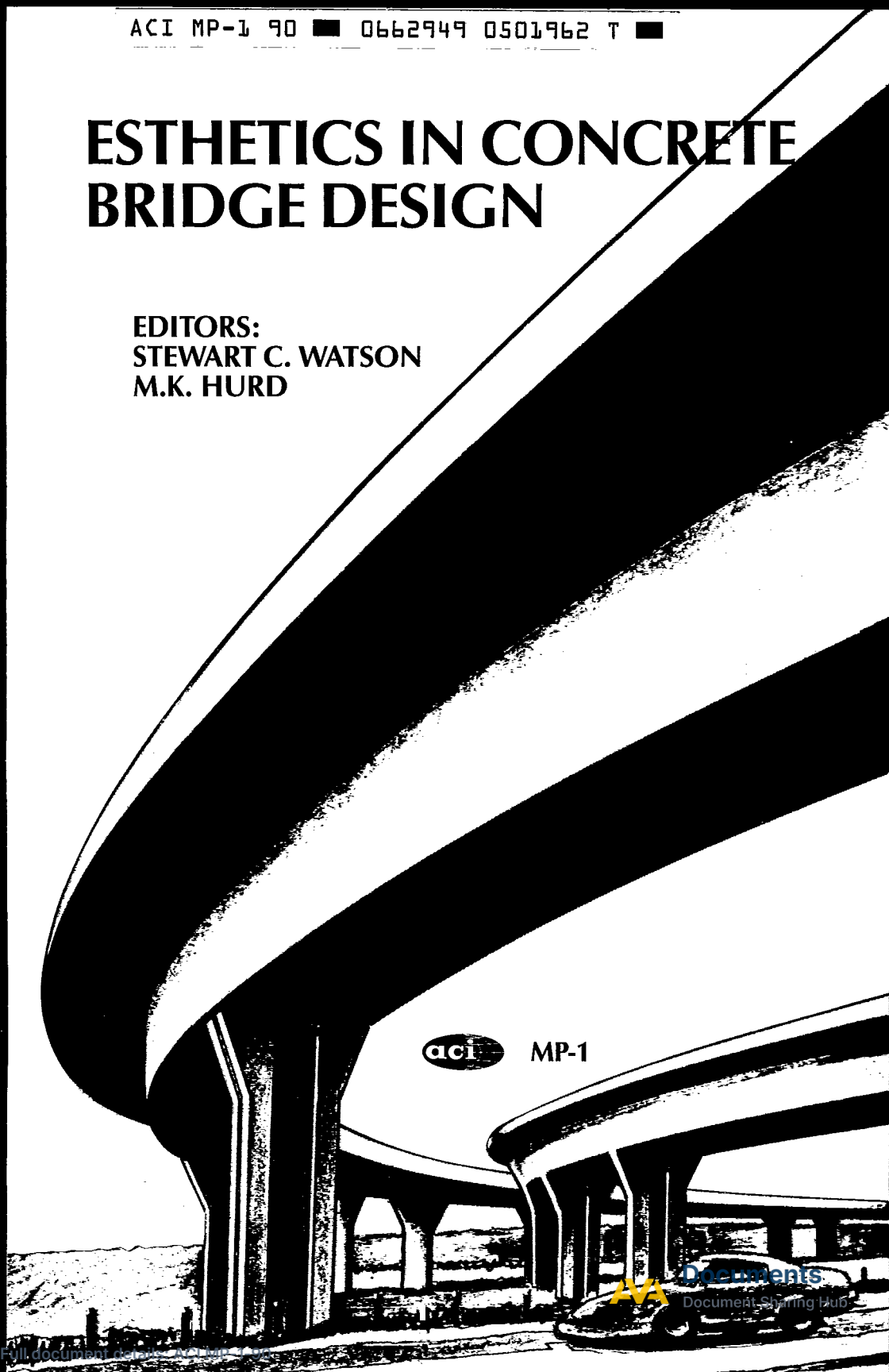
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FORWARD

In the present age of heightened public awareness, bridge design engineers can no longer be allowed to limit their activity to static calculations and monitoring of construction. The public will not permit us to create unattractive structures. After a bridge is constructed it actually changes its particular part of the environment for 50 years or longer. There is a growing perception that ugly bridges actually are a form of pollution and in fact seem to breed discontent and despair.

The selection of a bridge design--whether the most attractive, the best for its structural qualities, or the most economical for the public--is often in the hands of those who are not specialists in bridge design. With this in mind ACI Committee 124, Concrete Esthetics, decided to try to identify the fundamentals of bridge esthetics, which could be shared among decision makers and professionals alike. We searched worldwide, asking distinguished members of the bridge design fraternity as well as their architectural counterparts to help us in this task. The result was four symposium sessions presented at ACI conventions, two in Seattle, Washington on November 12-13, 1987, and two in Orlando, Florida March 24, 1988. These proceedings constitute the record of the symposia where the question was addressed.

In approving the papers for publication, Committee 124 waived the peer review process usually followed for ACI symposium volumes. The reason for this decision is that the content is highly subjective, nondimensional, and generally not quantitative. This reflects the nature of esthetics as a branch of philosophy and respects each writer's right to expression of a personal point of view. Critiques or criticism may be appropriate as discussion later, but they have not been used to influence authors of these invited papers to change their drafts.

Information contained in these proceedings indicates the present state of the art. It is hoped that it will serve to time-bind this generation of bridge designers and builders to those generations to come. If we have been successful in this endeavor, then all the hard work of the many people involved will have been worthwhile.

Stewart C. Watson

Symposium Chairman

April 1990

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PREAMBLE

by Fritz Leonhardt

We are living in an "age of awareness"--becoming aware of the faulty and damaging consequences of some doubtful achievements based on the enormous scientific, technical, and economic progress of the last century, which was governed by a primarily materialistic philosophy of life. One of these faults was the lack of sense and feeling for the value and essence of beauty--leading to much ugliness in our built environment, mainly in big cities. This causes psychic diseases, depression, or aggression, sometimes with suicide or crime at the end of the chain.

Fortunately we also became aware of the fact that human well-being and happiness, joy in living, and psychic health depend to a large extent on the esthetic quality of the environment in which we live. For recreation and holiday resorts we prefer beautiful landscapes, unconsciously feeling the healing power of unspoiled nature. For most people the daily environment means the built environment, and this is shaped by architects and engineers who therefore are responsible for its esthetic qualities. Somehow most of them lack the ability to create beauty by their designs because they have never studied the fundamentals of esthetics.

However, mankind has a deeply ingrained sensitivity to beauty which has often been analyzed, leading to rules for esthetic design. In my book, Bridges, Aesthetics and Design, published by the MIT Press, I have tried to describe how man perceives esthetic values, how esthetic judgment or taste can be gained, and how guidelines for good design can be derived by analyzing masterpieces of generally acknowledged beauty.

Such guidelines can also be applied to bridge design. During the last century we have built many thousands of bridges to serve modern traffic requirements, and we have to build many more, replacing worn-out bridges, often in urban environments. Some of these bridges are really ugly. It is indeed important to improve the esthetic quality of the future bridges and get away from choosing the cheapest bridge.



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It pays to spend some money for better esthetic quality. It pays not only because of the favorable social and health effects of beauty for the well-being of our fellow citizens, but also for the reputation of our profession.

The age of awareness must lead to the age of beauty for all our environment so that life can become more joyful and healthy.

Honorary Member of ACI, Fritz Leonhardt is a consulting engineer and principal of the firm of Leonhardt and Andra in Stuttgart, West Germany. He is also professor emeritus of civil engineering at the University of Stuttgart. Dr. Leonhardt has received numerous honors and awards from governments, societies, and educational institutions throughout Europe and North America. Holder of many patents and author of 330 publications and 12 books, he is noted for his design of long span bridges, prestressed concrete design and construction methods, his study of bridge esthetics, and his contributions to engineering education.

Dr. Leonhardt prepared this preamble, which was read on his behalf at the ACI Committee 124 Bridge Esthetics Symposium in Seattle, November 12, 1987.

CONTENTS

FOREWORD.....	iii
PREAMBLE	
by Fritz Leonhardt.....	v
IN THE EYE OF THE BEHOLDER	
by E. Cohen.....	1
BRIDGE DESIGN PROCESS -- ACHIEVING THE GOAL OF AESTHETIC QUALITY	
by K.E. Kruckemeyer.....	13
FUNDAMENTAL PRINCIPLES OF BRIDGE ESTHETICS	
by R. Lacroix.....	29
CREATING A BEAUTIFUL CONCRETE BRIDGE	
by J.C. Ritner.....	33
THE CONTROVERSY ABOUT RULES FOR THE AESTHETIC DESIGN OF BRIDGES	
by A.C. Liebenberg.....	47
BEAUTY AND BRIDGES	
by A. Grant.....	55
ESTHETIC PRINCIPLES IN BRIDGE DESIGN -- A MEMOIR	
by U. Finsterwalder.....	67
BRIDGE AESTHETICS -- RULES, FORMULAS, AND PRINCIPLES -- THE NEGATIVE VIEW	
by M.P. Burke, Jr.....	71
INTEGRATION OF FUNCTION, FORM, AND MATERIALS IN TODAY'S BRIDGES	
by D. Stevens and J. Kopetz.....	81
BRIDGING THE ARTISTIC GULF	
by D. Lee.....	101
SOME THOUGHTS ON BRIDGE ESTHETICS	
by C.S. Gloyd.....	109
CALIFORNIA'S WAY TO AESTHETIC BRIDGES	
by A.L. Elliott.....	119
ON THE AESTHETICS OF PEDESTRIAN BRIDGES	
by J.M. Schlaich.....	133

ESTHETICS FOR CONCRETE SEGMENTAL BRIDGES by J.M. Muller and L.F. McCallister.....	149
ESTHETICS AND ENGINEERS by F. Gottemoeller.....	167
AESTHETICS IN BRIDGE DESIGN ACCENT ON PIERS by C. Seim and T.Y. Lin.....	189
AESTHETIC RULES SHOULD NOT BE SET IN CONCRETE -- A BRIDGE ARCHITECT'S VIEW ON BRIDGE DESIGN by R.R. Mays.....	203
TENNESSEE BRIDGES THE COLOR LINE by C.L. Loveall.....	229
THE INHERENT BEAUTY OF CABLE-STAYED BRIDGES by P.G. Buckland.....	233
AN AUDIENCE PARTICIPATION RESEARCH PROJECT ON BRIDGE ESTHETICS by P. Smith.....	247
PRECAST STRESS RIBBON PEDESTRIAN BRIDGES by J. Strasky.....	257
BRIDGE AESTHETICS AS PRACTICED BY MODJESKI AND MASTERS by J.M. Kulicki, H.H. Snyder, and D.R. Mertz.....	275
AESTHETICS AND ECONOMY IN COMPLETE CONCRETE BRIDGE DESIGN by J.E. Roberts.....	293
SI (metric) TABLES.....	331
INDEX.....	333

MP 1-1

In the Eye of the Beholder

by E. Cohen

Synopsis: Presents some personal thoughts on bridge aesthetics, with other ideas drawn from the work of Ammann, Billington, and Whitney. An ideal bridge must at the very least have structural efficiency and unity of appearance, executed with simplicity. The same fundamental aesthetic values apply to bridges just as they do to more conventional works of art.

Keywords: bridges (structures); engineering; esthetics; structural design

2 Cohen

Edward Cohen, managing partner of Ammann & Whitney Consulting Engineers in New York, is a past president and honorary member of ACI. A member of the National Academy of Engineering, he is also an honorary member of ASCE and NYAS and a fellow of ICE and ACEC. After receiving bachelor's and master's degrees from Columbia University, he joined Ammann & Whitney in 1949 as a structural engineer, working directly with Othmar H. Ammann and Charles S. Whitney.

Mr. Cohen became a partner in the firm in 1963. He directed the work of Ammann & Whitney for the restoration of the Statue of Liberty, The United States Capitol, and the Roebling Delaware Aqueduct Bridge. All of these projects have received national awards, including a Presidential Award for Design Excellence.

Presented here are some personal observations and thoughts on bridge aesthetics. I have drawn freely on the works of Othmar Ammann, Charles Whitney and also David Billington and, therefore, ask that if you find comments of which you approve, please give them the credit --- if on the other hand you disagree with my remarks, I accept the blame.

In the past when I commented on aesthetics, I hesitated in awe of architects and aesthetes and then prefaced my remarks with an apology for being "just an engineer." I still hesitate, as Stewart Watson knows, but I no longer apologize.

.....

Engineering is a fine art as well as practical art, in which form must be skillfully interwoven with function and economy. For other arts it is often enough to express the message or passion of the artist or to be purely decorative. The art of designing and building bridges requires a twofold definition of art. First the term "art" must be interchangeable with technological "skill" and fine craftsmanship, and secondly with the ability to create beauty that goes beyond practical competence. It is why some bridges distinguish themselves well beyond others, why the bridges of some engineers become famous--even beloved-- by those who know them. New Yorkers "love" the Brooklyn Bridge... but not the Williamsburg. The Golden Gate Bridge is cherished; the Oakland Bay Bridge has become known as the "other bridge."

As an engineer, I enjoy talking about bridges, because nowhere else does the art of engineering express itself so totally and so visibly. They are also among the few works of man for which the engineer is given total responsibility

Bridge Design 3

with credit or blame for both beauty and strength or lack thereof.

Bridges have touched the lives of millions upon millions of people, often with an uplifting mystique. This may be diminished for us who now live in an aerospace age; but in

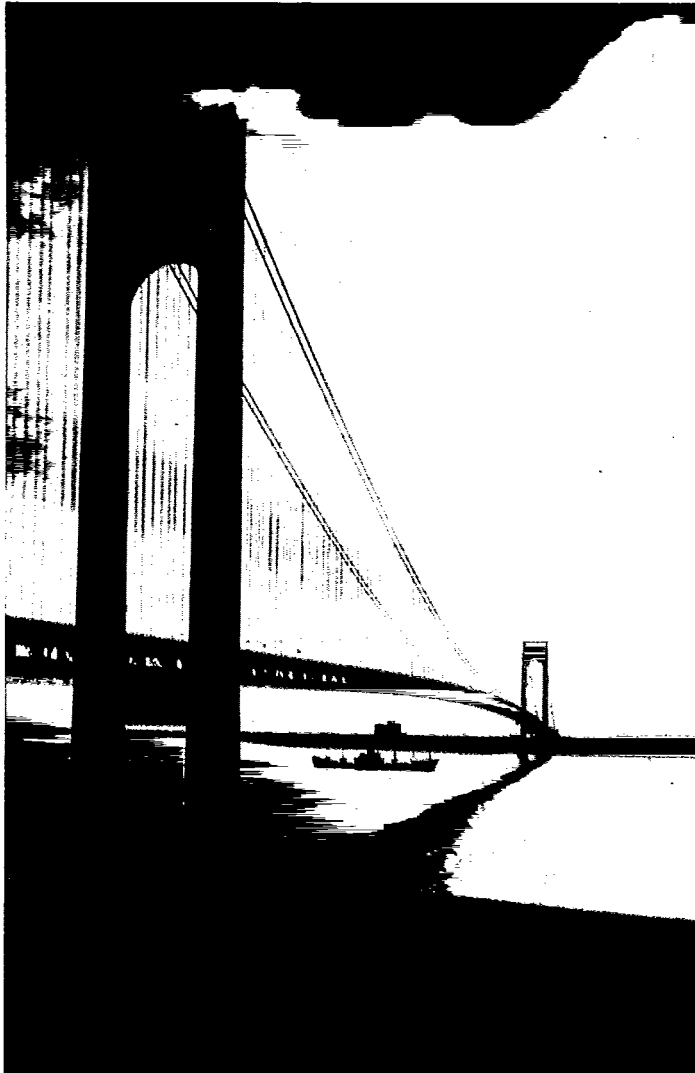


Fig. 1--Verrazano-Narrows Bridge, New York --
Ammann & Whitney Consulting Engineers



4 Cohen

"Bridge on the Drina", the Nobel prize-winning novelist, Ivo Andric, retells an ancient myth which brings home the "miracles" that bridges were before people started to take them for granted.

According to this myth, the devil was envious when God bestowed upon man the gift of this beautiful planet, earth. So, in revenge, he scratched gashes into the earth's surface, seeking to prevent men from getting to and from their fields, from gathering together-- in effect from surviving.

But when the angels saw this, that men could not pass those abysses and ravines to finish the work they had to do, but tormented themselves, and looked in vain for help, and shouted from one side to the other, they took pity on man, and spread their wings above those places, so that men were able to cross. Thus, according to the myth, men learned bridge building from the angels of God. And thereafter, ... it was considered to be one of the greatest blessings to build a bridge.

Bridges typify the march of progress more than any other structures built by man. They spanned obstructions in his path and opened new routes of communication. Considered from the beginning, the growth of bridge building seems almost biological, sometimes accelerated by fertile civilization and sometimes blighted by barbarism. In the early days, the engineer was a builder unhampered by the complexity into which the art has since fallen. He built structures that appeared correct to his critical eye. If they fell, he rebuilt them with sturdier proportions. The results were often pleasing in appearance. In this way were built the marvelous Roman aqueducts and bridges, the picturesque medieval spans, and the beautiful masterpieces of the Renaissance.

Since the 17th century, the science of bridge building has progressed more rapidly than the art. Because the materials and methods now used are so different from those of the past, the modern bridge engineer may have paid too little attention to the works of previous centuries which have made modern bridge building possible. Bridge designs are still based on the principles of the beam, the arch, the truss and the stay cable or catenary suspension system. They apply alike to ancient bridges and our modern spans. Materials and forms change, but the principles of art remain the same.

As Charles S. Whitney reminds us, beauty is a thing apart from technical progress. And in the 20th century, as in the old Yugoslavian myth I quoted before, Othmar H. Ammann still felt it was a blessing to design a beautiful bridge and a sin to design an ugly one. In his diaries, he once wrote:

"A great work of art evolves from an idea in the mind of its creator. It is brought (transcribed by the engineer) on(to) paper, or into more contemplative form, and then changed and remodeled. Not until the plans have passed the

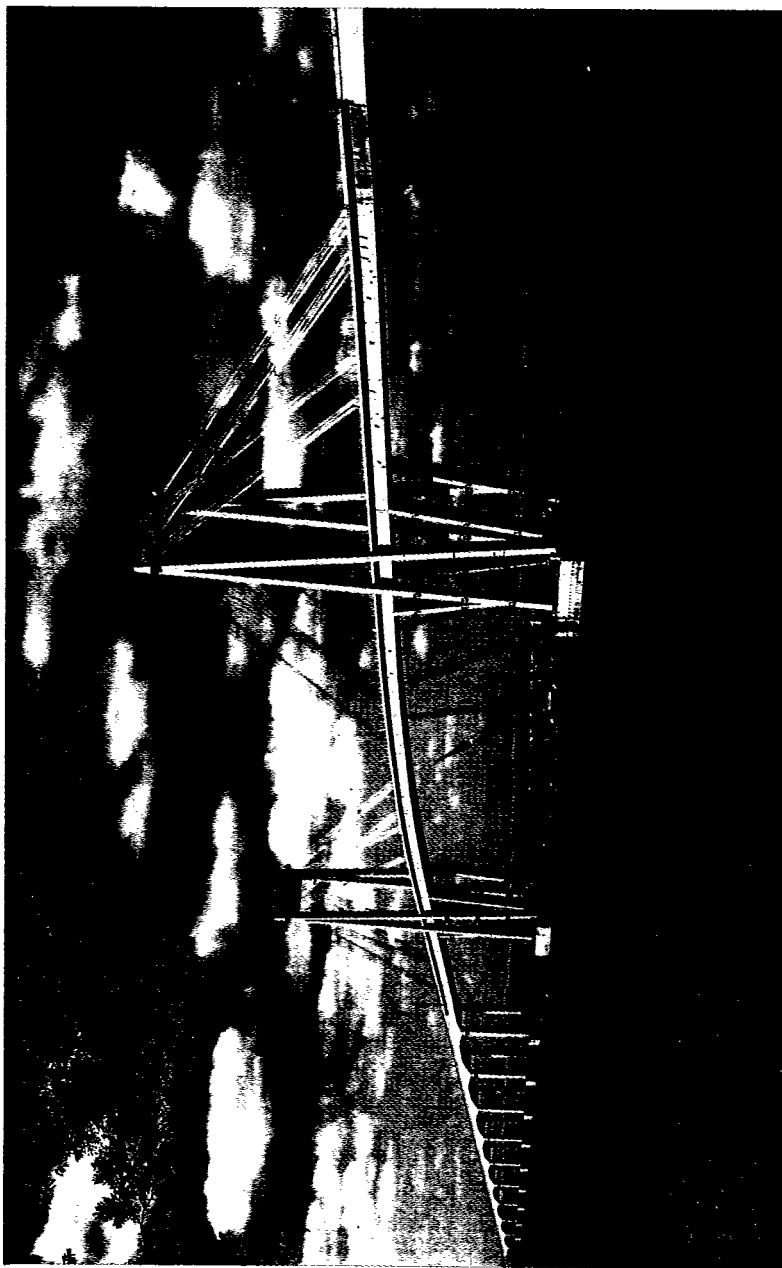


Fig. 2--Chaco-Corrientes Bridge, Argentina--
Ammann & Whitney Consulting Engineers

6 Cohen

and corrections, and have been submitted to an almost endless series of finishing touches, does the great work of art attain perfection.... A great bridge in a great city, although primarily utilitarian in its purpose, should nevertheless be a work of art to which science lends its aid. An elaborate stress sheet, worked out on purely economic and scientific bases, does not make a great bridge. This is only accomplished with a broad sense of beauty and harmony."

As professionals, all of us fully appreciate the need for designing a bridge for economy and ongoing durability. Our clients, too, seem to emphasize these priorities: maximum function, ease and speed of construction, lowest cost, and the least disruption possible to the area surrounding the site. Indeed, it sometimes seems that if a bridge turns out to be beautiful too... well, that is a bonus.

Nevertheless, today I would like to focus on the "poetry" of bridges, the aesthetics of bridges in the eye of the beholder, on bridges as graceful additions to the day and night-time environment. Many people consider our best bridges to be among man's most outstanding sculptures.

When each of us first decided to become an engineer, before we learned about statics and dynamics, building codes, contractors claims and union rules, if we were going to build bridges, we wanted to build beautiful bridges. That was our first goal.

Our priorities changed as we became immersed in the complexity of bridge design. The aesthetics of bridge design tended to be put aside --both by the individual and the curriculum--until technical competence was mastered.

Once the technology is mastered, however, aesthetics should again be a primary focus. One can measure the length of a bridge and compute its strength, but how do you measure beauty. Beauty is an indefinite, elusive quality, it depends not only on what a thing is, but what it appears to be. However, beauty can be seen, strength and economy cannot!

The technical side of design must be second nature before the engineer can begin to explore its poetry. Fortunately, the shapes and lines of an optimal technical solution often develop their own poetry.

Unfortunately, while one can talk about certain abstract basic concepts, artistic guidelines and architectural rules, these offer only glimpses or partial insights for aesthetic requirements. Creativity is the uncharted water beyond the safe harbor.

What makes a bridge beautiful? Does beauty really lie in the eyes of the beholder? There is an implication that

beauty is a matter of opinion. That it is quite arbitrary. What one finds beautiful, another may find quite ordinary--or even unattractive. When artists and professional art critics cannot agree, how is the layman to judge the merits of a design?

We all accept the truth of the French adage-- Chacun a son gout-- and agree that to some degree, taste is a personal thing. It varies from age to age as well as from person to person. In the 1960's, tailfins on automobiles were all the rage. In painting, beauty as expressed by Rubens is quite different from beauty as expressed by Picasso. Beauty as expressed by the Greeks is different from beauty as expressed by the Japanese. Beauty as expressed by Van Gogh is quite different from beauty as expressed by Andy Warhol.

Yet, in spite of different times, different cultures, different means of expression, beauty transcends styles and changing tastes. There is general agreement that an ideal bridge must possess at least two qualities: structural efficiency and unity of appearance.

Structural efficiency means much more than convenience and durability at the least cost. It means providing convenience, durability, and beauty by the simplest and most direct means. Beauty does not demand elaborate ornamentation, and is not in any way opposed to efficiency. Beauty is, in fact, so closely related to efficiency that sometimes it seems to result entirely from fitness. Elegance, a major attribute of beauty, may be defined as creating a great effect with minimal means.

Strength, although absolutely necessary, is to some extent a negative virtue. Strength is invisible when present and conspicuous in its absence. Beauty, on the contrary, which in itself demands an appearance of strength, gives pleasure wherever it is found.

"A weak bridge is admittedly more dangerous than an ugly one", Whitney said, "but to seek strength at the lowest cost with no regard for appearance is only one degree worse than it would be to attempt a beautiful design without thought of stability."

The appearance of strength in a bridge gives the user confidence. It is most important for the viewer from afar. But a bridge is also viewed from the totally different perspective of one traveling over it. Here it is often better to let the user forget about the bridge and let him enjoy the open landscape spread before him.

There is beauty in simplicity, it is in fact one reason for a 20th century preference towards simple designs that allow the unembellished form and function of the material to dictate the design of a structure. Since unity of appearance

8 Cohen

of the necessary attributes of a beautiful bridge, and simplicity enhances unity, it is often a real aid to beauty.

The aesthetics of a bridge must be considered from many perspectives by people on foot, on high, or in vehicles. From afar, traversing it, and passing beneath it. From a distance, in its given setting, it is the poetry of the bridge's geometry that predominates, the proper solution being strongly influenced by its relationship to its surroundings. It is an environmental sculpture.

Close up, the bridge is enjoyed in one way by those traveling across it; in another by those passing under it. Surface textures and embellishments are noticeable and can be enjoyed if one is not traveling at high speed and/or by pedestrians.

Architects, after moving towards ever greater simplicity for much of this century, letting the pure geometry of design "speak for itself", have begun to accept embellishment to add warmth and the pleasure to the cold elegance of technology. Perhaps for bridges, too, embellishments should be considered to enhance the enjoyment of the structure for the general public -- who, after all, use and support our bridges. However, we must recognize the danger of what damage inspired artistic pretensions can do to a fundamentally beautiful structure.

Although the beauty of every bridge is affected by attention to details, surface finishes, quality and durability of materials become of critical importance when surrounded by pedestrian traffic in urban and recreational settings.

Perhaps I have become oversensitized by spending so much time on rehabilitation of deteriorating bridges, but I feel that scaling, cracking, rusting, crumbling, even dirt can change beauty to ugliness. A deteriorated urban viaduct cannot be equated with the noble ruins of Roman aqueducts. Although the fault for much of the deterioration lies with neglect and poor maintenance, in some cases more thought and attention to details during design and better quality control during construction might have made the lack of maintenance less critical.

Fundamental aesthetic values, proportion; harmony; balance; consistency; the rhythmic use of repetitive patterns,-- symmetry but also the judicious use of dissonance or asymmetry to create an interesting juxtaposition. All of these apply not only to painting, sculpture, music, architecture, drama and the like, but also to bridge design. In all art, an appreciation of the qualities of the materials to be used is essential. Michaelangelo's marble sculptures are successful, in part, because he understood his medium so well. The limitations of the materials used set limits for the expression of the artist or designer. But the true artist knows his materials



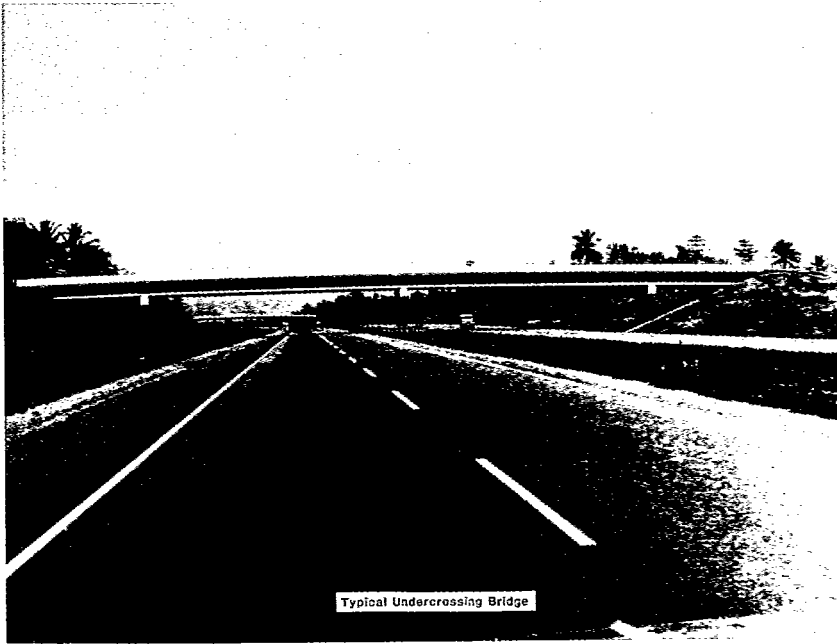


Fig. 3--Jagorawi Highway, Indonesia --
Ammann & Whitney Consulting Engineers



Fig. 4--Garden State Parkway, New Jersey --
Ammann & Whitney Consulting Engineers

10 Cohen

so well, his masterpieces can be attributed to his ability to stretch them to their limits.

Major bridges have the possibility of drama by mass, elegance and daring. Like the masterpieces of great artists, they also have the aspect of uniqueness. They are one of a kind and provide the engineer with the opportunity to successfully create beauty-- or to fail. The arch and the catenary are generally admired as examples of graceful forms. Yet either form can, with all good intentions, be desecrated and made into an unattractive structure by lack of harmony and inconsistency with its surroundings or other components of the bridge.

The challenge to create beauty for a major crossing is one that cannot be put aside. While poor musical compositions are just not performed, pedestrian paintings or sculptures gather dust in storerooms and even masterpieces must wait to be seen and heard by the public, a major bridge, beautiful, ugly or ordinary, is immediately thrust upon the public and will continue to affect the public environment for generations-- for better or worse.

Smaller bridges-- and I think here of fly overs-- do not have the aspect of uniqueness of their big brothers. Because of their multiplicity, they often become subject to a kind of mass production. Although they must meet the criteria of structural efficiency and unity of appearance, "convenience" requirements of roadway clearance, alignment, grades, elevations and cost often limit the designers prerogatives to innovate. One of the early parkway designs in which I participated made a concerted attempt to individualize each overpass with a different design and architectural treatment. I traveled that road many times but was never certain how successful the effort was, except that it did relieve the monotony of my trips, which may be all that can be expected. Such bridges, even masterpieces often fade into the landscape as components of an attractive (or conversely an ugly) highway.

The better one understands sculpture, the more one can appreciate Michaelangelo, the more one knows about music, the better one can appreciate Beethoven. The same is true in engineering. The better one understands the technology of structural engineering, the better is one able to appreciate outstanding bridge design. Thus, engineers may have quite a different and more sophisticated appreciation of a bridge than does the public.

I would like to see the engineering community do more to help the artistic community understand bridge design. I believe it would be enormously beneficial for them, and for us, for them to understand the quantitative requirements of technology that are the criteria for efficiency and for us to understand the qualitative criteria for aesthetic judgment.

of bridges. Mutual education would be useful to both. Engineers should not depend only on authoritative guidance in this matter. They should develop their own capabilities to judge aesthetics through experience gained from participation in and enjoyment of all the arts. Not only will they produce beautiful bridges, but they will enrich their lives.

Public bodies--our clients-- are more inclined, once again, to view bridges as aesthetic elements in their environment. Elements that with good maintenance could last for centuries. While economics are clearly a major consideration, lowest cost at the expense of aesthetics is increasingly understood to be short-sighted. More money is being expended with public approval for the sake of heritage and culture than at any time in our history.

This environment presents us with a unique opportunity to advance the appreciation of our profession, if we are prepared to meet the challenge.



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Bridge Design Process— Achieving the Goal of Aesthetic Quality

by K.E. Kruckemeyer

Synopsis:

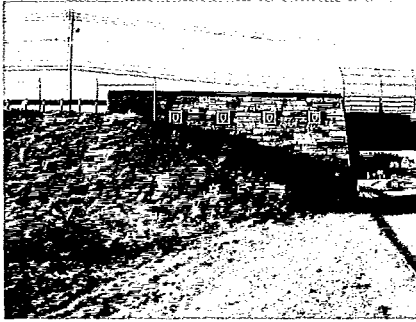
To achieve aesthetic quality in bridge design the primary responsibility falls upon the public agencies which must design, construct and maintain them. As the owner and representative of the public interest, the agency and its Bridge Engineer have the unique ability to choreograph the forces which result in extraordinary bridges.

The process of design must begin with a clear understanding of the challenge; it must proceed quickly so that the vision is not lost; and the knowledge gained through construction and maintenance must be continually recycled so that the designer rides the crest of the wave of both experience and technology development.

To be successful, the product of this effort must be a bridge which is beautiful both in its basic structure and in its details. Its beauty must be understandable in pure form (as an object) and appropriate in context (how it looks and works for the user and for those who live or work nearby). In addition to the quality which should be represented in all public works, bridges give us the opportunity to also provide great joy.

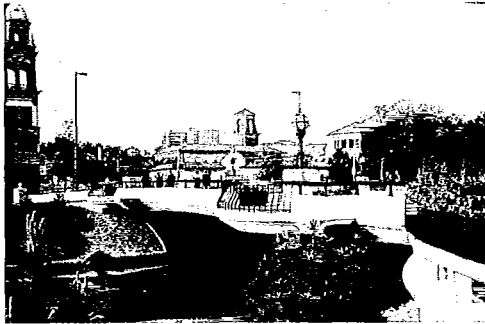
Keywords: bridges (structures); detailing; esthetics; quality; structural design

14 Kruckemeyer



Lajos Heder

The Bridge Architect was responsible for the details, but seldom for the overall aesthetic impact of a bridge.



Lajos Heder

The bridge adjacent to Country Club Plaza in Kansas City, Missouri by Howard Needles Tammen and Bergendoff sets the stage for a vibrant shopping area. In this case the bridge plays a greater role than carrying traffic.

Kenneth E. Kruckemeyer is an Associate Commissioner of the Massachusetts Department of Public Works where he oversees the Highway and Bridge Design Sections. As the former Assistant Project Manager for the Massachusetts Bay Transportation Authority's Southwest Corridor Project, Mr. Kruckemeyer was responsible for the engineering, architecture and landscape design of the project, a \$750 million investment in public transportation and urban revitalization in Boston. Mr. Kruckemeyer is an Architect with degrees from Princeton University and the Massachusetts Institute of Technology and was a Loeb Fellow in Advanced Environmental Studies at Harvard University.

When I first raised the issue of aesthetics with the engineers in my Department, I received a universal response: "We used to have a Bridge Architect — he was the person who figured out the coursing for the ashlar masonry on the bridge abutments and who decided where to put the state seal on the bridge... but he retired, and then we got to building the interstate system and we couldn't afford to spend money on those sorts of things anyway."

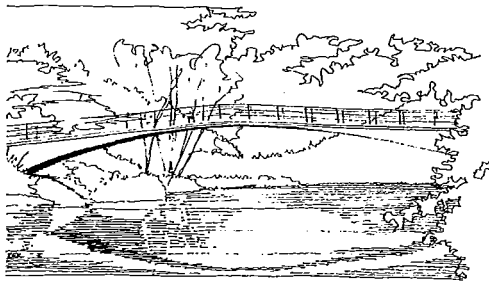
There is a fallacy in this concept of bridge aesthetics. It makes the basic assumption that aesthetics are additive—that aesthetics take longer and cost more money. It perpetuates the myth of "stage-set design" which implies that a bridge is good only if it looks like a wedding cake or a natural phenomenon. I do not deny that there are times when bridges appropriately serve other functions than solely to provide a crossing; when added decorative design features become an integral part of the visual character of a particular place. Examples such as the new bridge at Country Club Plaza in Kansas City or the bridge which creates Freeway Park in downtown Seattle show how the added features of graceful railings and light fixtures, landscaping and fountains, can become extraordinary additions to the basic bridge.

But more often what is really needed is just a VERY GOOD BRIDGE. A bridge whose simplicity and gracefulness is there for all to see and use. A bridge which is there for generations. Not a bridge which tries to hide itself and blend into its environment, but a bridge which is compatible with its environment. (There is a big difference here!) A bridge which exhibits the very highest level of QUALITY.

In my opinion there are two basic issues which must be satisfied in a good bridge: the structural design, and the details. It is not sufficient to have a Bridge Architect who "pretties things up" for any kind of structure that the bridge section or our consultants turn out, whose efforts are additive at the end of the design process, and whose efforts can frequently be dismissed as unnecessary additions to the budget. You know the argument: "I'm sorry, Ken, but that gargoyle could be a simple plastic pipe; our money has to be spent on things that benefit the driving public".

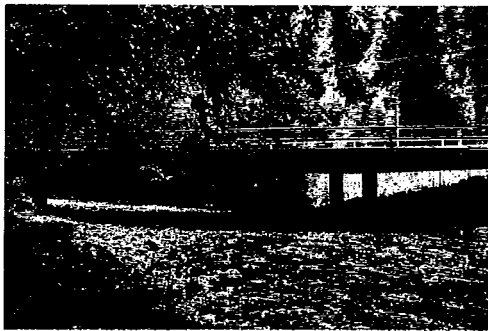
Aesthetics must be a part of the program for a bridge from the very beginning. They must be an active part of bridge engineering decisions at every step of the way, and they must be a part of the careful application of each detail of the bridge and its approaches. Thus aesthetics cannot be fully achieved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

16 Kruckemeyer



Kenneth Kruckemeyer

Fritz von Emperger's 1895 steel reinforced concrete arch pedestrian bridge across the Housatonic River in Stockbridge, Massachusetts represents a breakthrough in technology and aesthetics.



Arvid Grant

Arvid Grant's bridge over Mill Creek in Kooskooskie, Washington combines gracefulness with economy of materials.

The Responsibility of the Owner

My presentation here is not that of a Bridge Engineer with the experience of years of design calculations and bridge construction supervision under my belt. My experience lies in the coordination of large projects and in the administration of public agencies. The structural engineering courses which were part of my architectural training are perhaps of no greater importance than is looking at the watercolors of bridges which my father did when I was a child. Last year my agency, the Massachusetts Department of Public Works, and the Massachusetts Council on the Arts and Humanities sponsored a conference, three workshops and an exhibition entitled: Bridge Design—Aesthetics and Developing Technologies. The presentations and discussions of that conference have become an integral part of my ideas about both process and product of good bridge design.

This background brings me to a realization which I believe all of you will surely share: that good bridges don't just happen. They must be the specific goal of those who are responsible for them. That starts with the public agencies who are responsible for bridges since it is the owner who must demand quality, and it is the owner who bears the responsibility to see that quality is delivered. To be certain, the bridge designer (whether in-house or consultant) plays a key role, but the owner must have the intent, must nourish the production, and must ultimately provide the continuing loving care of the finished product.

There are three specific parts to successfully fulfilling that intent which I would like to discuss: Project responsibility, Project speed, and Recycling of experience. My comments may seem bureaucratic to those who are interested in the meat of engineering, but I hope you will see them as I do, as ways to effectively apply the bureaucracy towards the achievement of superior products.

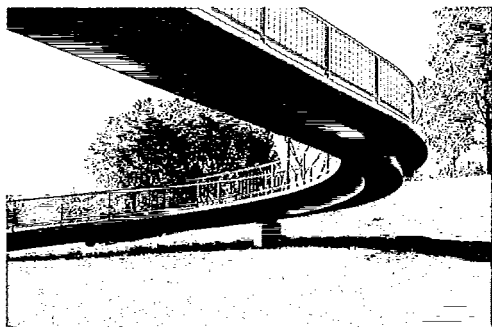
Project Responsibility

The very first step which the owner must take is to define the problem to be solved and to identify a project manager to follow the project throughout its development. We must be able to answer the questions: What are we trying to do here? Who will insist that the goals are being met? This means going to the site and absorbing the essential elements of that site in order to establish the vision for the project. This project description must follow the project from beginning to end, it must be there as a constant reminder of the challenge. The project manager, because he or she knows that challenge, has the tools to insist that that challenge be met. Together the description and manager serve to prod the designers, to reinforce the detailers, and to inform the reviewers of what the goal is which must be achieved.

"A 130-foot single span across the Millers River, abutments founded on bedrock" is an insufficient description. The full description also needs to set the requirements for aesthetics, abutments, land use, construction, traffic, and maintenance. It is used throughout the design process. When waivers are necessary, the project description becomes the justification. When it comes time for approvals, it becomes the standard for that review. It places the design into context rather than into the tables.

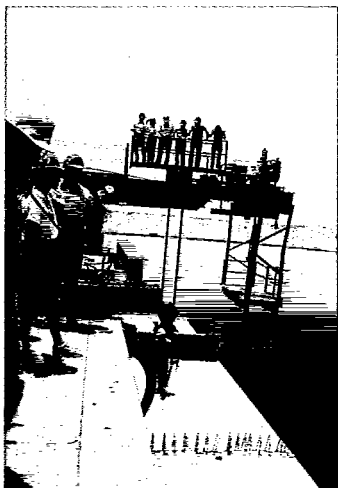
The assembly line approach, passing the project from one person to the next for each

18 Kruckemeyer



Arthur Hedgren

This fast-tracked steel pedestrian bridge by Arthur Hedgren of HDR - Richardson Gordon in Omaha, Nebraska retained its grace through the design process.



Kenneth Kruckemeyer

On the construction site of the Sunshine Skyway across Tampa Bay designed by Figg and Muller.

succeeding phase, doesn't work for the basic reason that continuity of vision gets lost along the way. We aren't just putting together the latest model Ford here, we are creating something — this is art as well as technology.

Project Speed

A design may take thirteen years to process from its initial concept, slowly advancing through environmental impact statements, preliminary design, public hearings, final design, through innumerable reviews, and to PS&E, before finally arriving at the actual point of construction. This is not an unusual length of time for large projects across the country. All too easily the vision that someone may have had is lost through this long process.

I can identify several reasons why speed is critical to the delivery of a superior bridge design: it saves money; it makes it possible to deliver up-to-date technology; it provides emotional rewards to design personnel; it builds public support for the agency; and, most importantly, with speed it is harder to lose vision.

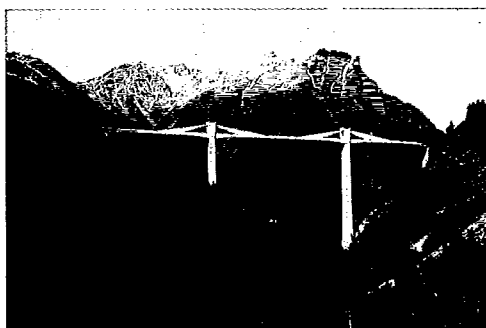
The effect of inflation on the cost of a bridge is an important reason to build the bridge sooner than later: time is money. Another good reason for project speed is to take advantage of new technologies. Materials and construction techniques are continually changing, and it is to our benefit to take advantage of these new developments. If all were perfect with our bridges today perhaps we could rest on our laurels and continue to turn out carbon copies of yesterday's bridges. But all is not perfect. Not only are there new physical challenges to be met, but there are also issues of deterioration, heavier loadings, salt corrosion, lead paint poisoning, and environmental requirements, which all add up to continuously changing responsibilities for the bridge designer. A thirteen year schedule forces us to constantly rework projects to meet new requirements, and it prevents the rapid recycling of experience which makes technological development possible. While speed does not assure that we will use new technology, it is necessary to advance that technology and to put it to practice to solve the current problems with bridges. The positive results of such advancements are important to the morale of the workers and to the general public.

How does one prevent taking too long to design a project? The first point is not to start too early. Projects should be programmed so that design begins only when delivery is in sight. Secondly, determining the essential elements and getting agreement on them is imperative if the goal of continuous project management is to be met. Who wants to work on a project if they expect it to take thirteen years? Re-doing things that are already done is a destructive process. With the expectation of a lengthy project schedule one is forced into the assembly line approach, and the continuity, the vision, is lost.

Recycling of Experience

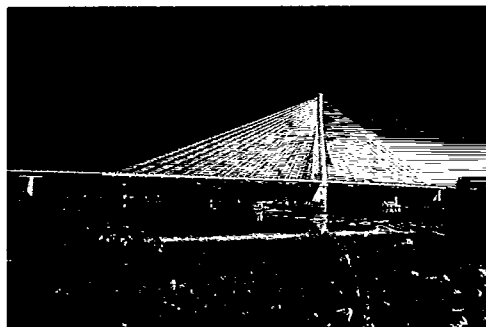
When things are going badly, when there is too much work to be done, when budgets are stretched, when personnel are cut, the tendency is to try to limit the scope of work, to reduce the number of variables, and to minimize the inputs. Staff can no longer get out to the field at the beginning of design. "Let's not send the engineers out to look at that construction problem", "We don't have time to go to that conference on new technology", "Get the work out" becomes synonymous with putting the blinders on.

20 Kruckemeyer



David Billington

*Christian Menn's Ganter Bridge
boldly illustrates the skill of Swiss en-
gineering.*



Arvid Grant

*Arvid Grant's cable-stayed bridge
across the Ohio River at East
Huntington, West Virginia.*

But these experiences are an absolutely essential part of learning, and learning must be a continuous part of both personal and institutional life. Seeing the design which you have sweat over for months become reality, understanding the fabricating and construction process, and then taking that knowledge back to the drafting board is not only essential to the development of technology, but is also essential to the development of the individual designer, and thus to the product which we are trying to achieve. In addition it is a primary opportunity to reinforce visual issues, to see the bridge in its context, and to evaluate the success of one's efforts. Without understanding the construction impact and the maintenance implications of a design, we make not only visual errors, but financial errors as well.

Because of public bidding laws, contract documents have become a funnel through which all knowledge about a project must flow. It is nearly impossible for the lore and vision of a project to flow through these pieces of paper, and for experiences to be recycled. This must happen through people and personal contact.

The development of competent Project Managers comes from this experience of seeing all sides of a project. A manager is better able to draft the project description, control the schedule, negotiate the variances and permits, and deliver the project on budget because he or she has seen all of the parts of a project from beginning to end, and has seen things fall into place as well as having seen missed opportunities and things gone wrong. Thus recycling of experience becomes an essential ingredient in the process which starts with the project definition and moves quickly toward conclusion.

The Work of the Bridge Designer

With some of the bureaucratic issues under control let us return to the bridge team's approach to design and focus on the two facets which I mentioned: basic engineering and details.

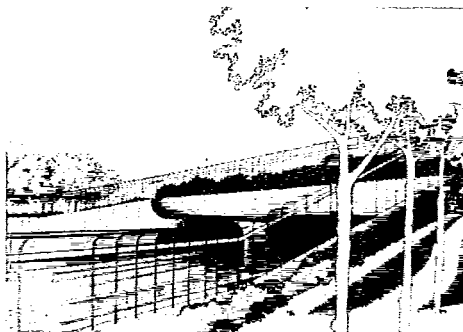
Basic Design: should a bridge blend in?

I mentioned in the beginning that structural design and details are the two basic issues which must be satisfied in a good bridge. I would like to offer several observations on both.

We are thrilled by Christian Menn's Ganter bridge not just because of its spectacular mountain environment, but also because its shape and color (structure and detail) clearly illustrate to the observer the effort and the grace of the structure which has been built to cross the gorge. Similarly, the beauty of Arvid Grant's East Huntington bridge across the Ohio comes both from its straightforward but graceful structural design and from careful attention to detail. I frequently hear engineers and lay people alike espouse the goal of bridge design as being one of making a bridge blend into its environment, yet neither of these bridges make the error of relying upon inconspicuousness as a measure of success.

Throughout this country we can see the results of the effort to make a bridge "blend in" by the green paint or stone facing applied here and there. It doesn't work! By their very nature bridges are not receding. They are objects which are very much in our attention,

22 Kruckemeyer



John Rolly

The cast-in-place reinforced concrete bridges of Boston's Southwest Corridor were designed within the context of a linear park and major urban development project.



Kenneth Kruckemeyer

Traditional materials enhance the gracefulness of the bridges across the Charles River between Boston and Cambridge, Massachusetts.



Lajos Heder

Wood trusses, vertical siding and shingles give scale and character to traditional covered bridges.



David Billington

The refinement of classical proportions through a design competition and intense public debate gave the 1889 Washington Bridge across the Harlem River its visual integrity.

and it is because they are not background objects that we must treat them with great care.

Design in Context

I have said that a bridge is often unsuccessful when it attempts to blend into its environment; however, this is not to imply that careful attention to context should not be reflected in bridge design. A bridge must be a good neighbor. As such, the planning issues of adjacent land use, the visual character of the built and natural environments, the roadway and bridge geometry, and the costs of the entire construction project are all important components of working out a successful design. This is where the project description mentioned above is critical. These items must be described as part of the challenge to the bridge designer from the very beginning as an integral part and parcel of the problem.

The twenty-three bridges of the Southwest Corridor Project exemplify the importance of context. In this three-quarters of a billion dollar transit, railroad and urban development project in Boston the bridges were considered both individually and as parts of the whole. Although a simple span steel structure appeared the least expensive individually, this was not the case when placed in context. Issues as divergent as railroad profiles, storm sewers, existing houses and shops, maintenance access, fireproofing and the desire to prevent pigeons from roosting above transit platforms all established a context where a cast-in-place rigid frame concrete bridge was determined to be the best alternative. In fact, this was also the least expensive bridge in terms of lowest total project cost. Individual and isolated bridge type studies would not have resulted in the best answer.

Straightforwardness of Design

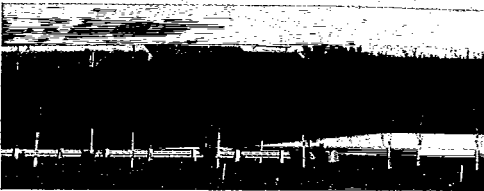
Efficient use of materials and technology as another part of basic engineering comes from my earlier list of administrative requirements. This is a challenge to the response that we cannot afford to pay attention to aesthetics that we have all heard too often. When a structure uses materials efficiently there is less waste to be paid for. When a structure takes advantage of contemporary construction techniques, there is less wasted labor. Some of the bridges which we all refer to as being the most aesthetically pleasing, for example Maillart's arched bridges in the most remote corners of Switzerland and the coastal highway bridges in California built during the depths of the Great Depression were created because of, not in spite of, financial pressure. But they were also the result of the conscious and careful massaging of sound structural theory into an artistically pleasing result. I subscribe fully to David Billington's thesis that "aesthetic motivation in a structural artist seems in fact to stimulate efficient designs". The two must go hand in hand.

A good looking bridge is not necessarily more expensive; in fact, it may be less expensive because of skillful use of materials and technology. The bridges of earlier centuries were limited by the strength and colors of natural materials, and by shapes and sizes which could be handled within the limits of human strength and limited machinery. These very limits somehow make them pleasing and beautiful. Today the challenge is greater because we can go far beyond these "natural" limits and therefore must establish our own controls.

24 Kruckemeyer



Lajos Heder



John Rittner

Installing protective screening in Massachusetts — one of the most noticeable and objectionable of all bridge details.

Careful attention to the location of this well-designed pumping station in California placed it in the shadows and where it did not need to be surrounded by chain link.

Pedestrian bridge over Central Parkway in Cincinnati, Ohio, by Vogt, Ivers and Seaman, 1958.



The French King Bridge, designed by the Massachusetts Department of Public Works in 1931, pays special tribute to the crossing of the Connecticut River by its design .

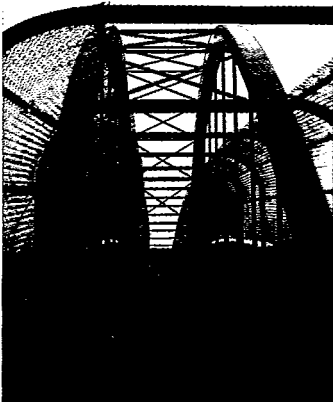


Kenneth Kruckemeyer

Except for the sign, a driver on I-89 would probably be unaware of crossing the Connecticut River between New Hampshire and Vermont. The roadway profile provides no clue and there are no end-posts to provide any celebration.



Kenneth Kruckemeyer



Kenneth Kruckemeyer

Pedestrian bridge over I-75 in Cincinnati, Ohio, by Vogt, Ivers and Seaman, 1959. Protective screening added later by others.



Kenneth Kruckemeyer

26 Kruckemeyer



Lajos Heder

Bridges are the signature of the bridge designer and provide a memorial — this one is to Leonard Russell, former mayor of Cambridge.



Lajos Heder

This bridge, also in Cambridge, memorializes Charles Eliot, the American editor and educator. By which of these bridges would you choose to be remembered?



Arvid Grant

Every bridge is the result of conscious choices by its designers.



Lajos Heder

Instead of chaos, the choices can result in extraordinary simplicity and grace.

Details

Next let us consider details. Poor details can easily destroy a good looking bridge. In addition to the view of the bridge from the riverbank, the view from on top is critical here. Become the driver, or more important, slow down to the speed and closeness of the pedestrian and concentrate on the details. It is at this level that many of our standards present the very worst of bridge design, and it is not until we, as administrators and as engineers revise current practice that we will be successful at producing good bridges.

There is an extreme contrast between the care given to details in the past, through perhaps the thirties, and present-day bridge details. Look at the bridge railings, the protective screening, the end-posts, the abutments, the right-of-way fencing. We must question why we tolerate these assaults on our minds and on our clothing.

For the Bridge Design conference, Lajos Heder and I prepared an example to illustrate the relationship of details to the whole. Two arched pedestrian overpasses in Cincinnati, Ohio demonstrate how overwhelming protective fencing can be to the pedestrian, even when it is barely noticeable to the driver. One overpass has no protective fencing, while another has been retrofitted with fencing. The structural statement of both bridges is sufficiently forceful that, from the driver's perspective, even the bridge with protective fencing is able to retain its gracefulness and proportions. The detailing of the fencing is so clumsy, however, that the experience of walking across the screened bridge has been transformed from a pleasant passage into an assault of chain link.

Someone must be the guardian of these details. Seldom is there one drawing or model prepared which shows the whole accumulation of details; and often, if a drawing is done, its purpose is for public review, not for critical analysis and development by the designers. Reference to standard details may be appropriately expeditious for speedy production of working documents, but the whole is not seen in one place until it is produced in real life. Then it is too late to change the details. And even then have we made certain that the designer goes out to experience the full impact of his or her design and recycled that experience?

Summary

In his workshop at our Bridge Design Conference, Lajos Heder, author of [Aesthetics in Transportation](#), asked each engineer to be conscious of the choices which are his or hers to make. We each determine the legacy which we leave for this and future generations. The structures which we build have a story to tell about what we have determined is important and necessary in our public as well as our private worlds. With this in mind let us respond to the importance of aesthetics as an integral part of every challenge in bridge design.



MP 1-3

Fundamental Principles of Bridge Esthetics

by R. Lacroix

Synopsis: Historically the bridge has been a major work of art, but today we require many smaller bridges to facilitate freeway traffic flow as well as bridges for major crossings. Esthetic considerations for design of the two extremes are quite different. For best results the engineer collaborates with an architect trained in bridge design, but retains leadership.

Keywords: architecture; bridges (structures); engineering; esthetics

30 Lacroix

Roger Lacroix, a consulting engineer in Paris, is professor and head of the civil engineering department at the Ecole Nationale des Ponts et Chaussees. He serves as advisor to the chairman of Freyssinet International, has been president of the Association Francaise pour la Construction, and is honorary president of the Federation Internationale de la Precontrainte. He also presides over the French committee in charge of the reinforced and prestressed concrete code.

For centuries the bridge has been much more than a common structure. It is the symbol of communication, a link between people across a river, the key to new territories.

This noble nature is recognized by the French language, which refers to "l'Ouvrage d'Art." not to mention the Pontiff, a word whose origin is "le Pont" (the bridge).

Indeed the ancient masonry bridges, with their elliptical or circular arches looked very proud, and a number of them, still in use after several hundred years, are religiously preserved.

Nowadays the situation is entirely different. A growing number of highways, expressways, and motorways cut up our countries, creating an enormous need for smaller bridges, of which the main quality is to remain unnoticed by the driver who is preoccupied with questions of safety and speed limit.

On the other hand, very large crossings have required the construction of new types of Ouvrages d'Art: steel suspension bridges, elegant viaducts, cable stayed prestressed concrete bridges.

The fundamentals of esthetics are quite different for these two extremes. In the first case of the small bridges the designer has almost no freedom to express himself. He must be sober, and the esthetic quality of the bridge is more in its details than in its shape:

- o The color of the painted steel parts
 - o The fineness or the relief of the concrete surfaces
 - o The color of the cement and aggregates
 - o And of course, proper maintenance
- These are all very important factors which are too often overlooked.

The case of long bridge crossings is at the opposite extreme. For such bridges, the rhythm of the spans, the layout, the shape of the supports, and many

other features may be chosen freely by the designer without modifying significantly the total cost of the work. The designer is able to create an authentic work of art according to his own temper and suited to the surrounding landscape.

An important question is whether the designer has received a proper foundation in esthetics. He is generally very skilled in structural analysis, in construction management, soil mechanics, and various other fields pertaining to civil engineering, but what about esthetics?

After studying numerous examples it is easy to recognize the sites which have or have not profited from the work of a skilled engineer. Some viaducts are "ouvrages d'art" while others are only "outrages a l'art."

In order to avoid such mistakes the designer must not hesitate to call in an architect who can play an important role in the definition of the bridge, provided the two following conditions are fulfilled:

A. The architect has received specific training for bridges since bridge esthetics is governed by different principles from building esthetics.

B. The architect must accept the leadership of the engineer. Both must be good natured enough to achieve actual teamwork...but that is another story.



MP 1-4

Creating a Beautiful Concrete Bridge

by J.C. Ritner

SYNOPSIS: The ideal bridge is identified and its creation established by the laws of physics interfaced with existing technology. This result is compared with the actual bridge. The ideal bridge and the actual bridge are brought together from a visual stand point by utilizing classical considerations of proportion, rhythm and balance.

This actual bridge relies on overall integration of engineering, architectural and environmental considerations. The ideal bridge should be considered a first attempt at a solution.

The final solution is the result of reprocessing the original information to include cost, possible widening and the requirements of special interest groups.

Architectural features are used to enhance a bridge's strong points and to reduce the impact of its weak points.

Bridges for interchanges have basic requirements different from river crossings, undercrossings, overcrossings and pedestrian structures. These different requirements are brought together visually by using standard details and standard structural systems. The structural systems are optimized to create bridges with the longest possible spans within the economic and physical restraints capable of construction.

Contemporary technology is used in the engineering and architectural development by utilizing three dimensional computer aided drafting techniques.

Keywords: architecture; bridges (structures); computer programs; drafting (drawing); engineering; esthetics; maintenance; specifications; structural design

34 Ritner

John Ritner, a registered architect, has 23 years experience in the design of bridges. Now in charge of the Aesthetics & Models Unit for Caltrans, he provides consultant type services throughout the State of California with award winning results.

DEFINITION

"Beauty is in the eye of the beholder." For the purpose of this paper, visual beauty is something that is not awkward, it is something that does not appear to be out of place.

The State of California builds bridges incorporating standard details. It does not build standard bridges.

The cast-in-place concrete box girder is our standard to which all other bridge types are compared. Mr. J.E. Roberts, Caltrans-Division of Structures Chief, has written a paper explaining this situation.

PHILOSOPHY

The ideal bridge, for the purpose of this paper, is the maximum utilization of existing technology and standards. This description satisfies the requirement that bridges be produced with a minimum amount of effort.

The actual bridge must include other requirements such as satisfying the public and providing appropriate aesthetic considerations.

The ideal bridge based on advance planning studies represents the actual bridge in its most elementary form. For example: balanced spans, span length based on efficiency, round columns, vertical side exterior girders, minimal abutments, optimized deck overhang and standard surface finish.

The first attempt to produce a bridge for a specific site usually involves a cast-in-place concrete box girder solution. If the bridge site problem cannot be resolved due to span length, column placement, public opinion, or political concerns, other solutions such as precast concrete or steel are considered. The ideal bridge and the actual bridge are brought together from a visual stand point by utilizing classical considerations of proportion, rhythm and balance.

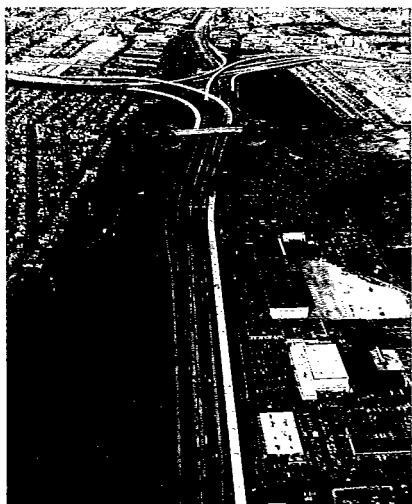


Fig. 1--San Francisco Airport viaduct and Route 380



Fig. 2--San Francisco Airport viaduct and crossover structures

36 Ritner

Architectural features are used to enhance a bridge's strong points and to reduce the impact of its weak points.

This system of producing beautiful bridges requires a team of professionals to produce the best compromise of engineering, architectural and construction effort at the lowest cost.

River crossings and interchange structures represent problems requiring relatively long spans with fixed footing locations. Structure depth is limited by clearance requirements and the desire to maintain low approach heights.

The appearance or architectural style of river crossings is usually considered independent of the architectural style determined for the Route. This policy is based on the assumption highway users should be exposed to a unified compatible style as they travel along a route. Undercrossings and river crossings are usually not within the users focused viewing area, therefore, they are not required to comply as closely to the approved route style as overcrossings and connectors.

Undercrossings and river crossings can be considered a relief or an opportunity to pursue a deviation from the approved design. This deviation is usually influenced by community desire for individual recognition.

Approved route style usually consists of architectural column standardization, outside girder position (vertical or sloped) outside girder to soffit detail, abutment detail (sloped or vertical) and barrier railing detail.

Girder depth and column dimensions are usually determined by structural considerations. Generally speaking, a long span with the smallest possible girder depth is preferable. Visual limits to maximum girder depth result from the size of the opening below the girder. A small opening for a deep girder is cause for designing a haunched girder. The design feature is considered architectural when it influences appearance without structural necessity. The best use of architectural features incorporate structural requirements in the solution, thereby combining both structural and architectural considerations to enhance the overall solution. Flared columns can be an example of this enhanced solution when the flare is used to transfer forces in a rigid column to superstructure connection.

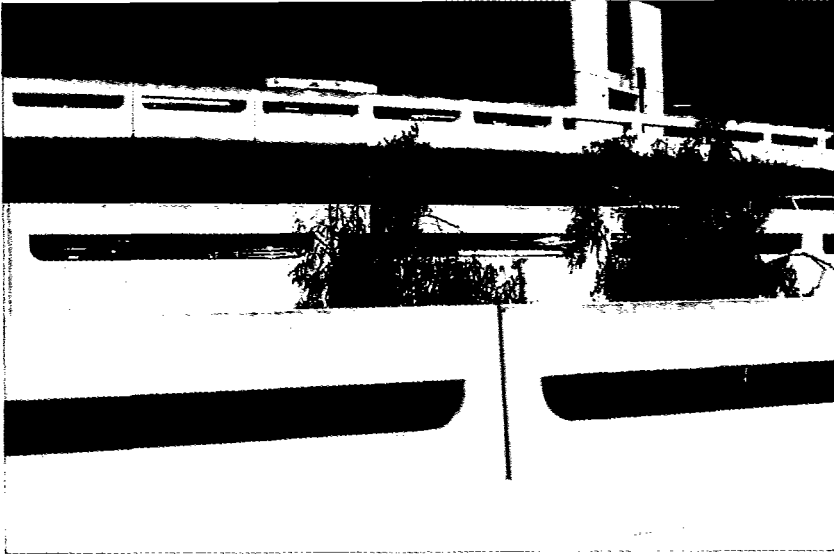


Fig. 3--San Francisco Airport parking



EQUAL DEPTH GIRDERS

R t e . 3 8 0

Fig. 4--Route 380 cross-section



UNEQUAL DEPTH GIRDERS

R t e . 2 8 0

Fig. 5--Route 280 cross-section

38 Ritner

INTERCHANGE

The San Francisco Airport Viaduct and cross-over structures connect San Francisco International Airport with Route 380 and Route 101. (Fig. 1) (Fig. 2)

DESIGN CRITERIA

Existing Airport bridge structures (Fig. 3) with unique architectural/engineering features, present a design theme at the southern boundary of the project.

The northern boundary is defined by Route 380 (Fig. 4) with existing features resulting from architectural/engineering rationalization of Route 280. (Fig. 5) For example, the impression of thinness achieved by blending the sloping soffit completely into the exterior girder results in an outside girder with less depth than the other girders. Approximately the same visual effect can be achieved by blending the soffit from the outside girder to edge of deck. An architectural solution which provides a smooth transition between these two architectural styles was required. (Fig. 6)

The overall theme is smooth rounded surfaces to recall the shape of aircraft. The concrete box girder of basic rectangular shape was modified to reflect this theme. (Fig. 7)

The standard barrier rail is a component which can be modified from its rectangular cross sectional shape. The barrier rail is a major part of the design theme. It not only continues the smooth rounded theme but also incorporates a grooved design in its exterior face to continue the pattern produced by openings in the railing of the San Francisco Airport structures. The standard barrier rail may not legally have openings when used on state highway structures.

The columns are standard architectural single flared circular plan columns as used in existing Route 380. This column type along with the stained exposed aggregate texture column insert is continued.

The viaduct and cross-over structures have longer spans than the San Francisco Airport parking structures. These longer spans require larger columns. The smooth rounded columns are less eye catching or less inhibiting to visual flow than rectangular section columns. Therefore, they are appropriate not only because they reflect a theme similar to 380/101, but also fulfill the basic design philosophy of creating the least visual distraction.

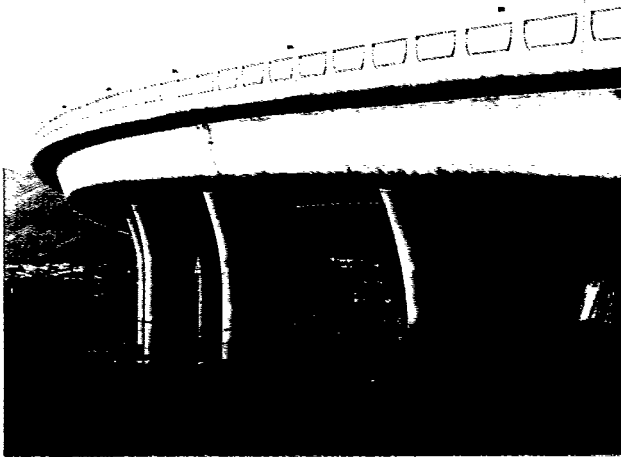


Fig. 6--San Francisco Airport viaduct



A I R P O R T V I A D U C T

Fig. 7--San Francisco Airport viaduct



Fig. 8--San Francisco Airport viaduct abutment exposed aggregate



40 Ritner

Abutments are made as small as possible. Where closures are required, the exposed aggregate theme of the columns is repeated. (Fig. 8) The super structure cross-section extends beyond wing walls.

RIVER CROSSINGS

River crossings generate strong response from the communities located near them.

Two bridge replacements on the Russian River demonstrate our process for providing bridge replacements.

RUSSIAN RIVER BRIDGE AT JENNER

The town of Jenner is located on the Pacific Ocean confluence of the Russian River.

DESIGN CRITERIA

The existing bridge was considered to be exactly what the local residents wanted. (Fig. 9) They believed it would last forever. Several investigations disclosed very little sound metal remaining under the paint. Reconstructing a bridge that would have a very high maintenance cost was unacceptable to the Highway officials.

The problem was to convince the local inhabitants their existing bridge could be replaced with a new bridge which would conform to their desires and not damage the environment.

The Division of Structure Design sent engineering and architectural representatives to attend a public hearing in the community. Models, renderings and photo retouches were presented. The public accepted the proposal and the completed bridge was a 1985 Post Tensioning Institute Award of Excellence recipient. (Fig. 10)

This modification of the basic concrete box girder contains the following features.

The railing which includes bicycle capability is derived from the Standard New Jersey Barrier. The outside face is sloped to catch reflected light. A texture to reduce the stark qualities of smooth concrete is used. The texture also suggests a thin bridge across the river to visually tie the ends together.

The deck has exceptionally wide overhangs to create a deep shadow on the exterior girder. This shadow reduces the apparent depth of the girder. The lower edge of the inclined exterior girder is rounded to reflect the countryside and blend the soffit with the girder to make these two structural elements appear continuous.

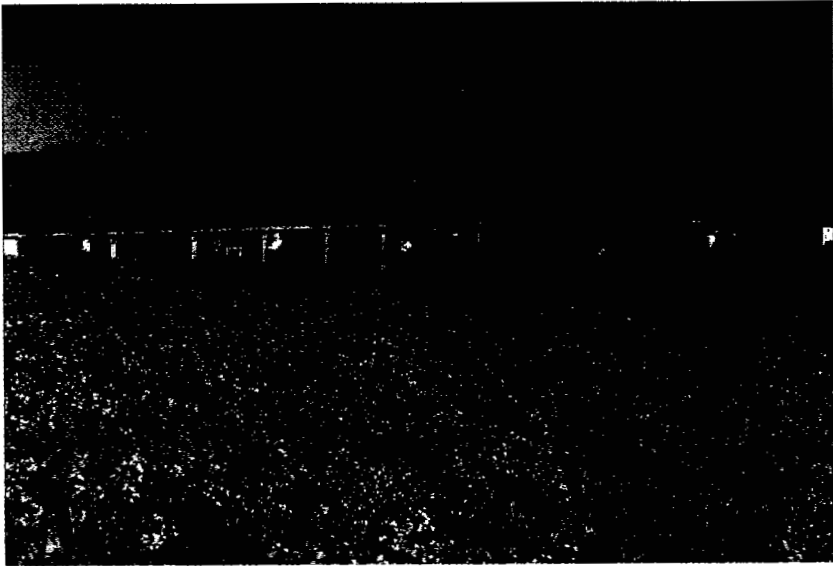


Fig. 9--Old Russian River Bridge at Jenner



Fig. 10--New Russian River Bridge at Jenner

42 Ritner

Columns with rounded qualities provide the least resistance to river flow and reflect the rounded qualities of the environment. Texture was not used because the columns were intended to appear to be the least complicated means of support. Standard architectural columns with one way flare were capable of performing the structural requirements. Forms for these columns are available. They have been used on many overcrossings and undercrossings.

The texture on railing and abutments was intended to reflect the geological out-croppings. (Fig. 11) This texture was theoretically a form liner produced feature. Environmental restrictions, during design, dictated construction waste would not be allowed in the river. During construction, the texture was produced with a chipping hammer at the Contractors request. The waste problem seemed to disappear.

RUSSIAN RIVER BRIDGE AT GURNEVILLE

The town of Gurneville is located 9 miles upstream from Jenner.

DESIGN CRITERIA

The environment could not be more different from Jenner. The problem however was similar: replace the existing beloved bridge. (Fig. 12)

Gurneville Citizens expressed their dislike for the award winning Jenner Bridge and a preference for a through truss.

Preliminary meetings between the District Highway officials and elected Public officials generated a stream of protests from the Public to Caltrans. Requests for through truss bridges were received by the District. Discussions between the District and Office of Structure Design produced an agreement to offer a concrete box girder bridge: the ideal bridge. A study for a through truss did not occur at this time. An advance planning study was developed by the structural engineers. An engineer and an architect visited the site and obtained photographs. These photos were used as a background for the actual bridge presentation. The actual bridge, utilizing the engineering Advance Planning study, was developed by the Aesthetics and Models section. The architectural design process was performed under the following considerations.

The Jenner bridge was a "clean design" in an open environment. Gurneville is a compact village located in a forest.

The proposed bridge is intended to reflect its position in the environment.

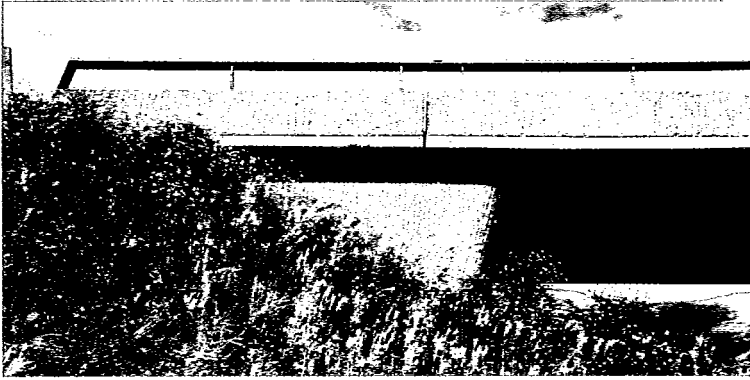


Fig. 11--New Russian River Bridge at Jenner abutment



Fig. 12--Existing Russian River Bridge at Guerneville



Fig. 13--Proposed Russian River Bridge at Guerneville

44 Ritner

Span lengths are based on structural efficiency. Pier location is not critical.

The basic trapazoidal concrete box girder is notched at the soffit exterior girder location and architectural dentils are created. (Fig. 13)

All architectural design elements attempt to reduce mass.

Trees are composed of many small parts. A structure attempting to relate to trees and a village atmosphere would relate to these elements if it appeared to be composed of relatively small detail parts, such as the coffered railing.

The bicycle rail is a standard picket modified to create an impression of the old truss bridge.

The columns are angular and grooved to produce a shape which definitely does not look like a freeway bridge. The pier wall type column design reflects old river crossing design and the grooves reduce the apparent mass.

A CADD system is used to develop the design in three dimensions. (Fig. 14)

Abutments are as small as possible with a texture to reflect the column design.

The architectural renderings were shown by Caltrans to elected public officials. The public officials approved the scheme and will confer with other public officials without Caltrans representation to decide what will be shown at a public hearing.

DESIGN PROCESS SUMMARY

In each of the examples presented, a standard procedure was followed.

1. Bridge Engineers obtain the Job from Highway Officials.
2. Bridge Engineers produce an Advanced Planning study consisting of plans, elevations, sections and cost.
3. Engineers and architects discuss the study or studies informally.
4. A general plan derived from the informally discussed Planning study is developed.
5. Structural engineers, architects, construction engineers, specification writers and maintenance engineers cooperate in a formal meeting - the type selection meeting - to arrive at an agreement of approval.