Hoover Dam Bypass
Colorado River Bridge

Prospectus

The Hoover Dam Bypass Colorado River Bridge is joining one of the most famous civil engineering landmarks in the world, and pairing off in such close proximity that the visual presentations of each will forever be tied together as one. This circumstance creates a solemn duty for design – an obligation to present a design that meets the challenge of visual appeal and engineering excellence that the designers of the dam met in their day. Heightening this challenge is the need to provide value, and design within funding priorities for the project.

Project Setting and Circumstance

The Black Canyon below Hoover Dam is an 800 feet deep gorge carved by the Colorado River through a rugged, hard rock landscape forged by eons of geologic transformations. The dramatic rock cliffs reveal a palate of geology that ranges from clear basalts to ash flows and seams of dikes and infills from the volatile geologic history, which collectively paint an incredible mosaic of colors and forms on the cliffs below the Dam. The new bridge will soar across this dramatic landscape with a span of between 1080 and 1330 feet, framing the view of Black Canyon from the Dam below and offering a breathtaking perch above the entire Hoover Dam site.

Hoover Dam is one of the engineering wonders of the world – an internationally recognized civil engineering landmark that is known as much for its grandeur as it is for its engineering achievement and utility. There are large dams around the world, but few are recognized for their elegance and grace in a setting as spectacular as Black Canyon. Hoover Dam is a magnate for millions of visitors in large part because the designers and builders of the Dam expressed an art for engineering that went beyond the austere and functional. They created a colossal civil engineering facility with a unique identity – one with both strength and grace, and one that has been the standard of excellence in dam design for over 70 years.

This dramatic setting for the Hoover Dam Bypass would be spectacular even in the absence of the Dam. The natural beauty and drama of this rugged rock gorge begs for simple elegance with a sweeping crossing of the River. The focus on the form and detail of this new bridge structure will be more like that for a major urban bridge due to the millions of eyes that will set first on the bridge as they enter the Black Canyon to visit Hoover Dam. The Bridge will frame the viewscape from the Dam, from the Visitor's Center, from the Café', and even from Lake Mead. Millions of visitors to the Dam will be drawn to near-field detailed views of the bridge structure as they tour the dam and visitor's center below. The bridge will frame Hoover Dam for future generations, viewed by association with the dam in person, in print and in the countless videos celebrating the setting and accomplishments of the Hoover Dam monument.

It is into this setting that we introduce a major new bridge crossing of the Colorado River for the Hoover Dam Bypass. This new bridge must be worthy of its setting and surroundings, as well as satisfy the utilitarian needs for the transportation corridor. The objective of the bridge design effort is to provide the maximum value to the public. Just as the appointing and features of the dam add tremendous value to visitors, so too will the right blend of engineering and architecture maximize value to both those visiting the dam or recreating on the Lake and River below, and those driving across the Bypass carrying commerce along Route 93.

Aesthetic Goals and Guidelines

The EIS lays out goals for the bridge design in terms of its asset to the visual resource of the Hoover Dam National Monument and Recreation Area. (EIS – 3.7) "Three criteria were used to evaluated the project areas proposed visual quality: vividness, intactness, and unity." …"Intactness of the proposed project area is demonstrated by the integrity of the features…unity is achieved by the mixture of natural elements and human-made alterations.." The EIS goes on to say "…Recreationists are considered a sensitive user group because their viewing of the Dam, the lake, the river and the canyon is expected to last up to several hours…recreationists..value..aesthetic quality.."

The Bridge will be one of the longer arches in the US, and a major engineering structure. There is no way to "hide" a 2000-foot long bridge over the canyon, so the Dam will now share its site with the new bridge crossing. Following the guidelines of the EIS, the bridge structure should have "unity" with the site. Just as the Dam is so perfectly seated into the canyon walls that it seems to 'grow' from the earth, so too must the new bridge spring from the canyon as though it belongs to the site. The rugged elegance and simplicity of the rock canyon site must be matched by the bridge form in order for this unity to exist.

The Design Advisory Panel (DAP) recommended a canon for the new bridge design. The clear message taken from the December DAP meeting is to strive for engineering excellence in the design of today that honors the engineering excellence that went into the Dam in its day. The designers and builders of Hoover Dam expressed a pride in their creation and a respect for the visual impact of their work on future generations. These duties, as much as any engineering achievements, are what separate Hoover Dam from other large piles of rock and concrete. The drive for engineering excellence at Hoover Dam took the builders beyond a minimum functional level to achieve an expression of form and a grace of detail that has made Hoover Dam the enduring landmark that it is today. This same simple elegance is the aesthetic goal for the new bridge.

The guidelines for architecture follow the design tenets noted above. The design team's view of project objectives may be summarized as follows:

- develop visual unity with the dam and the canyon walls that frame the bridge
- develop a visual aesthetic that compliments the views from vantage points assumed by recreationists, including visitors to the dam and pedestrians/hikers within the LMNRA
- develop an engineering solution that respects the creativity and commitment to engineering excellence that went in to the design of the dam

Designs and Renderings

Introduction:

The Colorado River Bridge type study follows on the decision process of the Structures Management Group and PMT selecting the deck arch as the preferred solution for the Colorado River Crossing. Geotechnical engineering ran a parallel path with the bridge type study, and the geology of the potential skewback foundations in Nevada is only now confirmed. The aesthetics, alignment options, and logistics also differ for the short and long span options. Therefore, the preliminary design process followed a parallel path for two span lengths. One – termed the short span – calls for landing the arch on the rock knoll at the Highway 93 switchback leading down to the dam in NV. The second – termed the long span – calls for landing beyond the fault line west of the switchback, with an alignment that is approximately 30 feet to the south at the station of the skewback foundation. Roadway alignments were also being developed as the type study progressed. The ground profiles within the range of alternatives are sufficiently similar that a single ground profile was used for all the alternatives.

The type study is being advanced with 6 deck arch alternatives, 3 for each span length. On the assumption that steel is relatively more efficient at the longer spans, there are two alternatives in steel for the long span layout, and two alternatives in concrete for the short span layout. However, four of the six alternatives are appropriate at either span. The long span Vierendeel truss would not be offered at the shorter span due to the effect that the high arch rise would have on the geometry of the spandrels. The long span concrete with integral crown would be less efficient and more massive at the crown with a taller rise to span ratio, and would defer to either the composite or short span concrete with an open spandrel at the crown for the shorter arch span.

Range of Design Elements

The objective of the type study is to develop designs with the greatest value to the project. Value in the context of Hoover Dam Bypass is a blend of engineering excellence, aesthetic impact and economics of construction. There are macro and micro aspects to each of these barometers. The type study endeavors to test a range of factors in order to view the spectrum of options that should lead to the preferred solution for the bridge.

There is a vast array of design elements that affect construction economy. The type study addresses designs in steel and concrete, as well as a combination of concrete arch and steel superstructure. Designs also vary in the techniques assumed for construction, in the way in which end spans merge with the rock excavation at the abutments, and in the way approach spans blend with the spandrel spacing over the arch. Each of these choices has advantages and disadvantages when measured against one criteria or another. However, it is the best blend that will provide the greatest value, and choices for that blend are what the type study seeks to create.

The steel alternatives consist of a long-span trussed-rib option, a short-span solid-rib option, and a long-span Vierendeel-rib option. The concrete alternatives consist of a long span twin rib box arch with an integral crown, a short span all concrete twin box rib arch with a twin concrete box girder deck, and a short span composite concrete system comprised of a concrete arch with steel columns and a composite steel box girder deck system. The six alternatives chosen for study seek to address the range of both aesthetic and engineering options. Yet there are additional "blends" of design – mix of box girders vs. plate girders, concrete vs. steel columns, various deck and deck forming systems, mix of span lengths from the approach to the arch, range of deck length vs. abutment height – that can be evaluated as design elements, and apply to a number of options.

Short Span Alternatives:

Site Layout: The short span layout for the arch spans from the rock knoll at the NV switchback to the hard-rock face on the AZ side of the canyon. The elevation of the arch springing is established by the rock knoll, being low enough to provide adequate width for the skewback foundation, as well as low enough to keep the thrust line of the arch within the rock mass behind the knoll. The resulting excavation will include rock anchor tie-backs to contain the existing roadway. The arch span of this arrangement is generally 1090 feet to the theoretical springing. The rise of arch options varies with alternative, but is generally in the range of 285 to 290 feet, for a span to rise ratio of under 4.

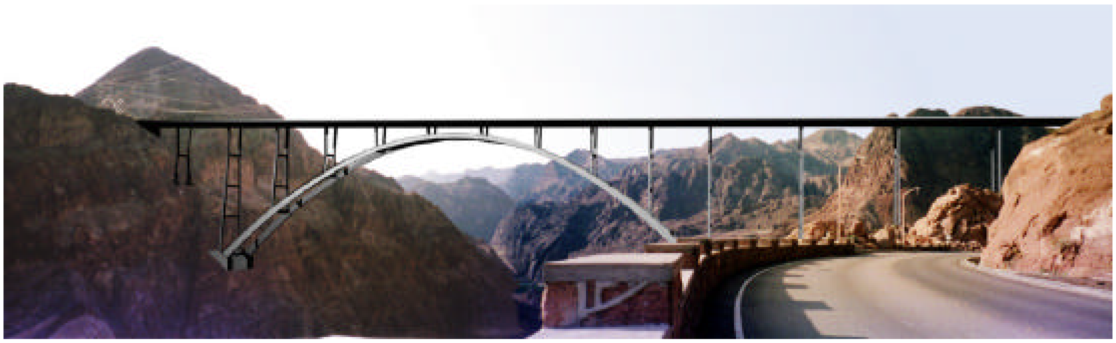
Given the span of the canyon and depth to the river, all designs are based on the use of a high-line cable crane and stayed erection of the arches. Various schemes for local access and erection are accommodated in the construction cost estimates, including benching for intermediate work areas and pioneering access roads along the approaches.

Long Span Alternatives:

Site Layout: The long span layout for the arch departs the AZ canyon wall in approximately the same location as for the short span layout. The preferred roadway alignment heading is slightly to the SW of the short span alignment when reversing station from AZ to NV. The long span traverses the rock knoll at the switchback, and founds just beyond the fault line behind the knoll in NV. A portion of the knoll must be removed to provide clearance for the arch to pass. The arch span for this arrangement is now 1325 feet to the theoretical springing. This dimension is also subject to some tuning for the final design, depending upon final roadway alignment and rock excavation requirements. The rise will vary with alternative, and generally ranges from 276 to 290 feet, for a span to rise ratio of about 4.5 to 4.8.

Design Options:

1. ***Steel Solid Rib:*** The short-span solid-rib alternative is a traditional engineering solution for a canyon crossing such as this. While a trussed-rib alternative will often be a more economical steel solution for spans in excess of approximately 700 feet, the solid-rib configuration is attractive because of its superior aesthetics, with aesthetic enhancements due to the solid rib framing, configuration of piers, and



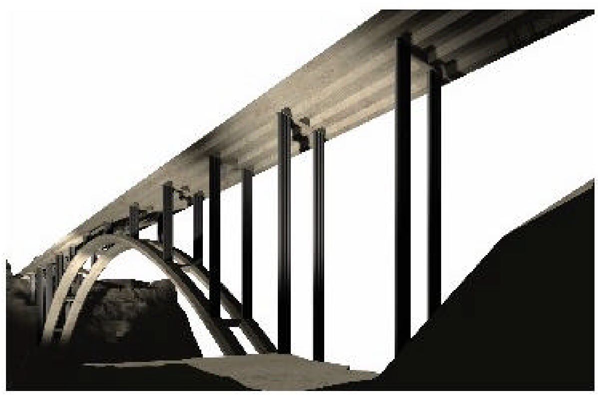
geometric blend of the piers, arch ribs and deck system. The overall structure is 2015 feet long. It is comprised of a 1090-foot main arch span, a 690-foot Nevada approach, and a 235-foot Arizona approach. The superstructure consists of steel box girders spanning approximately 120 feet on the main span and up to180 feet on the approach spans, with a composite concrete deck. The box girders were chosen over plate girders because of the improved aesthetics of the box girders when viewing the bridge from the dam vistas below. Bent-leg spandrel columns with Vierendeel bracing are being proposed to provide a light open appearance. The variable depth main span arch is inclined to match the plane of the spandrel columns, thereby resulting in a splayed rib configuration. The approach span bents are also a bent-leg Vierendeel-braced configuration for consistency.

2. ***Concrete Solid Rib:*** This concrete alternative is a classical twin rib concrete arch, with cast-in-place spandrel columns, and a cast-in-place concrete box girder deck.

The arch tapers from 18 feet deep at the skewbacks to 12 feet deep at the crown, and will be cast in place with stay support and form travelers. The overall length of the bridge is 1907 feet, with stepped wall abutments stationed to limit bridge length to the station of first rock on the southward sloping Nevada rim. The main span is 1090 feet, with typical spandrel spans of 155 feet. Columns are cast in place box sections, both in the approach spans and in the spandrels. The assumption is that the twin box girder decks will be incrementally launched from the Arizona abutment. The arch crown is open spandrel, which is more appropriate for the high rise of the short span arch layouts.

3. ***Concrete – Steel Composite:*** The concrete composite alternative combines a twin rib concrete arch with steel spandrels and a conventional steel box girder with

composite concrete deck. The focus of this alternative is to blend the economy of a concrete arch with the speed of erection of a steel deck structure. This allows the efficient use of high strength concrete in compression, casting the arch while structural steel is being fabricated and delivered to the site. In order to contain steel fabrication costs, the spandrel columns are comprised of three steel tube sections, connected with shear plates over their full height. Spandrel columns are unfilled steel tubes. Approach columns are either concrete filled steel tubes, unfilled steel tubes or reinforced concrete sections formed with the same tubular geometry. All three are projected to be similar in cost. The skewback column will be concrete filled in order to provide the additional capacity needed during arch erection. The deck boxes are conventional steel bathtubs, erected span by span using a girder launcher. The depth for these boxes is increased over normal roadway requirements in order to accommodate the connections with the integral diaphragms.



4. ***Steel Vierendeel Arch:*** The Vierendeel-rib alternative is an option that was devised

and advanced to provide a maximum opportunity for aesthetic expression. The proposed structure is 2015 feet long with a 1325-foot main span. The variable depth arch ribs will be vertical and parallel. The struts between the top and bottom chords of the ribs will be normal to the chords. The spandrels will consist of parallel tubular columns and be inclined to match the slope of the rib struts. The spandrels and ribs will have Vierendeel bracing. The superstructure will be similar to the superstructure proposed for the solid-rib alternative. The spans on the Nevada approach will be supported by a bent similar to those on the main span, except that it will be oriented vertically. We anticipate that this alternative would be erected vertically at each springing, and rotated down to closure through a temporary hinge at the spring line.

5. ***Concrete Solid Rib:*** The concrete arch for the longer span is a twin rib box girder. The box is tapered in elevation, and splayed in plan. The arch crown is integral with the deck, which lessens second order effects and blends well with the aspect ratio

for the long span alternative. The spandrel columns are also concrete, and assumed to be cast-in-place. Precast segmental columns may be considered, depending upon the capacity of erection equipment. The deck system is similar to the short span solid rib concrete, being a twin box girder structure.

6. ***Steel Trussed Rib:*** The long-span trussed rib alternative is a traditional engineering solution to a long span steel arch crossing. Before the advent of modern stay cable

erection methods, high strength steels and high strength concretes, the trussed arch rib and suspension spans were the only alternatives considered for spans in this range. The proposed structure consists of a 1325-foot main span arch with 455-foot and 235-foot approaches on the Nevada and Arizona sides of the river respectively, for a total structure length of 2015 feet. The variable depth trussed-ribs are vertically oriented with parallel and vertical spandrel columns. The superstructure is comprised of steel plate girders spanning approximately 130 feet with a composite concrete deck. The approach spans are similarly comprised of vertical column bents supporting a steel plate girder superstructure with spans to 160 feet. The vertical and diagonal web members of the trusses will be structural tubing. All bent and rib bracing members will be also fabricated from structural tubing.