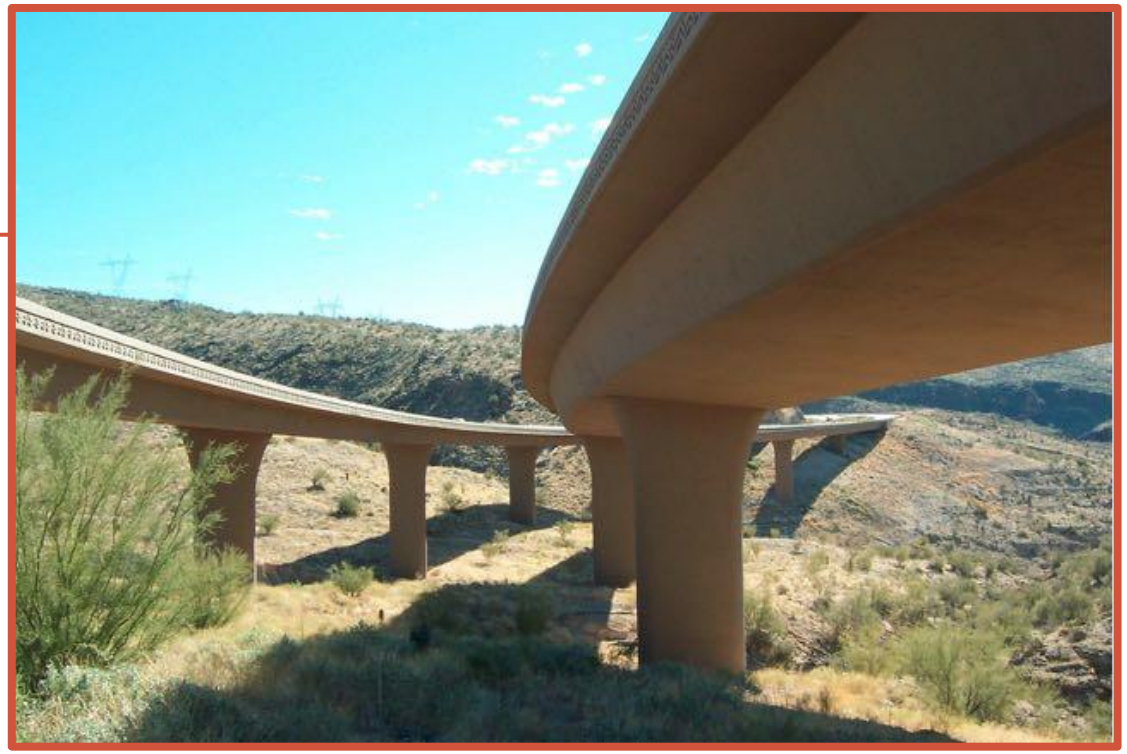
2016 ANNUAL ASCE / ASHE STATE CONFERENCE

FRIDAY, SEPT. 9, 2016

The High & Low of Engineering Options



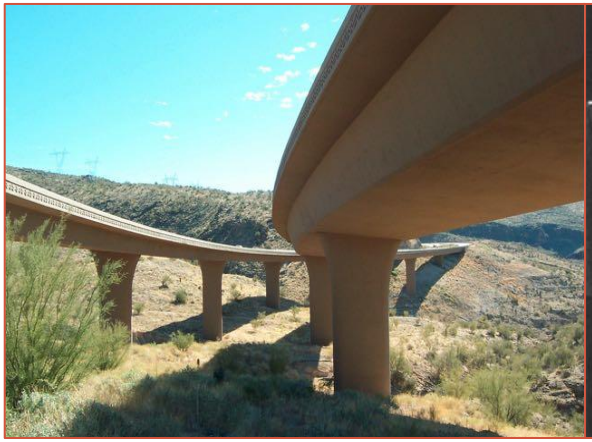
Presented by:

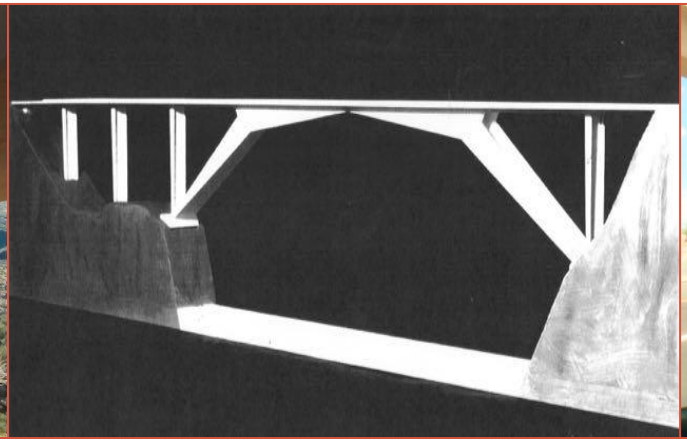
Jerry A. Cannon, P.E., S.E.
Bridge Engineer

Revised

High & Low of Engineering Options

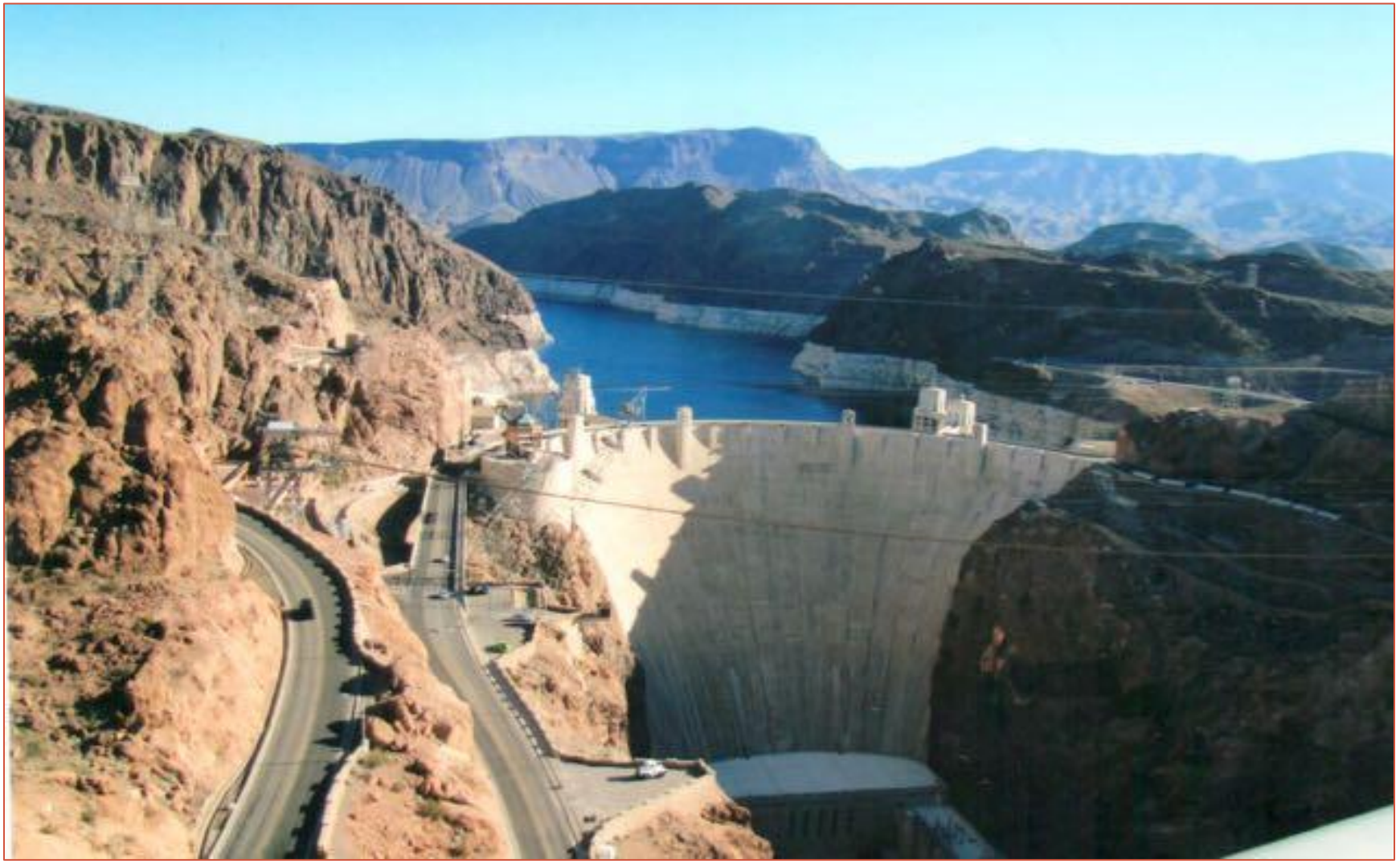
- Traveling over a bridge and viewing the landscape is a gift
- Design that is creative inspires visual drama and artistic pleasure
- Poor design decisions produce visual clutter & confusion
- Applied art on bridges can reduce sustainability
- Rehabilitated historic bridges enhance cultural resources





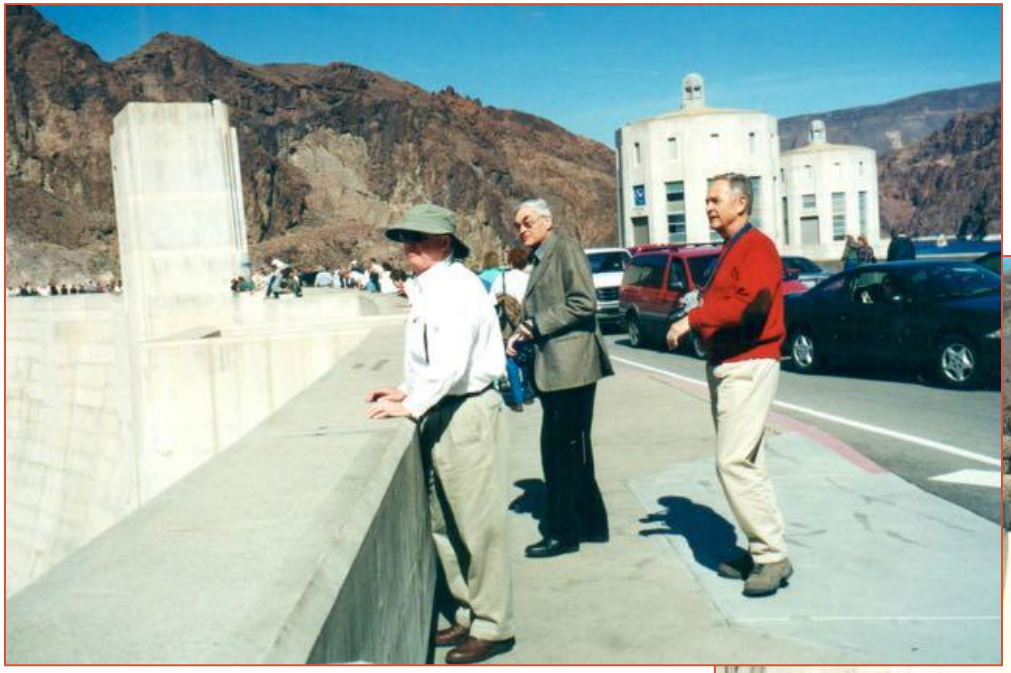
Hoover Dam

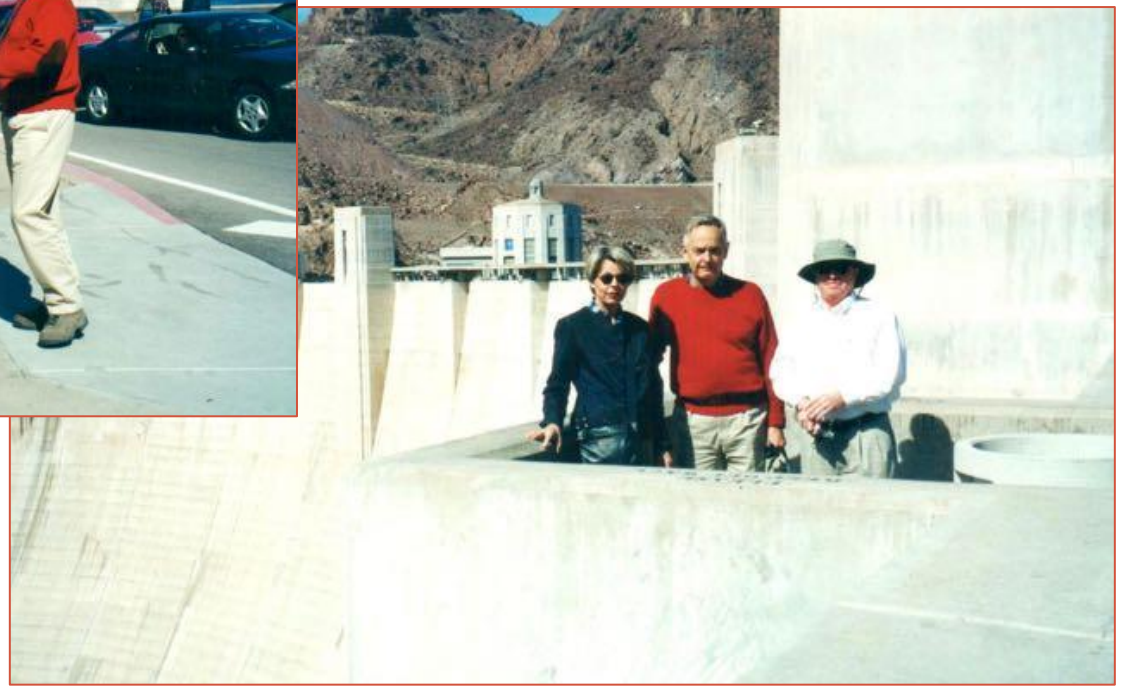
In 2001, the ASCE christened the dam as one of the marvels of modern civil engineering.



Hoover Dam

Low barrier rail and decorative design using concrete

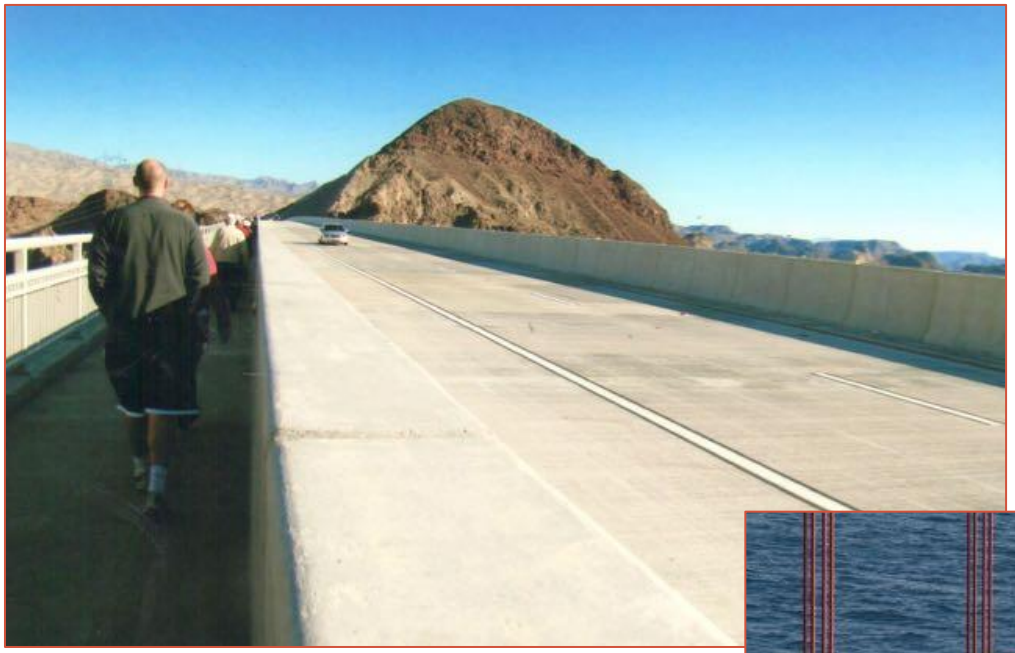




Transfer of Knowledge

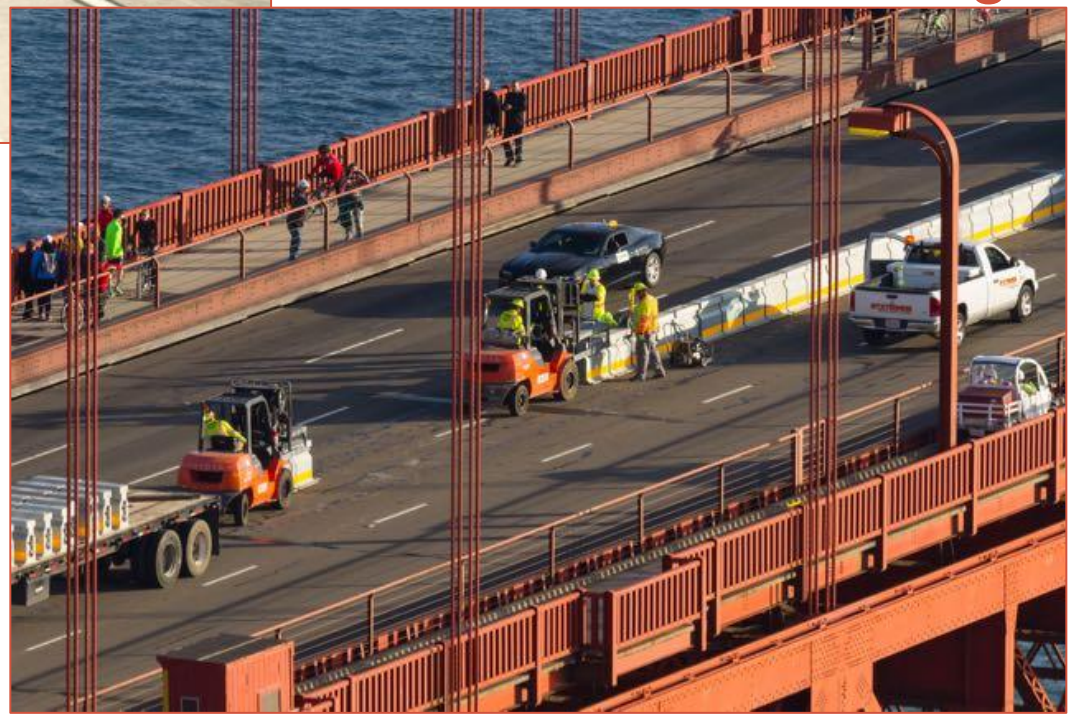
- Civil Engineers can be inspired and design great & noble structures when they set their minds to it

Hoover Dam Bypass Bridge



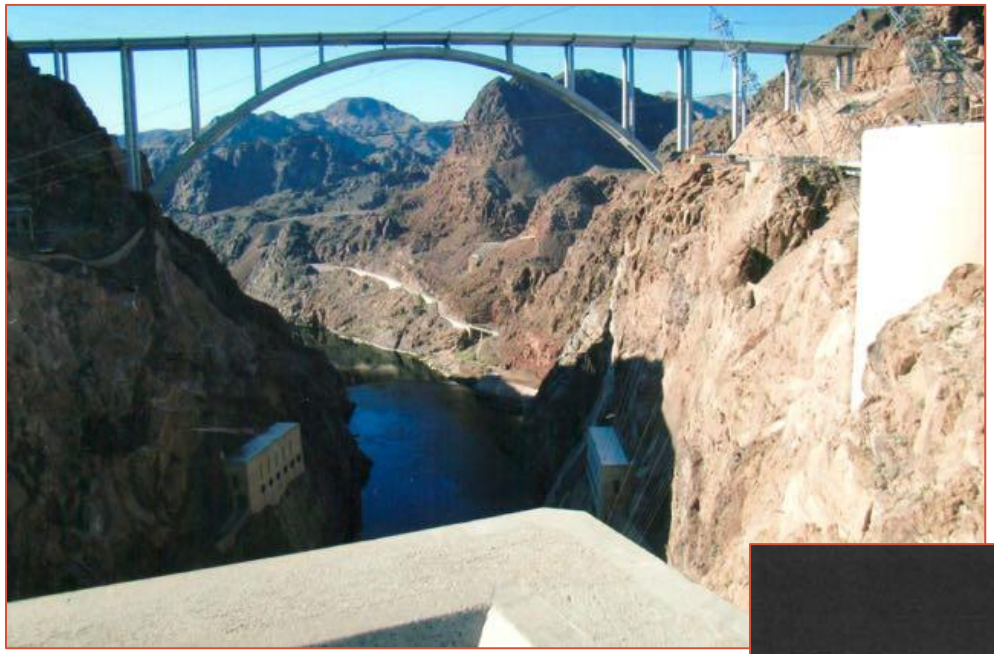
Motorist view of the dam and canyon blocked by 4’-0 high concrete barrier walls

Golden Gate Bridge



Motorist can view either the ocean or the bay through the see-through barrier

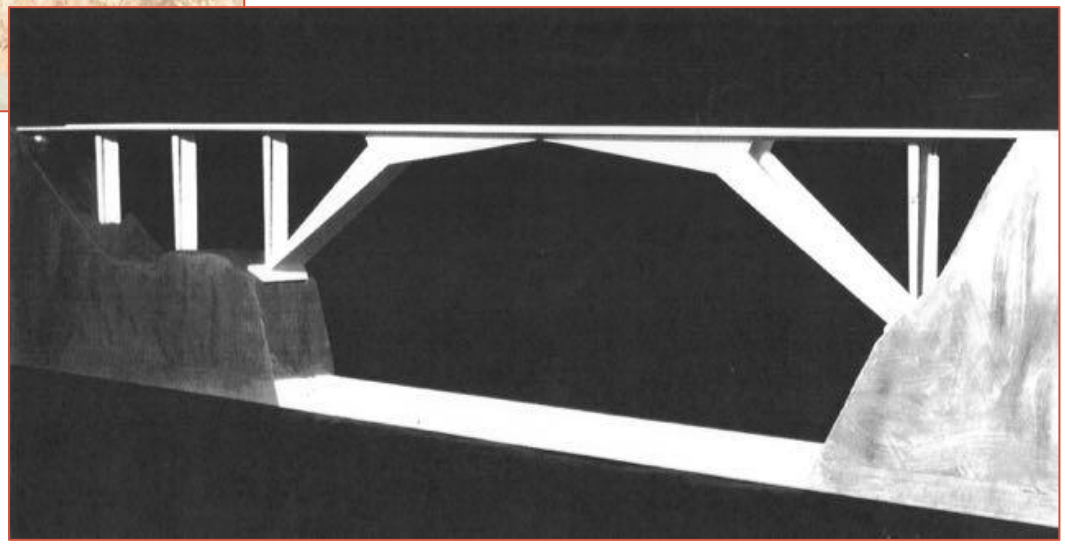
Hoover Dam Bypass Bridge



US93 Hoover Dam Bypass Bridge
Traditional Concrete Arch

Transfer of Knowledge

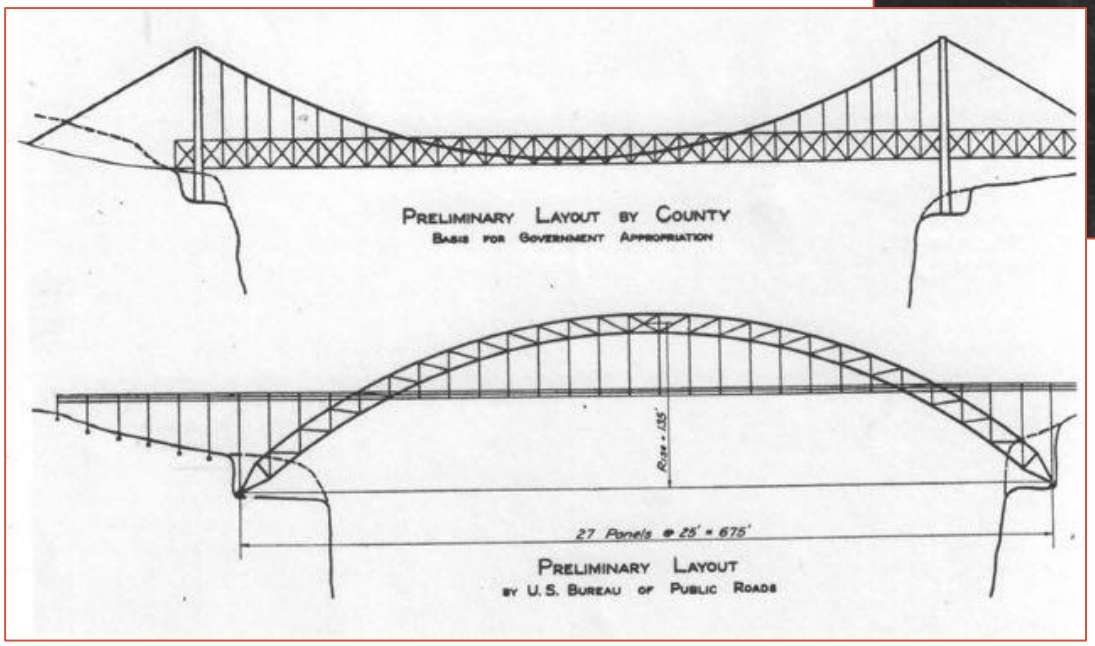
- Bridge design that is creative inspires travelers
- Bridge barrier rails don't need to block views



A more creative bridge design – modern concrete arch

Historic 1929 Navajo Bridge over Colorado River at Marble Canyon

It took courage and a vision for Ralph Hoffman, State Bridge Engineer, to select this more costly sustainable design option.



Navajo Bridges over Colorado River
(1929 & 1995)

New Navajo Bridge with Interpretive Center / Navajo commercial between two closely spaced bridges “a perfect fit”.

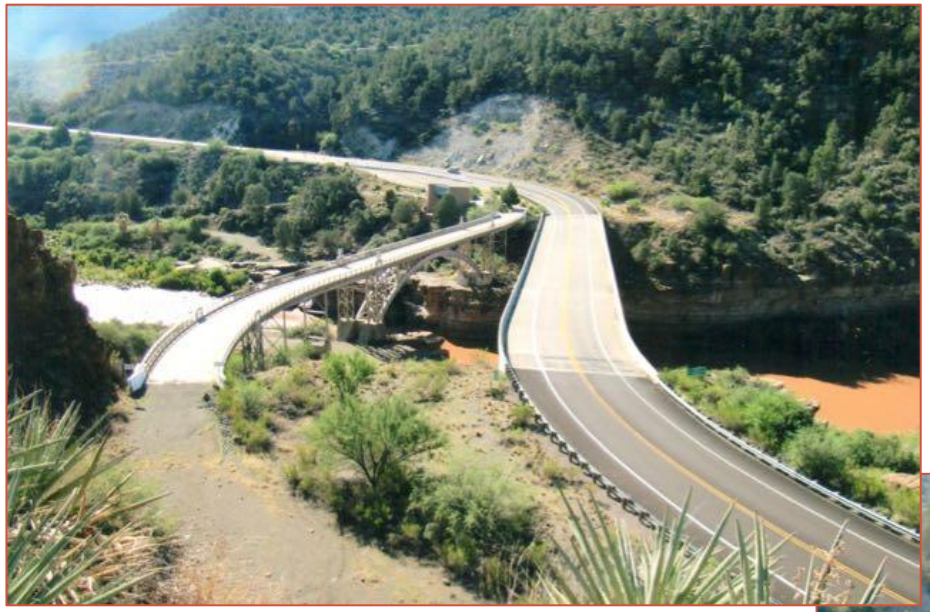
Watch Tower in Grand Canyon National Park

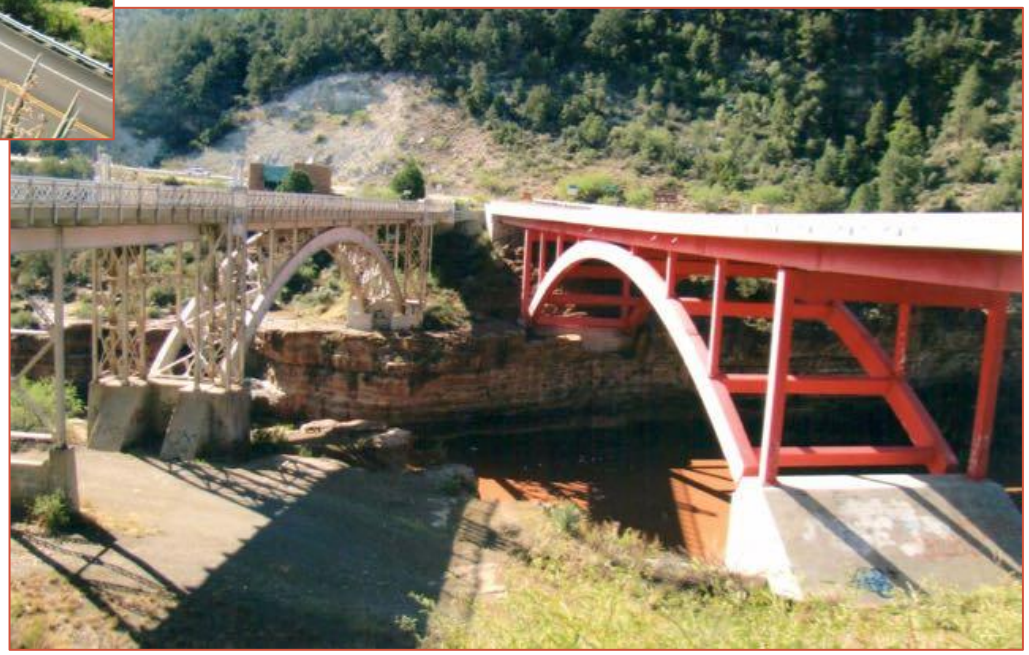
Designed by Mary Colter

Navajo Bridge Interpretive Center

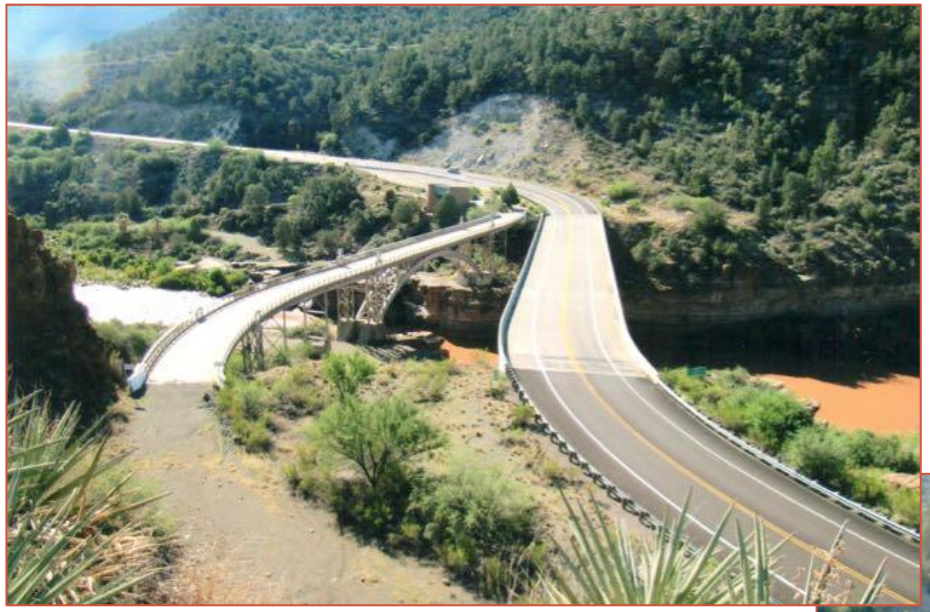
Designed inspired by Colter's Watch Tower

Two Closely Spaced Bridges



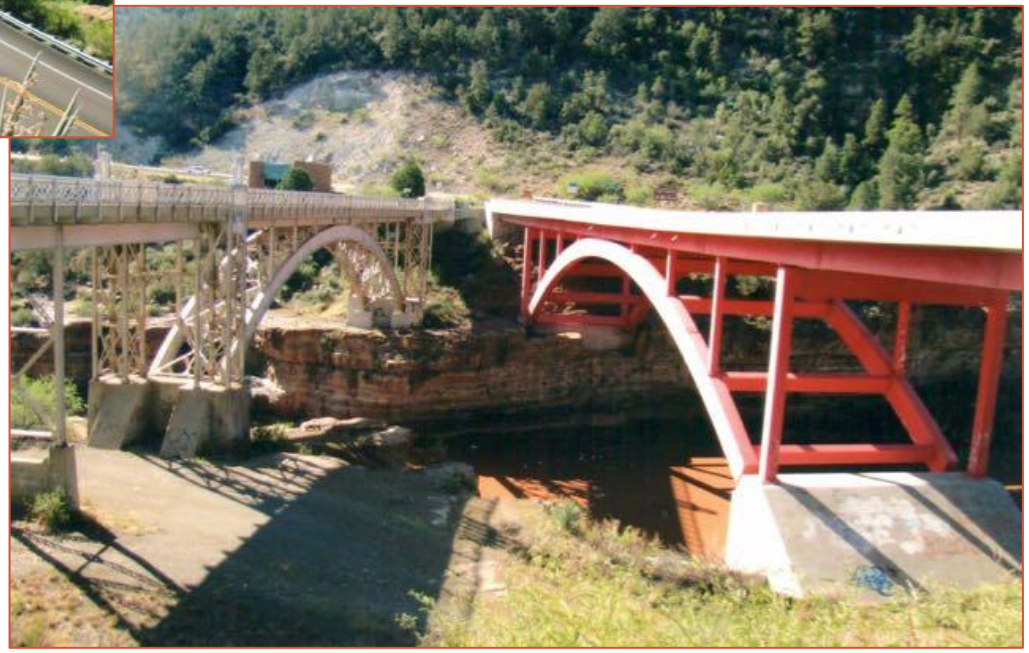


Two Closely Spaced Bridges

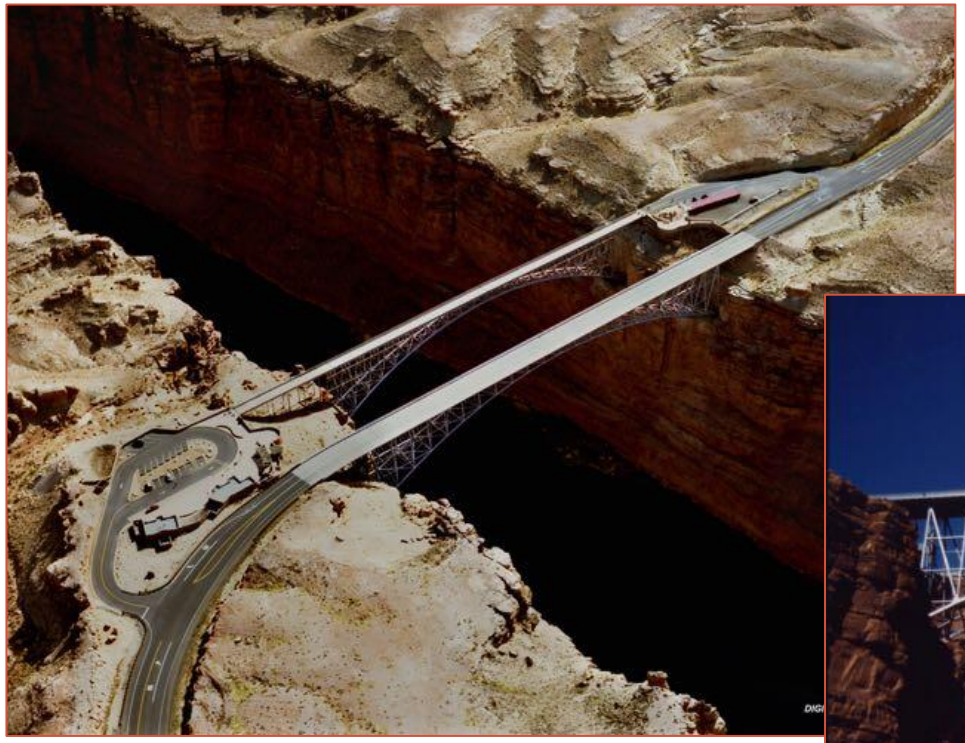


Non parallel bridges create visual confusion

New bridge design competes with historic bridge



Two Closely Spaced Bridges



Parallel bridges reduce visual confusion

New bridge design is compatible with historic bridge

Navajo Bridge over Colorado River

Transfer of Knowledge

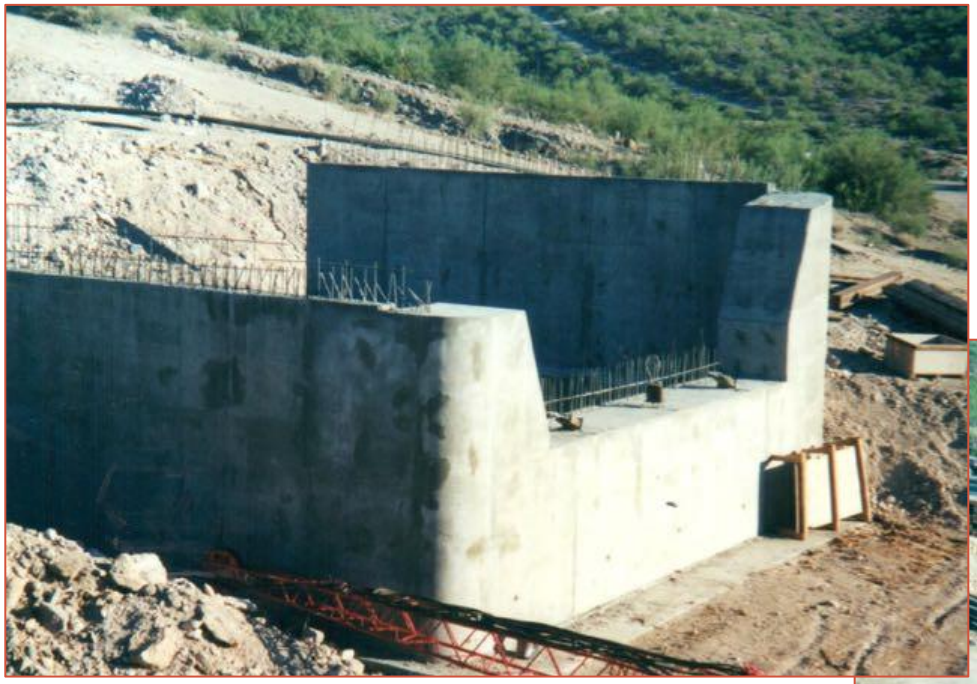
- Example of context sensitive design
- New bridge located to fit into site rather than by the roadway alignment
- Compatible appearance
- Spectacular view of canyon not blocked by new bridge
- Closely spaced parallel bridges reduce visual confusion

US93 Kaiser Spring Bridges

New piers located between canyons with spans over 200 feet.

US93 Kaiser Spring Bridges

Simple Aesthetic Treatments

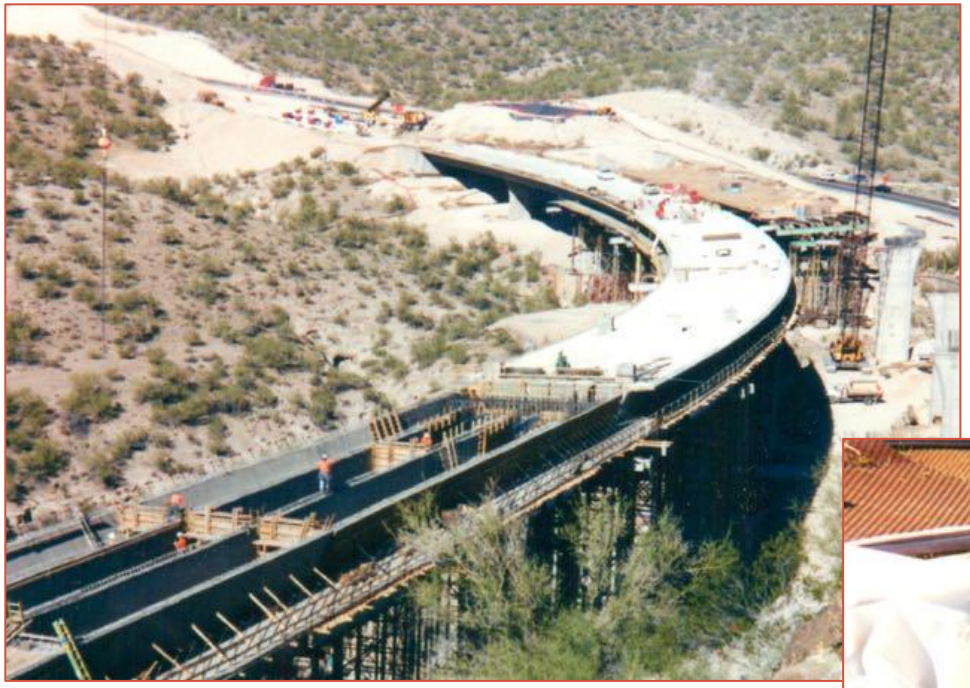


Low abutment walls
with curved corners

Pier columns with
slight taper

US93 Kaiser Spring Bridges

Simple Aesthetic Treatments



Cast-in-place
prestressed concrete
box girders on falsework

Bridge barrier wall
treatment

US93 Kaiser Spring Bridges
(Between Wickenburg & Wikieup)

Transfer of Knowledge

- Curved box girder fits nicely with curved roadway
- This engineering option was selected rather than using AASHTO I-girders
- Bridge length fits into landscape at site
- Integrated art is sustainable

The Art of the Bridge Engineer

Bridge Traffic Interchange Structure Types

Shorter span AASHTO I-girders require straddle bents which cause visual confusion.

Cast-in-place box girder with longer spans reduce visual confusion.

Bridge Traffic Interchange Abutment Options

Bridge Traffic Interchange Abutment Options

Abutments blend into roadway embankment and provide a more open feeling.

Full height abutment walls tend to narrow opening and become an impediment to traffic flow.

Bridge Traffic Interchange Pier Option

Bridge Traffic Interchange Pier Option

Tapered pier columns provide a simple and attractive appearance.

Unusual design of pier columns. Applied artwork doesn't always improve appearance – it just adds confusion and reduces sustainability.

Bridge Traffic Interchange Options

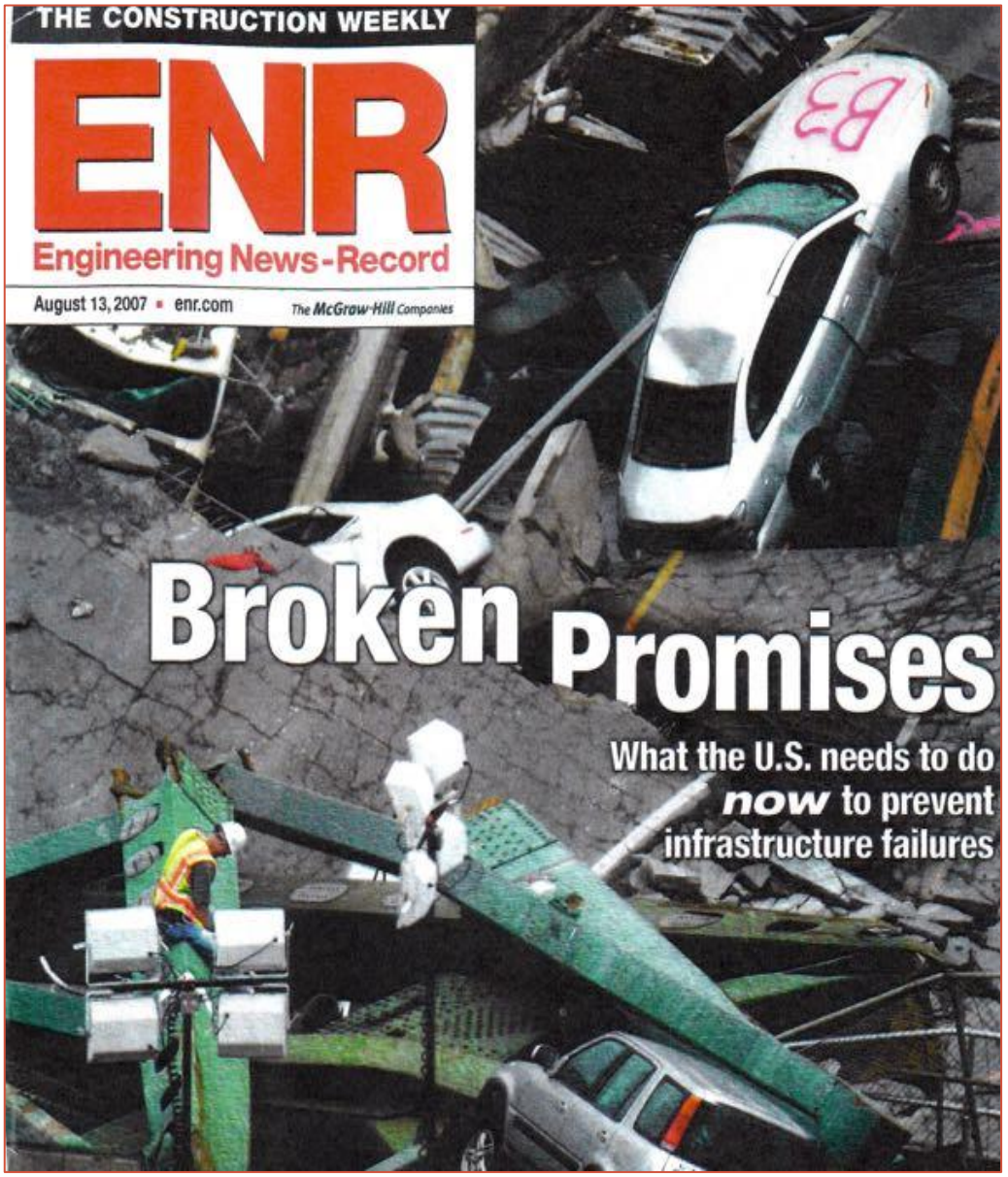
Cast-in-place prestressed box girder with short abutment walls – fits well into the landscape.

Transfer of Knowledge

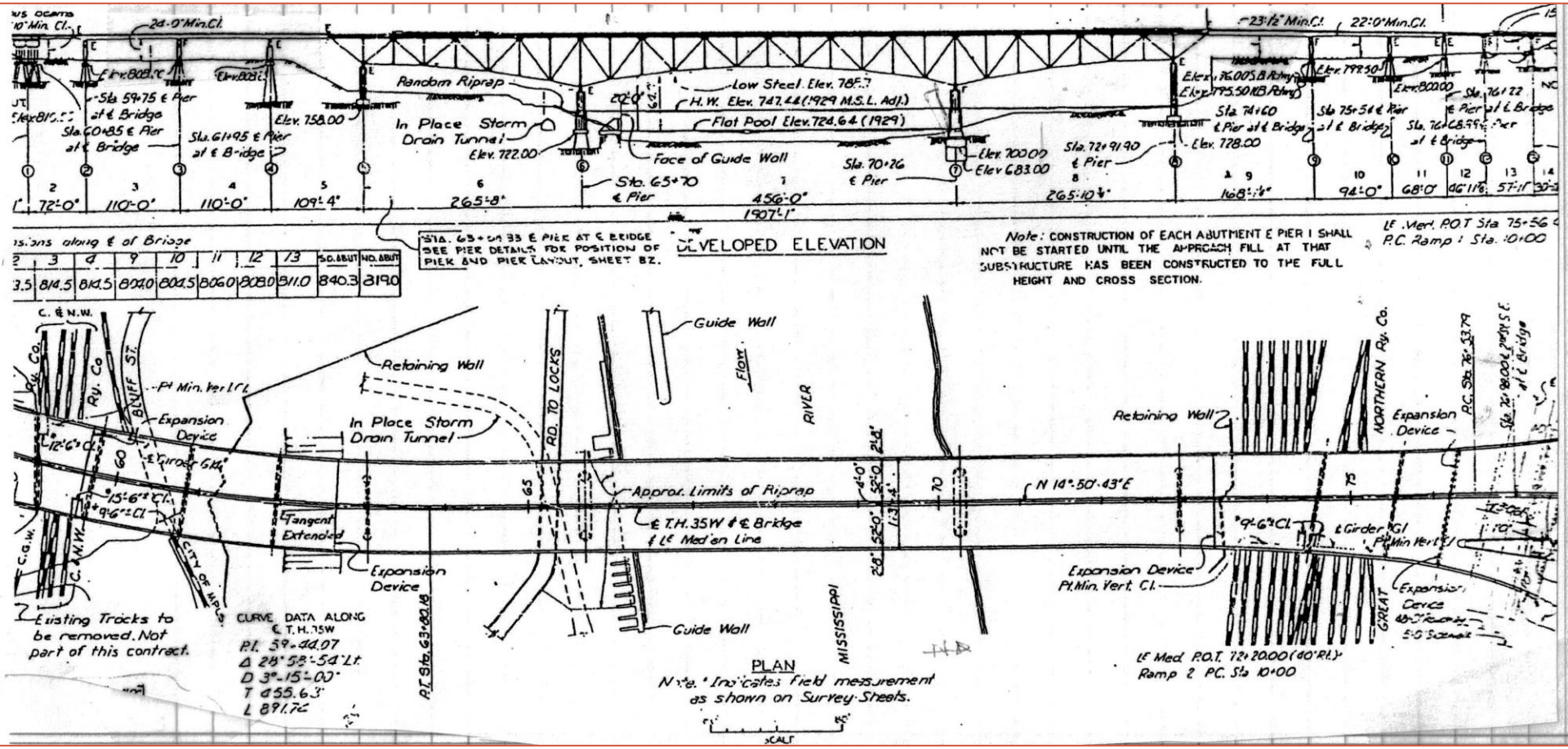
- Designers need to creatively use basic bridge elements rather than attaching applied art
- Cast-in-place box girders allow for longer spans which reduce clutter and visual confusion.
- The *least* structure is the best one.

I-35W over Mississippi River (1966-2007)

13 Fatalities



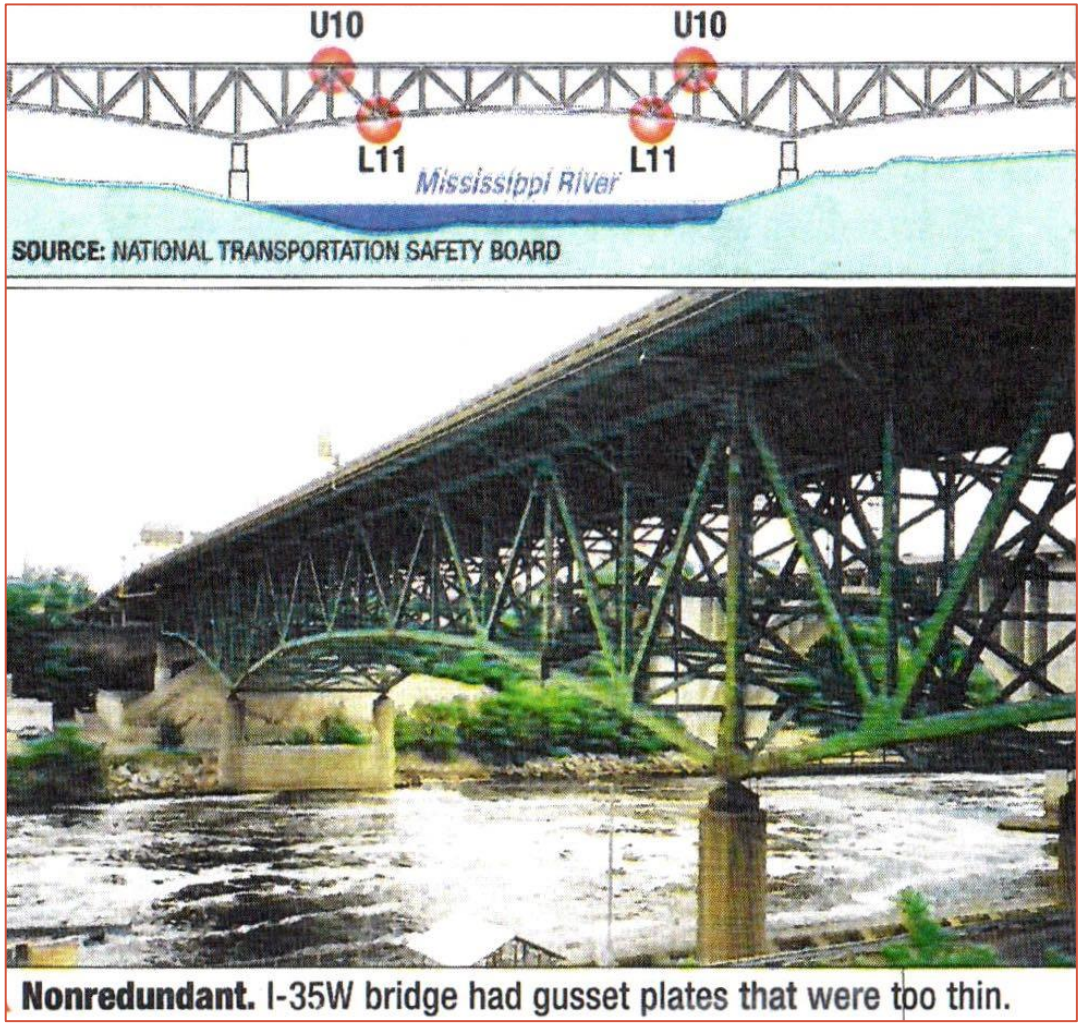
I-35W over Mississippi River (2007)



I-35W over Mississippi River

Gusset Plate Failure

I-35W over Mississippi River (2007)



Nonredundant. I-35W bridge had gusset plates that were too thin.

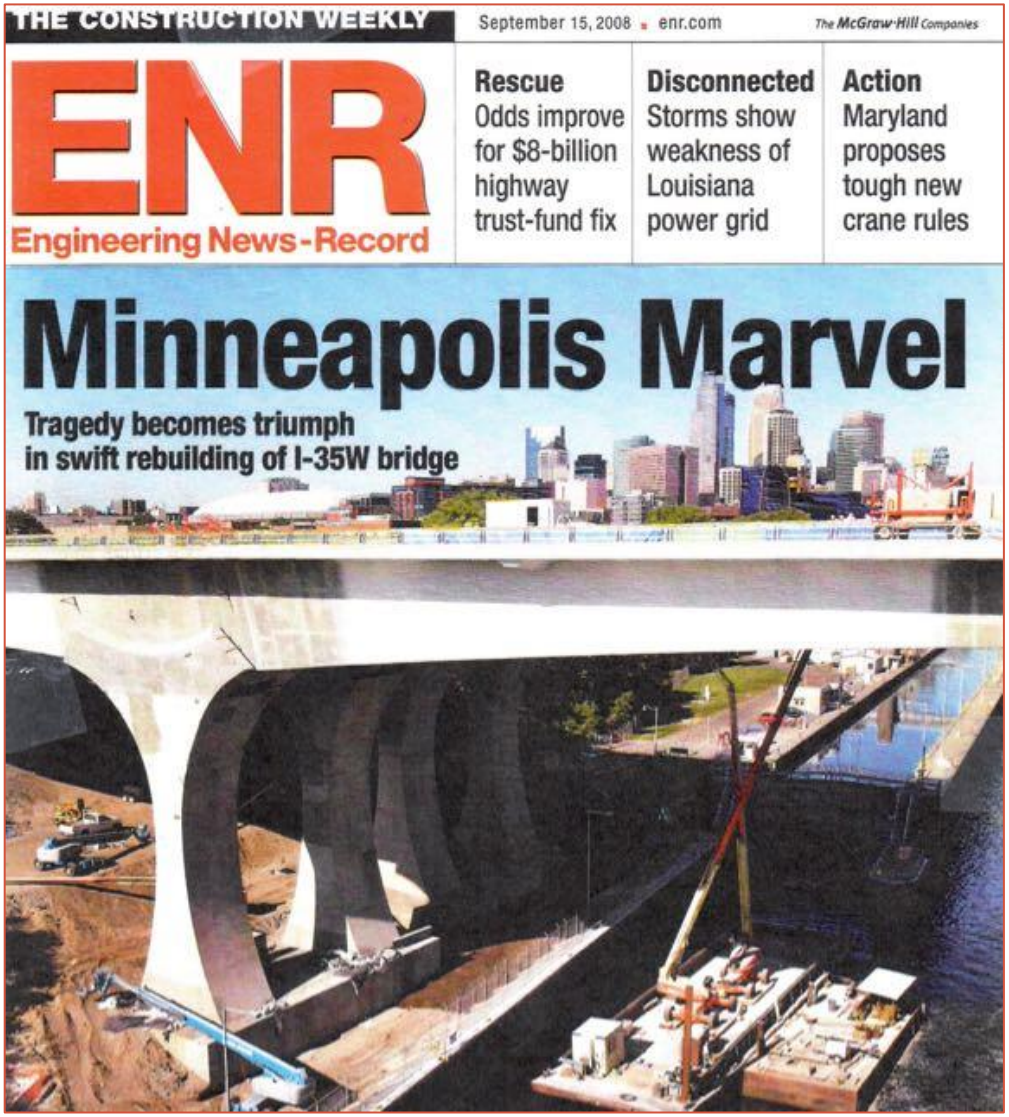
Cause of Failure

- Gusset plates were too thin
- Fracture critical bridge

Transfer Knowledge

- Closer attention to gusset plates design/inspection

I-35W over Mississippi River (2008)



Transfer Knowledge

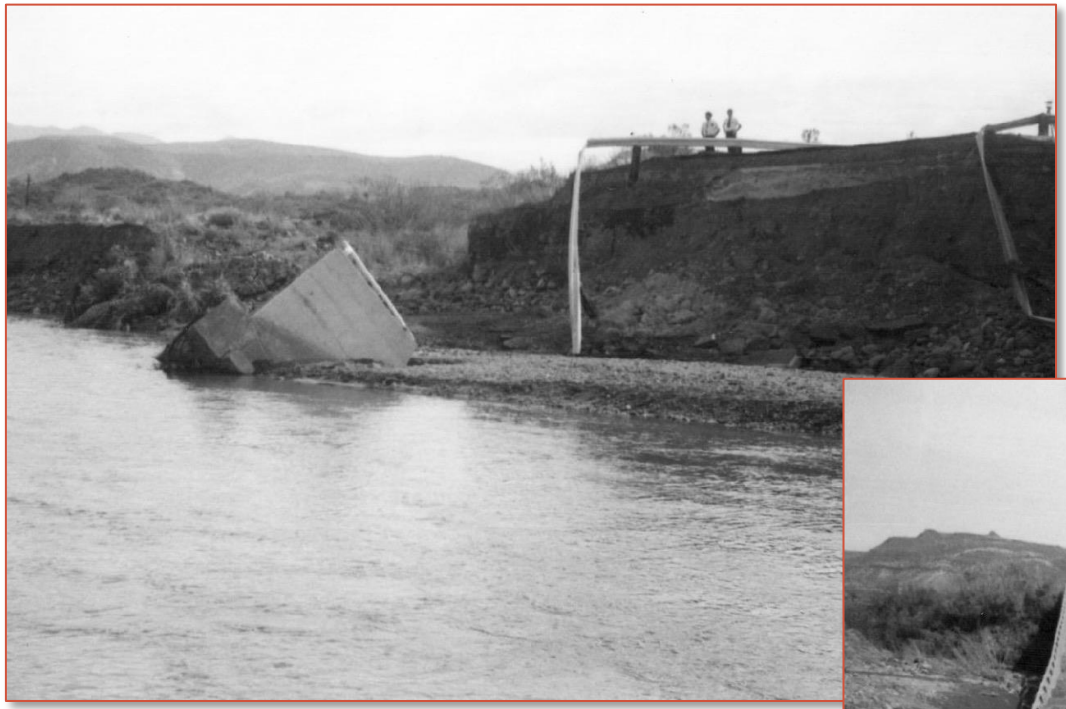
- Replacement bridge design by Figg Engineering using segmental concrete design
- Innovative design that was both cost effective and provided an attractive bridge.

“Death Bridge”

Six people dead as result of bridge failure

I-17 Bridge over Agua Fria River (Black Canyon City). (1960-1978)

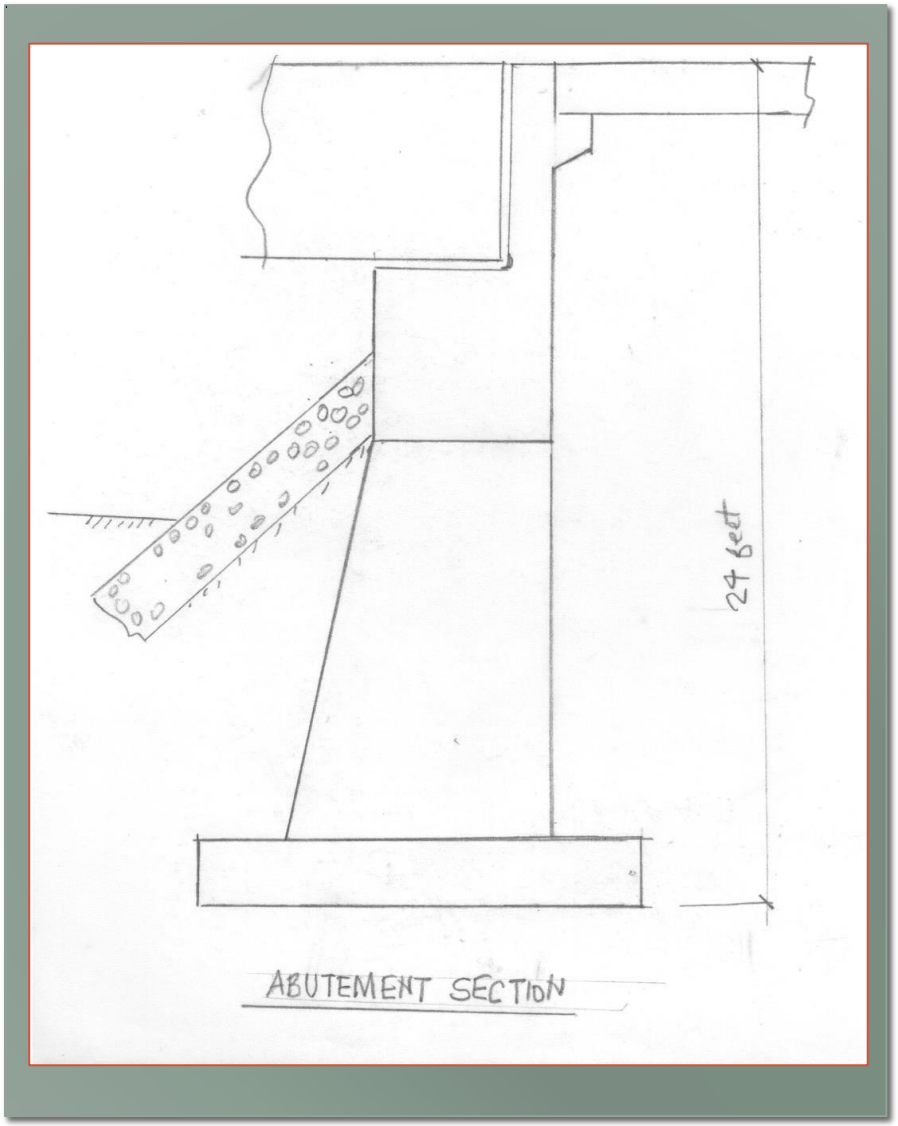
I-17 Bridge over Aqua Fria River



Abutment Failure –
footing on conglomerate

Collapsed Bridge - 1978

I-17 Bridge over Aqua Fria River - 1978



Cause of Failure

- Design flow 37,000 cfs; actual flow 60,000 cfs
- Rail bank protection failed
- Spread footing on conglomerate material

Transfer of Knowledge

- Footing needs to bear on bed rock

OR

- Deep drilled shaft foundations

I-10 Bridge over Wash - 2015

(between Los Angeles & Phoenix)

When will we ever learn – another bridge washed out.

PHOTOS BY NICK UT / THE ASSOCIATED PRESS

An eastbound portion of the washed-out Interstate 10 bridge lies in the wash it once spanned after a flash flood undermined it on Saturday.

I-10 bridge could hold cars, but torrent was too much

Historic Hereford Road Bridge over San Pedro River (1913, 1915, 1927)

Historic 3-span pony truss bridge posted for 15 ton live load

Historic Hereford Road Bridge Failure

Bridge posted for 15 tons.
April 2013 – 32 ton truck collapsed bridge

New Hereford Road Bridge

New three span, 1 lane, steel truss bridge dedicated March 6, 2006.

Transfer of Knowledge

- People don't always read signs

Historic Obed Road Bridge over Little Colorado River (1917)

Historic 6 span pony truss bridge – posted for 8 ton live load

New Obed Road Bridge Replacement (2011)

New 6 span, one lane steel truss bridge dedicated 2011.

Transfer of Knowledge

- Replaced steel trusses before failure

Historic London Bridge over Colorado River (1831 & 1971)

Historic London Bridge Lamp Post Repairs

Coping stone cracking at each lamp post

Cause of problem – removed rusted lamp support post

Historic London Bridge Lamp Post Repairs

Removal of deteriorated concrete

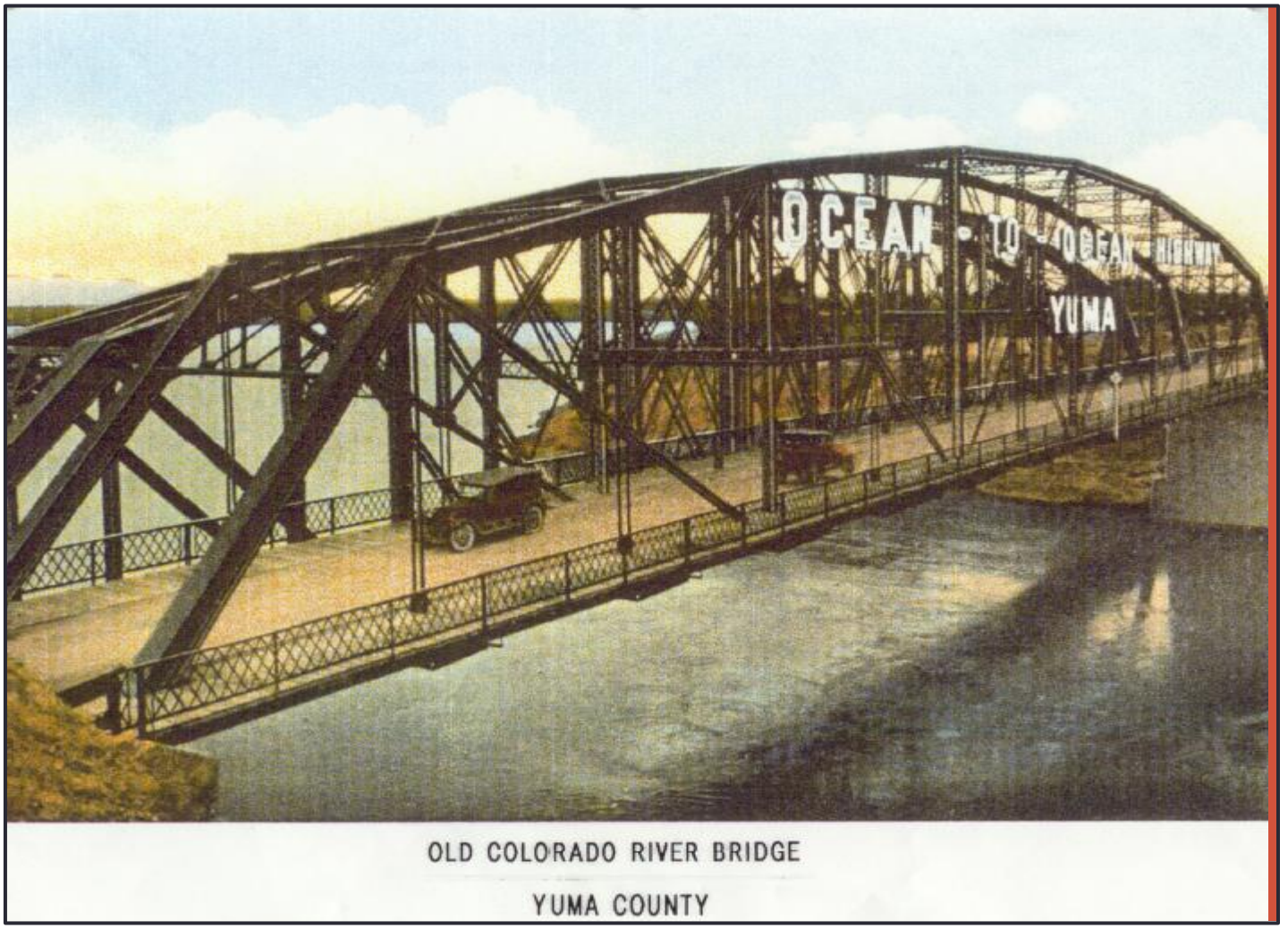
Forming edges and placement of microsilica concrete to protect reinforcing steel

Transfer of Knowledge

- Don’t assume anything – be curious
- Find out what caused the problem before fixing it

Historic Ocean-to-Ocean Highway Bridge over Colorado River (1915)

Historic two span steel truss bridge



Historic Ocean-to-Ocean Highway Bridge

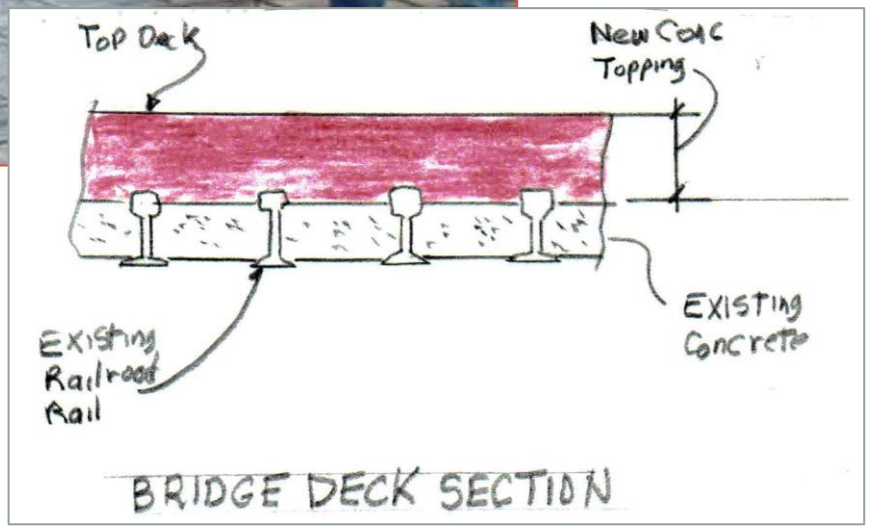
Bridge during construction in 1914

Historic Ocean-to-Ocean Highway Bridge Rehab

Steel truss attachment to pier wall

- Existing bolts rusted or missing – added new bolts

Historic Ocean-to-Ocean Highway Bridge Rehab



Bridge Deck Repair – existing asphalt topping replaced with concrete topping slab to prevent rusting of steel rail

Historic Ocean-to-Ocean Highway Bridge Rehab

Alternating One-Way Traffic

- Vehicles travel one-way over bridge
- Video cameras installed to detect traffic; all signal flash red if vehicle stops on bridge

Historic Ocean-to-Ocean Highway Bridge – 1915
Railroad Bridge – Southern Pacific Railroad – 1923

Transfer of Knowledge

- Visit site before designing bridge
- Try and save as much of existing bridge as possible
- Innovative approach to traffic control

Historic US60 Cedar Canyon Bridge (1937)

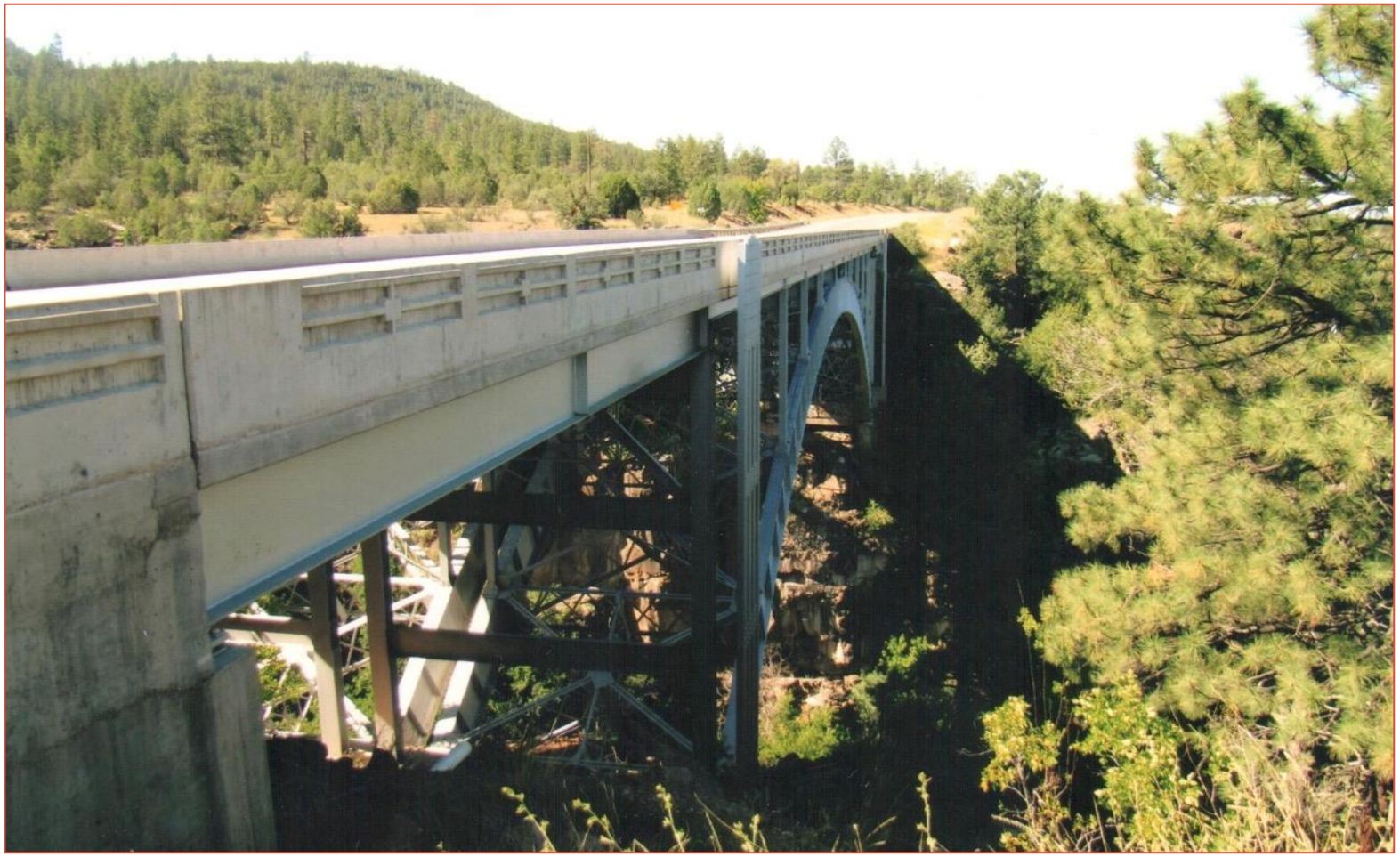
(Near Show Low, AZ)

Historic US60 Cedar Canyon Bridge Widened

Crane unloading steel arches from Corduroy Creek Bridge

Corduroy Creek arches set in place to widen Cedar Canyon Bridge

Historic US60 Cedar Canyon Bridge Widened



Transfer of Knowledge

- Reuse steel arches from nearby bridge
- Innovative widening making use of existing resources

Historic Concrete Luten Arch Bridges over Bloody Tanks Wash in Miami, AZ

One of 5 identical bridges that span Bloody Tanks Wash

Historic Bloody Tanks Wash Bridges

Miami, AZ

Deteriorated barrier rail in need of repair

Replaced barrier rail with near replica of historic railing

Historic Bloody Tanks Wash Bridges

Miami, AZ

New bridge barrier rail with decorative lights

Luten Arch Bridge – Cambered Bridge: posted speed / no trucks

Transfer of Knowledge

- Historic bridges rehabilitated; making use of existing cultural resources
- Bridge rehabilitation saved money rather than replacing the bridge

High & Low of Engineering Options

- Traveling over a bridge and viewing the landscape is a gift
- Design that is creative inspires visual drama and artistic pleasure
- Poor design decisions produce visual clutter & confusion
- Applied art on bridges can reduce sustainability
- Rehabilitated historic bridges enhance cultural resources