Innovative Concrete Solution Prevails Over Long Steel Spans

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ABSTRACT

A very simple, yet innovative structural concept -- one using a combination of site-precast post-tensioned concrete and common precast/prestressed concrete girders -- enabled designers to utilize concrete spans to bridge a vital roadway and even more vital waterway with no substructure intrusions. Besides simplifying analysis, design, and construction, the concept also features shorter spans and zero skew throughout. Although it sounds peculiar, the curved freeway alignment and curved canal alignment intersect, but special straddle bents are actually normal to the freeway and normal to the canal simultaneously. In fact, part of the WB bridge substructure is situated under the EB Bridge, and vice versa, yet the dual bridges do not touch.

Fundamental and efficient use of prestressed concrete facilitated two significant results:

1. *Several structural design issues pertaining to an initial 217-foot span, 61-degree skew, structural steel welded plate girder concept were avoided.*
2. *Estimated cost savings were reinvested in designing and constructing the bridges 12 feet wider WB and EB to avoid disruptive future bridge widening.*

The bridges are part of the final freeway segment of the first 20-years of an aggressive Phoenix Regional Freeway System program, and marks the first use of precast substructure in Arizona (except precast piles).

Keywords: Arizona Department of Transportation, Red Mountain Freeway, Power Road, Central Arizona Project (CAP), Site precast, Post-tensioned, Ply / plies, Straddle bents, Innovation, Stanley.

INTRODUCTION

In recent decades, the predominant new bridge type built in Arizona utilizes cast-in-place conventionally reinforced concrete (RC) for the substructure and prestressed concrete for the superstructure. The two prestressed concrete superstructure methodologies are fairly common – "pre-tensioned", in the form of precast concrete linear girder products, or "post-tensioned", in the form of cast-in-place concrete multi-cell box girders.

The largest precast products available in the Phoenix area are the AASHTO Type 6 girder and the AASHTO Type 6-(78"), stretched six inches in web depth. Both the 72" deep and 78" deep girders can be produced with 8" STD web thickness or 6" MOD web thickness. Using traditional 0.50" diameter strand and common concrete strengths, the practicable girder span limit is in the range of 140 to 150 feet.

To date, high performance concrete applications have been limited, and only very recently (mid-2007) has larger strand been allowed to be specified for use on Arizona Department of Transportation (ADOT) bridge projects.

It should also be noted that local precast producers only have forms for standard AASHTO shapes – Type 3 through Type 6 and Type 6-(78") I-girders. Variants like Bulb Tees, or NE Bulb Tees, or NU Girders have not found their way into the ADOT bridge population.

The initial design concept for the SR202L Red Mountain Freeway dual bridges over Power Road and the Central Arizona Project (CAP) Canal had a curvilinear 7-span arrangement, [125'+125'+171'+179'+217'+129'+108'] = 1054', as shown in **Fig. 1**:

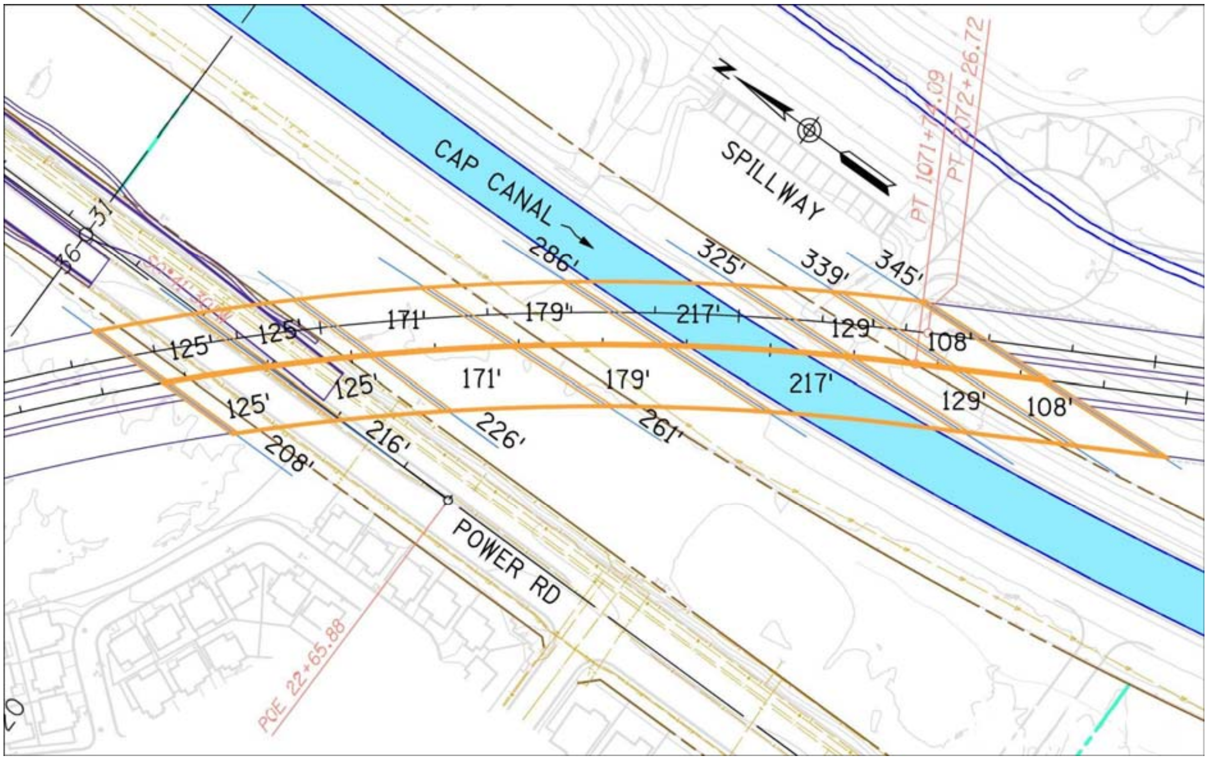

Fig. 1 – Initial Design Concept with long steel spans and severe skew

With such long 170' to 220' span lengths, the bridge design was likely to become a structural steel (curved welded plate girder) solution. Currently, there are only five steel bridges on the Arizona State Highway System with spans of 220' or more, none of which are on horizontal curves, and only four bridges on the Arizona State Highway System with skew angles over 61°, none of which are curved steel girders.

Bridges with large skew face another design and construction challenge that also increases cost – the transverse dimension of the substructure increases drastically. A comparison of out-to-out dimensions shows that the ratio of skew abutment and pier dimension, Initial Design Concept values shown in **Fig.1**, to the minimum (normal) width range from <u>139%</u> at the west abutment to <u>229%</u> at the east abutment.

Determined to find a more efficient and simple alternative concrete solution, the designers developed an innovative concept utilizing some precast concrete substructure (with post-tensioned prestressing) to cross the Central Arizona Project (CAP) Canal – an "untouchable" aqueduct vital to Phoenix and Tucson. The key objective of the concept is to pinpoint the issues created by the awkward CAP Canal crossing, and resolve them at the substructure level, allowing the superstructure to remain as simple and elegant as possible. The concept shortened the critical spans from 170'~120' to 114'~118'; has zero skew throughout; and proved to be economically advantageous.

Aesthetics is an important consideration of ADOT urban freeway projects. Usually, the bridges and walls become canvasses against which colors, textures, rustication patterns, and icons can be readily added. In this case, the “visible exterior” surfaces receive a rich reddish “chestnut” color, the columns bear saguaro icons, and the walls and back-of-barrier have a recurring saguaro spine rustication pattern. The radial two-column bents are considered to be an aesthetic enhancement over very long, very skewed piers.

Having separate WB and EB bridges allows for the abutment and pier locations for each bridge to be placed and fine-tuned independently to best suit the respective bridge spans. Stair-step staggering of substructure units effectively replaces varying skew and quickly led to a partial solution over Power Road at the west end of the bridges. Two-column bents suit the widths of both bridges.

At the east end of the bridges, the CAP Canal crossing concept was developed using an iterative process and the following checklist:

☑ Place the east abutments, Abt 2W and Abt 2E, far enough ahead to allow passage of the CAP Canal east bank Operations & Maintenance Road, but not too far as to intrude upon the Spook Hill FRS dam.
☑ Find candidate pier zones on the west bank clear of the CAP Canal.
☑ “Working backwards” from Abt 2W and Abt 2E, generate repetitive reasonable concrete span intervals that reach the candidate pier zones on the west bank of the CAP Canal.
☑ Check the resultant pier locations with respect to the east bank and west bank of the CAP Canal – (acknowledging that reasonable concrete span limitations will result in piers partially within the Canal area).
☑ Minimize the number of column locations that fall within the Canal area
☑ Develop a design concept to handle those columns – to keep them out of the Canal.

The iterations showed that an equal recurring span of about 116’ created an excellent pattern in which the last span is completely east of the Canal and it takes three more spans to reach the west bank clear zone. With minor fine tuning adjustments of the span arrangement, and an idea to intercept single columns that would otherwise land in the Canal, the final solution was complete. See **Fig. 2**.

Fig. 2 – Looking Back Station at three of the four special straddling piers.

The success in developing the unique concrete solution, made possible by using precast substructure components, was evidenced by huge estimated cost savings. Compared to the early concept comprising curved structural steel welded plate girders, the estimated savings was $2-million. Pursuant to discussion with the Arizona Department of Transportation, it was decided to reinvest the cost savings to design and construct the bridges 12 feet wider than originally planned. Accommodating the fourth general purpose lane now advances the planned future widening, completely eliminating the design, permitting, construction, and motorist inconvenience associated with future bridge widening.

THREE BRIDGE FRAMES – THREE FUNCTIONS

The Final Design span arrangements of the dual bridges are as follows and shown in **Fig. 3**. Collective spans forming a bridge frame are shown within [brackets]:

WB = [140'+114'] + [114'+114'] + [114'+114'+114'+114'] = 938'

EB = [108'+142'] + [103'+103'+103'] + [118'+118'+118'+118'] = 1031'

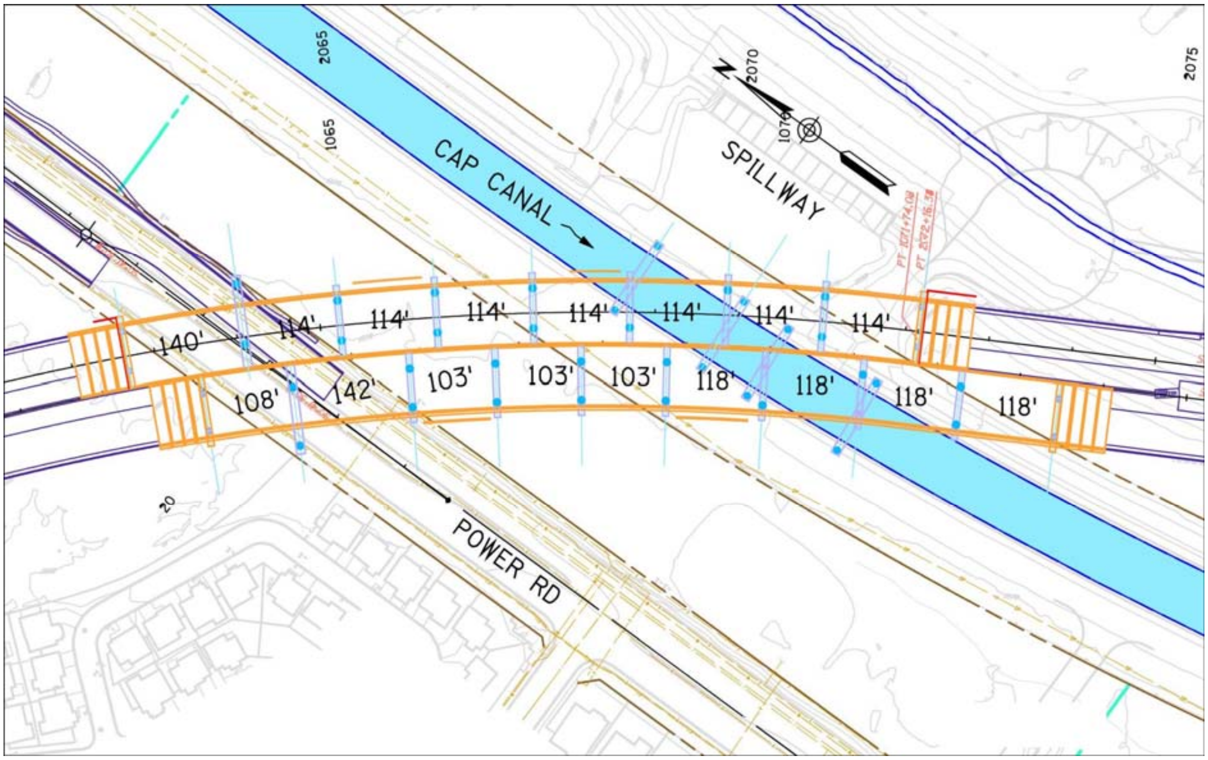

Fig. 3 – Final Design with shorter concrete spans and zero skew

The WB bridge is 88 feet wide and the EB bridge is 86 feet wide. Each bridge is designed to carry four general use lanes and one High Occupancy Vehicle (HOV) Lane. The bridges have RC decks cast-in-place on steel stay-in-place deck forms supported by eleven lines of precast prestressed girders, spaced at about eight feet. Each bridge has three bridge frames separated by expansion joints. All 19 substructure units – four abutments and fifteen piers – have zero skew.

The west bridge frames are 2-span frames that span SB and NB Power Road traffic. Piers 1W and 1E have two-column bents in an "outrigger" type configuration. Cap beams straddle the roadway and require post-tensioning for flexural strength. One column is under the bridge, within the raised roadway median, while the other column is offset further to clear the sidewalk, as shown in **Fig. 4**.

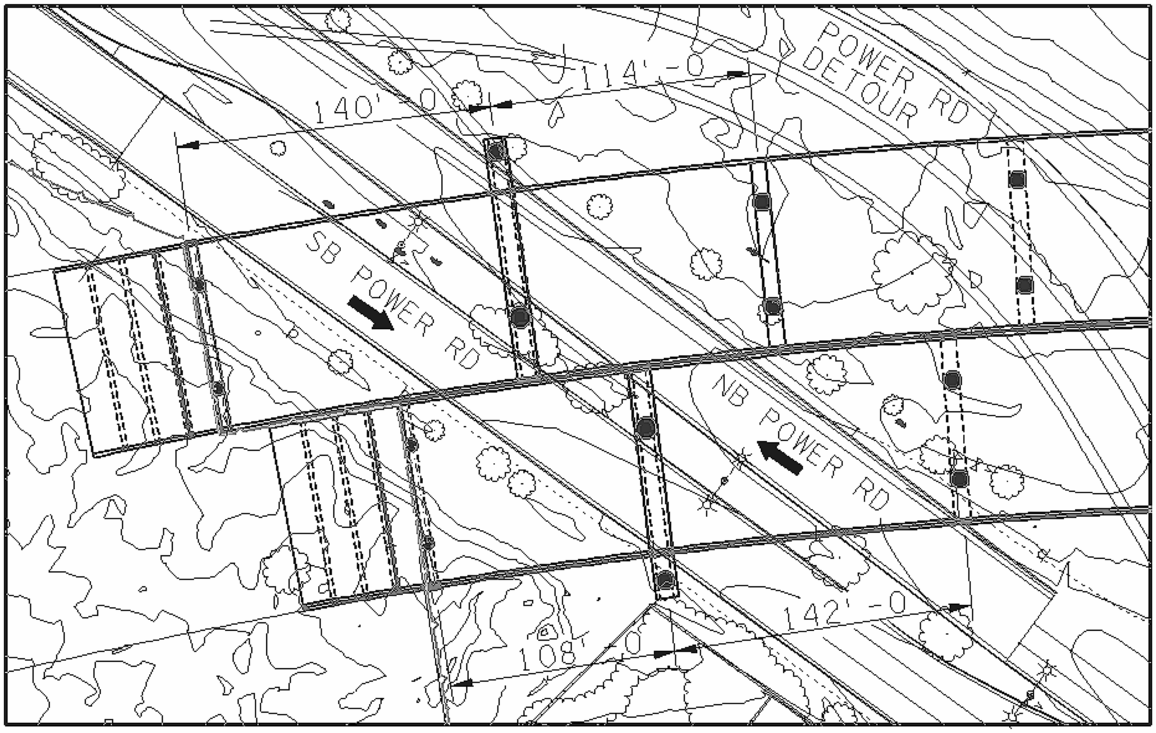

Fig. 4 – West bridge frames are 2-span units with outrigger type straddle piers.

This straddle configuration, with the superstructure bearing directly upon the cap beam, is fairly common. However, there are two noteworthy details used for this project. The cap beams have an inverted-T shape with two beam ledges so that the majority of the cap beam depth can be raised upward, in common with the bridge girder depth, thus preserving vertical clearance below. Also, the back-span and ahead-span differ enough that the typical AASHTO Type 5 girders can be used for the shorter span, but deeper AASHTO Type 6 girders are required for the longer spans – Span 1W and Span 2E only. See **Fig. 5**.

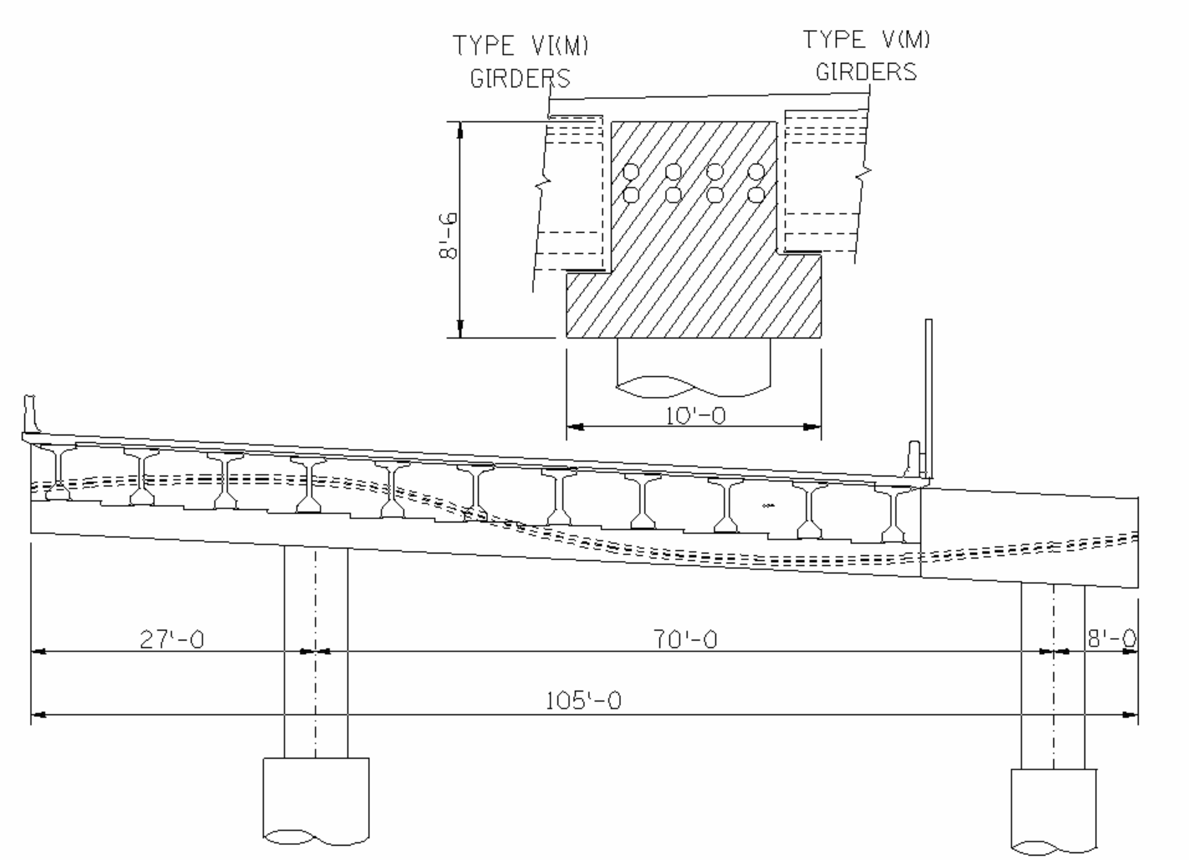

Fig. 5 – Inverted-T post-tensioned straddle bent. Pier 1E shown, Pier 1W similar opposite.

The center bridge frames are 2-equal-span WB and 3-equal-span EB frames over an area that is relatively flat and open. The key function of the center bridge frames is that they provided the zone wherein construction could be deferred, and through which the Power Road vehicular traffic could be detoured while the Contractor constructed the west frames and the east frames. Along the west bank of the CAP Canal there is an Operations & Maintenance (O&M) Road and its passage is preserved through the piers. The detour is barely visible in the background of photograph **Fig. 2** and shown graphically on **Fig. 4**.

The east frames are 4-equal-span frames that cross the CAP Canal, as shown in **Fig. 6**. Here is where the advantages of precast concrete are applied to solve a complex geometric and structural situation. The result is the marriage of a fundamental substructure and a fundamental superstructure, both using only standard materials and common/familiar construction methods, to hit the target objective – stay out of the CAP Canal. Along the east bank of the CAP Canal there is an Operations & Maintenance (O&M) Road and its passage is preserved through the piers. Directly east of the bridges is the Spook Hill FRS emergency spillway, the potential discharge of which must remain unimpeded across the Canal, through the bridges, and over to Power Road.

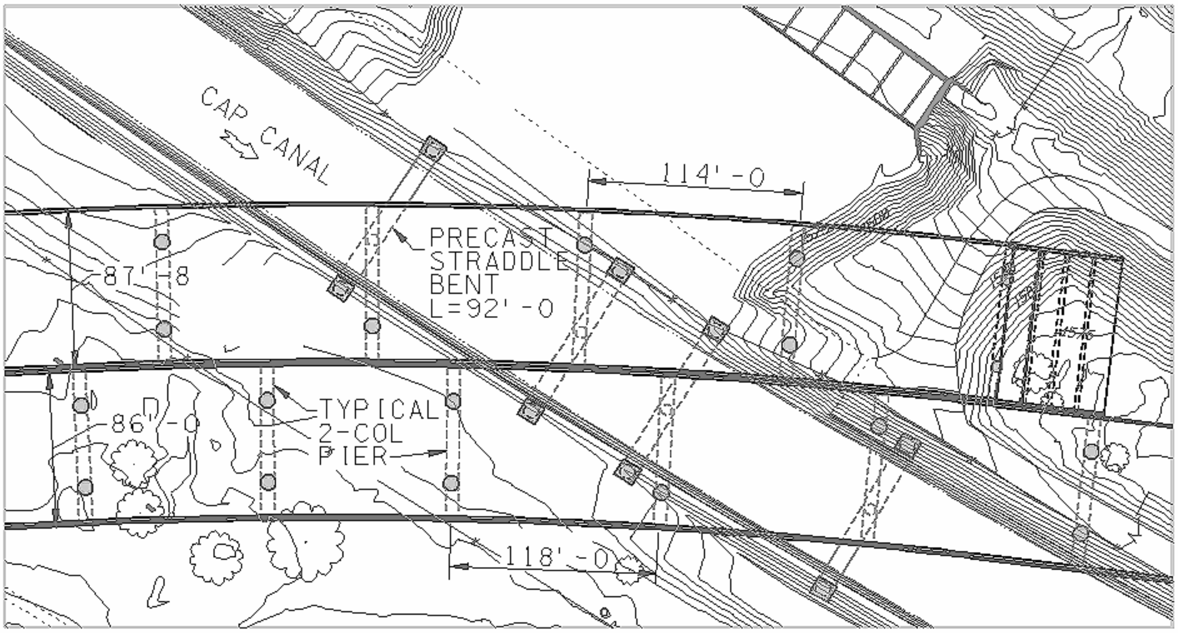

Fig. 6 – East frames have equal spans: 4@114' WB and 4@118' EB.

A DIFFERENT KIND OF STRADDLE BENT

Straddle bents are used for many bridge applications. Their most common configuration is a full cast-in-place pier carrying one back-span and one ahead-span – either an integral part of cast-in-place construction, or a "drop cap" beam upon which precast girders are set.

The straddle bent system developed for the Power Road & CAP Canal bridges is quite different. The solution borrows some design concepts from cast-in-place post-tensioned box girder bridges and some constructability concepts from precast spliced girders. There are four CAP Canal straddle bent assemblies (Piers WB5 & WB6 and Pier EB6 & EB7) spanning radial to the Canal's 01º00'00" LT horizontal curve. Each straddle bent assembly is precisely positioned to support a short "stub column" – one leg of the typical 2-column bent bridge pier. As mentioned earlier, all bridge piers are aligned radial to the freeway 01°53'00" RT horizontal curve. The straddle bent assemblies over the Canal are designed and detailed identically – just the 4 stub column heights and their footprint locations along the straddle bent assemblies vary slightly. See **Fig. 7**.

Fig. 7 – Special straddle assemblies normal to the CAP Canal.

Each straddle bent assembly has six rectangular, but non-prismatic, precast plies at 20" center-to-center spacing, bearing on a drilled shaft cap at each bank. Each ply is 12 inches wide and 92 feet long. The depth varies from 7.50 feet at supports to 10.50 feet in the middle. Considerations for reasonable crane size, access around the Canal, and lifting/handling led to a target upper bound of 75-tons as the maximum load limit. Each ply is fitted with a temporary W14 steel rolled shape attached snugly over the top compression fiber to provide lateral support during lifting and erecting. The design weight, including the 60-foot long stabilizer beam is 71-tons; four tons under the target. Lifting devices are included on the top of the precast plies at 66 feet on center.

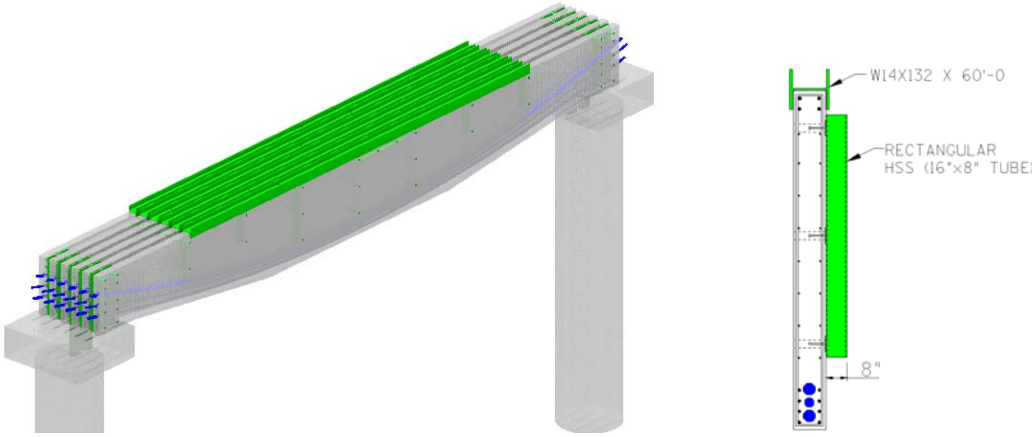

Fig. 8 – Schematic of straddle assembly and cross section (one ply).

The plies, each designed as a simple span RC deep beam for self-weight plus stabilizer, are clamped together transversely to work as a set by preloading 39 high-strength threaded rods fed through bushings at the end diaphragms and intermediate diaphragms. With six 12-inch plies and five 8-inch diaphragms "shimming" the plies, the complete 9.33-feet wide assembly is extremely stable. See **Fig. 8A** and **Fig. 8B**.

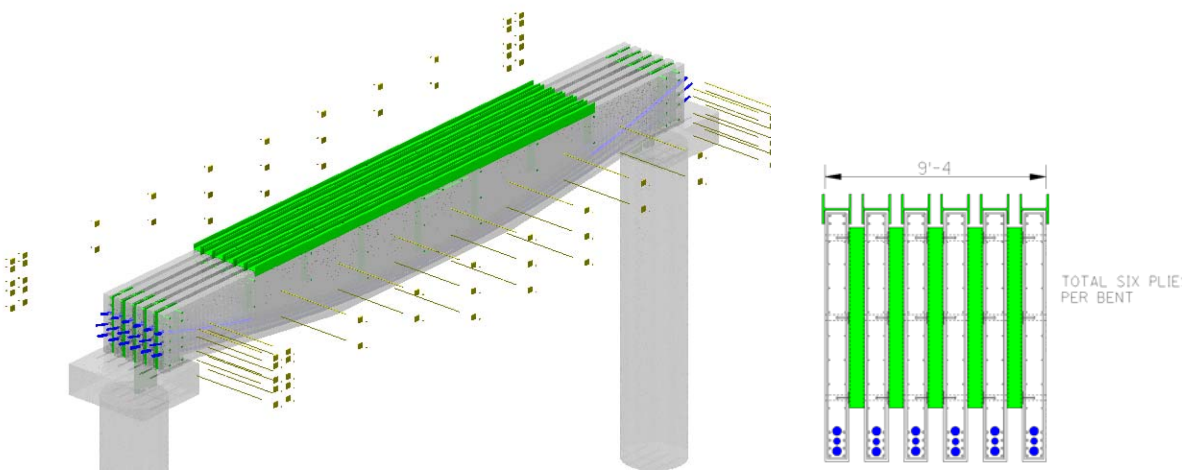

Fig. 8 – Schematic of straddle assembly and cross section (six plies).

The Canal crossing configuration has been described in several ways. Some call it a "bridge over a bridge" – the four straddle bent assemblies being the lower bridge and the rest being the upper bridge. Others have used the term "tripod piers" – referring to the three drilled shafts at the four unique piers. Yet others have called it an "elevated/exposed drilled shaft cap" serving as a load transfer beam over the Canal to intercept and redirect one stub column load to two drilled shafts. See **Fig. 9**.

Fig. 9 – One of four straddle assemblies with stub column, full column, and cap beam.

Whatever description is used, the combination of unique precast substructure and typical precast superstructure work well together to cross the CAP Canal in a triple jump – or “hop-skip-jump” manner. Beginning at a traditional 2-column bent on the west bank, the “hop” reaches the first special pier where the <u>left</u> stub column hovers above the Canal on a straddle bent assembly; the “skip” reaches the second special pier where the <u>right</u> stub column hovers above the Canal on a straddle bent assembly; and finally the “jump” reaches the rest of the way to a traditional 2-column bent on the east bank.

IT’S ALL IN THE DETAILS

Simplicity and extensive attention to detail during design led to complete success during construction. A repetitive “cookie-cutter” approach is clearly evident to the maximum extent practicable. All eight drilled shafts and drilled shaft caps that form bearing tables for the precast ply assemblies are identical in size, shape, and elevation. They are set high enough to meet freeboard requirements of the Central Arizona Project, and low enough to maximize safe construction and post-tensioning near ground level.

Prior to this project, the typical CAP Canal freeboard requirement was just one foot above the concrete canal lining. The desirable freeboard requirement has since been increased to four feet. These two bridges meet the new freeboard requirement, but other locations elsewhere on the project were approved with lesser freeboard because of the timing of the changes.

Each precast ply includes three empty corrugated steel ducts with parabolic tendon profiles that are identical for all 24 plies. The parabolic shape closely matches the efficient concrete geometry – 36 inched deeper at midspan than at the ends. See **Fig. 10A**. The diaphragm spacing is also identical – 16 feet from the ends and 10 feet on center. Although the four stub column locations vary, each one occupies a dedicated 10-foot bay between two diaphragms. See **Fig. 10B**.

Fig. 10A – Precast ply during site production. **Fig. 10B –** Completed ply being erected.

Cast-in-place end blocks encapsulate the ends of the precast plies and the anchor hardware for the post-tensioning tendons (18 total). The complete six-ply assembly with end blocks is 10 feet wide and 100 feet long.

Each of the four piers receives a total of 14,500 kips of post-tensioning jacking force applied symmetrically in three stages:

- 40% (5,800 K) for self weight, column table, stub column, cap beam, and girders – (3 bottom ducts and 3 top ducts, alternating);
- 40% (5,800 K) for diaphragms, deck, and barriers – (3 top ducts and 3 bottom ducts, altnernating);
- 20% (2,900 K) for live load and wearing surface – (6 middle ducts). **See Fig. 11**.

Fig. 11 – End block with 18 post-tensioning ducts.

Different straddle bent configurations were considered, but deemed problematic for the following reasons:

- Placement of falsework supports in the CAP Canal, or where they could damage the Canal's concrete lining, is absolutely forbidden.
- The clear span of 90'~100' and wet concrete dead load make the falsework requirements unwieldy.
- Precast concrete solid sections were ruled out because of excessive weight and crane requirements.
- Similarly, precast concrete hollow shells/tubs (to be filled afterward) were also deemed to be excessively large, heavy, and unstable.

Hollow structural sections (HSS), often called "tube steel", are used for the intermediate and end diaphragms and all the HSS pieces are pre-welded to embed plates accurately and strategically located in the precast plies, so there are zero loose pieces over the Canal. Small HSS pieces are also used to create a stay-in-place steel form at the location where a RC column table (for the stub column) is cast over the Canal. All the HSS diaphragm pieces start out empty to minimize crane lifting weight, and end up concrete-filled for compressive strength to sustain transverse post-tensioning.

Lateral stability being a very critical concern for the first two individual plies of the six-ply set, HSS pieces (two at each support) are cast plumb projecting upward from the drilled shaft cap to serve as temporary "hitching posts" and permanent end diaphragm components, simultaneously. These hitching posts help locate and center the middle two plies, and provide the means to weld and stabilize the middle two plies during construction. After the third/fourth/fifth/sixth plies are added, the transverse high-strength rods are initially installed hand tight to provide tremendous stability. See **Fig. 12A** and **Fig. 12B**.

Fig. 12A – "Hitching posts" in drilled shaft caps. **Fig. 12B –** First ply is set.

The precast ply embeds and HSS diaphragm pieces are fitted with steel pipe bushings at all 39 transverse high-strength rod locations for five reasons – facilitate accurate repetitive casting placement, prohibit concrete intrusion, prevent empty HSS crushing, facilitate ply-to-ply alignment, and optimize transverse prestressing diaphragm action.

All 24 precast plies were cast in a cleared level area on-site and erected into position without any errors or problems. See **Fig. 13**. Three sets (18 pieces) were transported and erected with one very large crane. Because of crane boom reach constraints, the Contractor transported the last set (6 pieces) with one large crane most of the way, set them down across the Canal momentarily, and re-picked the pieces with two cranes the remaining short distance.

Fig. 13 – Precast plies produced on-site eliminate truck haul.

ABUTMENTS AND WALLS – YET ANOTHER PRECAST ADVANTAGE

Mechanically Stabilized Earth (MSE) Walls, provide a simple, effective means of retaining earth, particularly in fill situations. The three main advantages over conventional RC base/stem cantilever walls are that they remain economical around and above the 25'~30' height range; the modular panel configuration is more flexible than rigid cast-in-place concrete; and they can be built in restricted space or ROW where larger excavations for wall base foundations often can not. Approximately 30,600 square feet of precast concrete MSE wall panels are used for the Power Road / CAP Canal Bridges' abutments.

The two west abutments, Abutment 1W and 1E, are staggered about 82 feet, an amount consistent with the 45-degree crossing angle of Power Road, so that the nearest corners are set-back adequately from the roadway and sidewalk. See **Fig. 14A**.

Fig. 14A – West Abt 1E & precast MSE wall. **Fig. 14B** – East Abt 2E & precast MSE wall.

The two east abutments, Abutment 2W and 2E, are staggered about 175 feet (1½ spans), the amount consistent with the very severe 60- to 65-degree skew east of the Canal, so that the nearest corners are set-back adequately to allow passage of the East O&M Road. One might ask, "Why not add another span to each bridge to reduce the wall height and area?" – The answer is not clearly obvious. The freeway profile ascends to reach its apex near the east abutments because it must cross the crest of the Spook Hill Flood Retarding Structure. The Arizona Department of Water Resources and the Flood Control District of Maricopa County absolutely prohibited excavation of, or penetration into, the Spook Hill FRS dam structural core prism. Thus, the drilled shaft foundations for east Abutments 2W and 2E are at the eastern practicable limit where deep foundations can be used. The precast MSE walls are used because their leveling pad foundations are deemed acceptable/permissible and because the addition of roadway fill surcharge are not detrimental to the integrity of the dam. See **Fig. 14B**.

The Power Road / CAP Canal Bridges' abutments and precast MSE walls are configured in a manner new to Arizona. The abutments are "exposed" and resemble a "half pier" – carrying a bridge span on one side only. The precast MSE wall panels are situated behind the abutments. There are three key reasons why this is done:

- Shorter girders – With the abutments exposed, the girder lengths are shorter because they do not have the additional reach necessary when the wall is placed in front and the abutment must be set back clear of the wall system.
- Design (structural) decoupling – In the more common configuration, there is an interaction among the bridge superstructure, abutment substructure, MSE wall, and backfill soil. Also, there can be serious design and constructability complications when reinforcing straps attached to the precast MSE wall panels must be deflected to clear abutment foundations, or augmented with additional strap anchoring mechanisms. It is also difficult to compact the special backfill around and between abutment foundation components.
- Construction (schedule) decoupling – Properly designed and detailed, the bridge construction and the wall construction are completely independent. Just like precast concrete bridge girders, the production of precast MSE wall panels can commence offsite

while the Contractor focuses on other critical path items onsite. For the Power Road / CAP Canal Bridges, the drilled shaft, abutment, and pier construction began very early and the wall construction lagged by several months. Meanwhile, the precast MSE wall designer/detailer prepared shop drawings and started wall panel production. Also simultaneously, the Contractor was performing massive excavation and earth haul, and processing/stockpiling onsite material to be used for the MSE granular backfill.

Leading abutment construction and lagging wall construction were well coordinated and competed successfully.

ARIZONA – IT'S A DRY HEAT

Arizona didn't become the 48th State until 14 February 1912, but it ranks second only to Nevada in two key statistical areas:

- Arizona has the second lowest average annual rainfall – metro Phoenix gets about 7.5 inches and metro Tucson gets around 12 inches.
- Arizona posted the second highest population growth ranking -- 40% during the 1990-2000 census decade.

Perhaps needless to say, the aforementioned rankings underscore the importance of two key necessities – <u>water</u> and <u>surface transportation</u>.

WATER – PRECIOUS AND PROTECTED RESOURCE

The Central Arizona Project (CAP) Canal brings about 1.5-million acre-feet of water annually across the country's hottest desert. Vital to Arizona, the allocation would otherwise be forfeit to California and Nevada. The CAP Canal is the largest single resource of renewable water supplies in Arizona. It is a 336-mile long aqueduct – the largest of its kind in the U.S. Construction began in 1973 at Lake Havasu, near Parker, and was completed in 1994, southwest of Tucson at a construction cost of about $4.4-billion.

The CAP Canal is primarily open aqueduct, but the system also has 15 pumping plants, 10 closed pipeline segments, and 3 tunnels. After all domestic and agricultural customer allocations are met, surplus supply is used to replenish subsurface aquifers at carefully selected recharge sites.

SURFACE TRANSPORTATION – DEVELOPING AND EXPANDING NEED

In 1985, voters of Maricopa County approved Proposition 300 to establish a one-half cent transportation excise tax (commonly called the one-half cent sales tax) for construction of controlled-access highways. State and County officials spearheaded an aggressive and complex program to commit to completing the Regional Freeway System by the end of 2007.

The "golden spike" of the Regional Freeway System under the *2007 Acceleration Plan* is the SR202L Red Mountain Freeway from Power Road to University Drive in Mesa, Arizona. This immense and complex project is the last project to be completed under the first 20-year program.

In 2004, the passing of Proposition 400, clearly demonstrated voter recognition of the growing transportation needs in the Phoenix area and voter acknowledgment of ADOT's commendable achievements to date. The second 20-year program (2005 to 2025) will raise an estimated $9 billion to perpetuate the efforts.

WATER AND SURFACE TRANSPORTATION INTERSECT

At over $200-million, the 4.8-mile long Power Road to University Drive Project is the largest and most complex urban freeway segment of the Regional Freeway System. About 75% of the freeway is situated within the Spook Hill floodway.

The Project includes 12 new bridges, 3 replacement bridges, 6 equipment passes, 1 stormwater pump station, and the construction of a new levee to protect the vulnerable 3.6-mile portion of the freeway from the 100-year storm event.

The showcase structures of the Project are the dual bridges carrying the SR202L (Red Mountain Freeway) at its profile apex, over Power Road, the CAP Canal, and the Spook Hill Flood Retarding Structure (FRS) – a complex multi-facility configuration. The SR202L mainline freeway alignment is curved both horizontally and vertically. The CAP Canal is on a horizontal curve. The Spook Hill FRS has yet another curvilinear alignment.

There are about 30 State Highway System bridges (16 locations, 9 major highways) over the CAP Canal. These dual "north crossing" bridges and a "south crossing" bridge, about 4 miles apart, are the newest CAP Canal freeway bridges, and the only ones along SR202L. The "south crossing" precast prestressed concrete bridge is also noteworthy inasmuch as its out-to-out deck width is 272 feet – currently the widest in Arizona.

To further complicate the design, additional agency constraints are as follows:

- *Arizona Department of Water Resources* -- Prohibit bridge substructure foundations from intruding upon the seepage-resistant core prism of the Spook Hill FRS.
- *Flood Control District of Maricopa County* – Prohibit major obstructions within the FRS Emergency Spillway adjacent to the bridges, and its emergency inundation flow path west across the CAP Canal all the way to Power Road.
- *CAP/CAWCD* -- Dictate continuous Operations & Maintenance roads flanking the CAP Canal on the west and east banks. They also have a fiber optic communications line along the west bank.
- *Federal Aviation Administration* (FAA) – Limit vertical intrusions into the Falcon Field air space.

- *Western Area Power Administration* (WAPA) – Transmission lines bound the project on the east side.
- *Salt River Project* (SRP) – Power transmission lines bound the project on the west side.

CONCLUSION

Bridge types and sizes are often chosen on the basis of the span, or spans, required to get from Point A to Point B, and the apparent constraints/criteria in between. For longer bridges with multiple spans, those constraints/criteria can vary along different portions of the bridge length. The SR202L Red Mountain Freeway, from Power Road to University Drive has more than its fair share of constraints/criteria, including those for two crossings of the CAP Canal, perhaps the most important water facility in Arizona and the largest of its kind in the U.S.

At the "north crossing", an initial design concept with long spans and severe skews to cross Power Road and the CAP Canal made curved welded structural steel plate girders the leading candidate structure – an expensive solution with design, fabrication, and construction complexity.

Innovative use of precast concrete for unique substructure components made it possible for designers to develop simple dual bridge span arrangements with zero skew throughout. Placement of pier columns in the CAP Canal is prohibited. Twenty four identical precast concrete plies, designed for manageable crane lifting size/weight, are strategically placed in groups of six at four key pier locations to intercept and support single columns of typical two-column bents. The precast concrete substructures span the CAP Canal, normal to its 01º00'00" LT curvilinear alignment.

Bridge piers, oriented normal to the 01º53'00" RT curvilinear freeway alignment, are staggered to suit the separate WB and EB bridge span arrangements. The unique precast concrete straddle assemblies serve as "stepping stones" for the bridges to cross the CAP Canal in a "hop-skip-jump" manner. Three identical spans stretch from the Canal's west bank to the east bank and a fourth identical span reaches the east abutments, situated at the Spook Hill Flood Retarding Structure. The [4@114'] WB and [4@118'] EB spans, like the other bridge spans, are ideally suited for precast prestressed concrete AASHTO girders.

Designed as conventionally RC deep beams for self weight, the plies were cast on-site to eliminate truck transport from a production facility. Post-tensioning symmetrically in three stages (40% + 40% + 20%) kept the straddle assemblies within allowable stresses during all construction steps – columns, cap beams, precast girders, diaphragms, deck, barrier, wearing surface, and live load.

This type of precast substructure is the first of its kind in Arizona, and the authors are not aware of such a "tripod" pier configuration used elsewhere. The use of precast concrete made the solution not only feasible, but also economical – Estimated cost savings

($2-million) were reinvested in designing and building the bridges with one more lane (17% wider decks) in both directions to preclude planned widening in the future.

FACTS, FIGURES, AND FIRSTS

The Power Road / CAP Canal bridges are the longest, widest, and highest structures over the CAP Canal.

Of Arizona's longest precast prestressed concrete girder mainline freeway bridges, they rank among the top 30, and they are the longest that do not cross a major river.

They are the only Arizona bridges that utilize precast prestressed concrete substructure components (other than precast piles).

They are the first ADOT bridges to utilize precast prestressed girders with ½"-HBS (0.52") strand.

REFERENCE LINKS

1. Arizona DOT Regional Freeway System Map -- http://www.azdot.gov/Highways/vpm/RegFwySysMapPM.asp

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3. Central Arizona Project -- http://www.cap-az.com

4. Central Arizona Project System Map -- http://www.cap-az.com/static/index.cfm?contentID=35

5. Stanley Consultants, Inc. -- http://www.stanleyconsultants.com/

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