

183A Turnpike: A Design-Build Success Story

Authors:

Lisa Carter Powell, P.E., President and Principal, P.E. Structural Consultants, Inc., 8436 Spicewood Springs Road, Austin, TX 78759, Ph: (512) 250-5200, lpowell@pestructural.com
Arthur Champlin, P.E., Structures Department Manager, URS Corporation, 3010 LBJ Freeway, Suite 1300, Dallas, TX 75234, Ph: (972) 888-2002, arthur_champlin@urscorp.com

ABSTRACT

This Paper presents the planning, design and construction experience of P.E. Structural Consultants, Inc. and URS Corporation structural design team on the 183A Turnpike Project in Austin, TX. An overview of the toll road project is provided and unique structural and aesthetic design solutions for the bridges and related structures are highlighted. Lessons learned through the Design-Build Delivery Method are offered.

PROJECT INTRODUCTION

The Central Texas Regional Mobility Authority (CTRMA) aimed to provide an aesthetically pleasing and economical solution to the congestion problem on US 183 in northwest Austin, Cedar Park and Leander. Delivered as a design-build project, the 11.6 mile, \$238 million toll road begins at the existing US 183 roadway in the City of Leander, just south of the San Gabriel River, and extends south until it ties back into existing US 183 at the RM 620/SH 45 Toll Road (Figure 1).

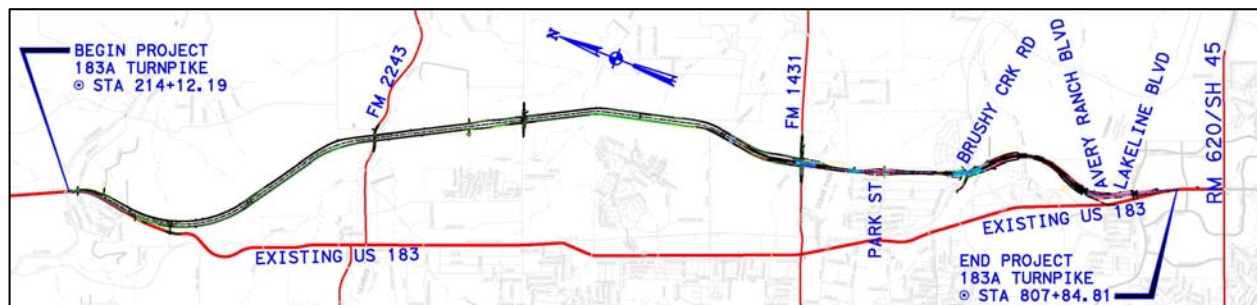


FIGURE 1 – 183A TURNPIKE SCHEMATIC

The beginning seven miles of the corridor comprise free frontage roads running north and south each side of a wide median reserved for future mainlanes (currently under design in a subsequent project). From FM1431 (the major route into the City of Cedar Park) to its terminus, the project consists of tolled mainlanes in each direction.

Design efforts began in January 2005 and concurrent construction commenced just a few months later in March 2005. The new road was opened to traffic in March 2007. The general contractor, Hill Country Constructors (HCC), a joint venture between Granite Construction, Inc. and J.D. Abrams, LP, engaged URS Corporation (URS) to serve as the Prime Design Consultant.

P.E. Structural Consultants, Inc. (PESC) co-led the structural design team with URS to provide design and construction support for the following structures (Figures 2 through 5 are typical examples):

- 23 Bridges spanning roadways, railroads, drainage areas and creeks
- 40 Mechanically Stabilized Earth (MSE) Walls
- 4 Noise Walls protecting residential areas (2 supported on bridges)
- Overhead Sign Supports and Electronic Toll Gantries
- Miscellaneous Drainage and Traffic Structures



FIGURE 2 – TYPICAL OVERPASS BRIDGE



FIGURE 3 – TYPICAL CREEK CROSSING



FIGURE 4 – TYPICAL RAMP BRIDGE



FIGURE 5 – TYPICAL SIGN SUPPORT

STRUCTURAL DESIGN HIGHLIGHTS

Bridge designers in Texas generally rely heavily on a well developed set of state-wide standard drawings and designs provided by the Texas Department of Transportation (TxDOT), resulting in Texas bridge construction being the most economical in the nation. This project capitalized on the economy offered by standardization, yet benefitted from innovative adaptation of standard details to solve project-specific structural design challenges. This effort, combined with the seamless integration of the aesthetic and structural design processes (as further described in the subsequent section on Aesthetic Design), yielded an attractive, functional and economical end product.

Typical bridge structures are multiple span prestressed concrete I-beam units spanning lower roadways, creeks and railroads. This project was initiated prior to the implementation of AASHTO Load and Resistance Factor Design (LRFD), so structures were designed in accordance with the AASHTO Standard Specifications, 17th Edition. Structural design challenges included the presence of karst geologic features; long spans which pushed the limit of TxDOT Type IV and Type VI (Mod) I-beams; and tall, stepped columns.

Bridge Superstructures

The TxDOT Type IV prestressed I-beam has historically been the workhorse in typical Texas highway bridge construction, with spans arranged in what are referred to as “poor-boy” continuous units (having continuous bridge deck slabs with control joints to mimic simple span construction in two, three or four spans between expansion joints). All mainlane overpasses, ramps and creek crossings used Type IV units; the majority of frontage road creek crossings also incorporated the 54 inch deep Type IV section where hydraulic considerations could accommodate the depth. Four frontage road bridges needed 34 inch deep Type B beams where a shallower section was required. Only one bridge on the project, at Park Street, spans over 183A; solutions for this atypical situation are described in more detail below.

Type IV beam spans designed under the Standard Specifications are generally limited to 115 to 120 feet in typical applications. While average span lengths were on the order of 115 feet, several overpass configurations mandated span lengths from 120 up to a maximum of 134 feet. In these cases, close collaboration with the beam fabricator, which was possible during design as an advantage of the design-build delivery method, allowed design engineers to rely on higher concrete strengths at release and/or 28 days, and the use of larger 0.6 in diameter strands to make spans work without significant impacts on beam production or cost.

Bridge decks comprise precast concrete panels (PCPs) and a cast-in-place topping slab. PCPs are thin (4 in) precast pretensioned slabs, designed to support fresh topping concrete and then act compositely with the topping and beams to support additional dead and live loads. In Texas, the use of PCPs is standardized based on TxDOT designs and drawings, and likewise contributes to the efficiency and economy of this type of structure.

Bridge Substructures

Aesthetic bridge structures consist of reinforced-concrete cast-in-place multi-column bents with trapezoidal caps and rectangular columns, supported individually by single drilled shafts. Typically, column cross section was 3 ft by 4.5 ft while the cap cross section was 4 feet deep.

An important substructure feature is the transition of the rectangular interior bent columns directly to the 48 in diameter drilled shaft foundations without a cap; increased attention to detail at this interface precludes the need for any cap at the top of the drilled shaft resulting in a simpler and more economical solution for the contractor (Figure 6).

The same basic bent cap cross-section was used for all aesthetic bridge bents, minimizing the number of unique form sets required. To keep concrete formwork economical, the cantilevers on aesthetic bent caps were held constant. PESC coordinated the aesthetic and structural design so for typical bents, a single extendable form set could be used to accommodate all bridge widths (from 51 to 88 ft), and skews (from 0 up to 39 degrees) and all variations in cross-slope without requiring modification. For constant soffit widths, deeper cap sections could also be constructed using the same form set.

Column heights up to 46 feet demanded a larger section than the typical 3 ft by 4.5 ft rectangular column resulting in stepped columns, with the cross section of the lower segment increased to 4 ft by 6 ft. Using stepped bases on columns precluded the need for a larger bent cap, providing additional structural bulk only where necessary (Figure 7). The larger 4 ft by 6 ft column section was also utilized for other bents within the project where a larger column was required, so those forms could be re-used; only three different sizes of aesthetic column forms

were needed on the project. The karst features in the native limestone rock also led to deep shafts and larger column sizes.

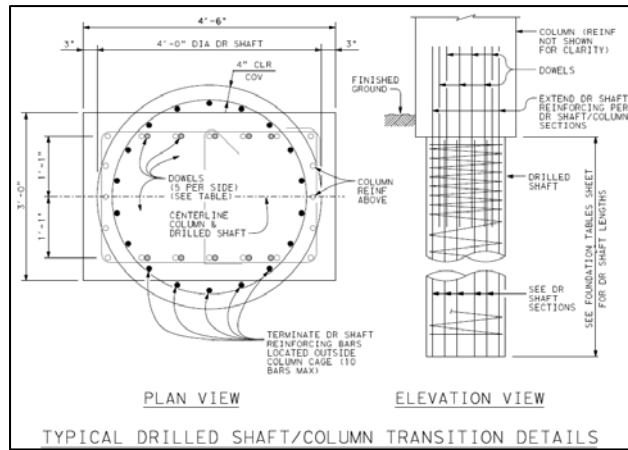


FIGURE 6 – FOUNDATION DETAIL



FIGURE 7 – STEPPED COLUMNS

Park Street Bridge

The Park Street Bridge (Figures 8 and 9) is the landmark bridge for the project. The bridge is prominently located over a 30 ft deep rock cut adjacent to the Main Toll Plaza, traversing over 14 lanes of traffic where the roadway is at its widest. The rock cut minimized the disruption of the Toll Plaza to the adjacent subdivision, yet introduced challenges to the design.



FIGURE 8 – PARK STREET BRIDGE

The Park Street Bridge also uses standardized construction details to an extent to capitalize on their inherent economies, but at the same time incorporates special features and innovations in order to successfully meet the unique challenges and constraints at this location.

This bridge has a constant overall width of 51 ft and consists of one precast concrete beam unit comprising two 158.68 ft spans for a total length of 317.36 ft. Type VI (MOD) prestressed concrete I-beams (72 inches deep) are composite with cast-in-place concrete slabs over precast concrete panels. Sidewalks are featured on both sides of the deck and aesthetic Type C411 combination bridge rail incorporates above-deck lights mounted within integral concrete pilasters. Bents and abutments are slightly skewed (less than 4 degrees) and the interior support is an aesthetic multi-column bent similar to the typical bents on the project with a slightly deeper cap (constructed with the standard form set, just cast to a higher level within form) to accommodate the heavier superstructure. The abutment structure is a unique load-bearing cast-in-place cantilever retaining wall with aesthetic treatments. The specific and unique qualities of these features are discussed in more detail below.

The length of each Type VI (MOD) prestressed concrete beam span is 158.7 ft, which makes the I-beams used in the Park Street Bridge some of the longest precast I-beams ever used in Texas (the record length is 159.0 ft) – almost long enough to span the width of a football field! Each span consists of 8 beams spaced 6.43 ft apart. Options with three and four spans were considered in preliminary design but traffic and roadway requirements as well as constraints associated with the function of the adjacent toll plaza necessitated two long spans. A steel superstructure solution was considered but rejected for several reasons: long fabrication lead times were incompatible with the fast-paced design-build schedule, costs were higher, no other steel was used on the project so additional work crews and subs would have been needed, plus there were concerns related to aesthetics and long-term maintenance. Although the required span lengths push the limit for the Type VI (MOD) beams (typically used for spans in the range of 130 to 150 feet), a resourceful design using larger 0.6 in diameter, 270 ksi low-relaxation strands combined with a final concrete strength of 9,000 psi, allowed the prestressed concrete solution to meet the design constraints with economy and grace.

Permanent steel diaphragm bracings, located at third points for interior beams, are designed to address lateral stability concerns associated with the modified AASHTO Type VI prestressed I-beam in such a long span (Figure 10). Additional temporary bracing was added during construction for slab casting at exterior beam bays.



FIGURE 9 – PARK STREET BRIDGE



FIGURE 10 – PARK STREET BRACING

Construction of drilled shafts at abutment locations was not feasible due to the lack of clearance for drilled shaft rigging equipment so close to the vertical rock cut. Over-cutting of the limestone cliff to allow access for construction equipment was not an option either as it would have increased the span length even more. Taking advantage of the quality of the limestone in the cut, spread footings were designed to support a cantilevered retaining wall and wingwalls at each abutment. Placement of the wall in front of the cut facilitated construction and helped to limit the span lengths. The primary abutment wall is designed to handle all dead and live gravity loads applied by the superstructure as well as the lateral loads due to the backfill and natural soils behind the abutment. The wingwalls are designed to cantilever horizontally from the primary abutment wall; the horizontal reinforcement is designed to carry the full soil load without contribution from the vertical reinforcement. The abutment design was also checked for the construction case where the wall is fully backfilled with the superstructure not yet in place.

AESTHETIC DESIGN HIGHLIGHTS

The aesthetic concept for all structures in the project is based on the desire to contribute to the visual identity of the growing communities that this toll road serves. Additional aesthetic design goals addressed compatibility with nearby toll projects, consistency in detailing for all the structural elements of the project (bridges, walls, sign structures, toll plazas), constructability, economy, and environmental sensitivity. This project illustrates how aesthetic treatments can be successfully incorporated into relatively utilitarian engineering solutions.

Early in the development, the CTRMA suggested an identity for this project encapsulated by the moniker “Chisholm Trail Parkway”. A fitting theme for a new toll road, the Chisholm Trail brings to mind images of enterprising, hard-working Texans creating a route that enabled them to prosper from one of the bounties of the Texas land – Longhorn cattle. HCC aesthetic designers looked for ways to incorporate into its aesthetic design stylized imagery of the Longhorn and of the Texas Hill Country’s special brand of western culture, imagery that reflects characteristics of both the rustic nature of the land and the refinement that comes with development and prosperity. This identity defers to the historical roots of the area from early Texas settlers involved in ranching and farming, while at the same time looks forward to the future by incorporating timeless and sophisticated details.

Crucial factors in the success of the aesthetic design for 183A were the true collaborative effort made possible by the design-build delivery method, and the integration of the structural and aesthetic design process. The design-build environment affords a unique opportunity for aesthetic designers, structural engineers, contractors, fabricators, form manufacturers, owner’s representatives and the public to each contribute their particular desires and expertise to the process, all while the project is being fully developed. Design efforts were prioritized to address first those items critical to the design and construction schedule; namely bridges, retaining walls and noisewalls, then sign and toll gantry structures and color schemes. The aesthetic design for structures was also coordinated with that for stormwater detention ponds, lighting, landscaping (both hardscapes and plantings) and toll facilities. The design team, in working together with the CTRMA and local communities, developed aesthetic treatments to reflect both the natural and built environment, as well as the historical significance of the region. For example, the color scheme emulates the hues of the natural limestone outcroppings prevalent in the area, and both native limestone as well as simulated limestone textures feature prominently.

Of all the structures within the toll road corridor, the mainlane aesthetic bridges have the greatest visual impact on the landscape, especially when viewed from areas adjacent to the right-of-way and frontage roads. The detailing on the bridge structures, especially at elevated road crossings, is highly visible and creates a strong identifying feature. For the types of bridges that are used on this project, the substructure elements – bent caps and columns and abutment retaining walls - provide the greatest opportunity for aesthetic treatment. However, aesthetic details were applied frugally; where visibility to substructures is limited, TxDOT standard style bents and abutments with sloped concrete riprap support the superstructure in lieu of the aesthetic bents and abutment walls used for overpasses.

Bridge Superstructures

Superstructure components – railing, exposed deck overhangs, and beams – simply use understated color, applied using a three-tone scheme to create contrasting but subtle bands of color, as the primary aesthetic treatment. Paint, as opposed to integral concrete color or opaque

sealers, proved to be an extremely cost-effective aesthetic enhancement, and today's formulations are guaranteed for a minimum of 10 years against fading, peeling or flaking.

Bridge Bents

Interior bent aesthetics draw on sculpted shapes and patterns of horizontal and vertical reveals to create a stylized “longhorn” motif that is reminiscent of, but does not copy, other aesthetic bridge structures in the Austin area. It incorporates details that are common to adjacent projects, such as canted faces and arches, to create an effect that is complimentary but unique. The longhorn imagery is formed with a trapezoidal shape over the column (for the top of the head), subtle arch at cap cantilevers (for the horns) and southwestern style vertical reveals at the top of the column (for the face). Rectangular columns are proportionally sized and enhanced with a series of simple horizontal reveals, for a look that is enhanced but not overdone. All aesthetic bents on the project - multi-column, single-column and straddle bents - incorporate similar detailing. The concept and implementation of the interior bent aesthetics are shown in Figures 11 and 12. Bents are painted a solid color; but variations and shadows are produced by sculpted shapes, formed reveals and indented surfaces.



FIGURE 11 – TYPICAL BENT

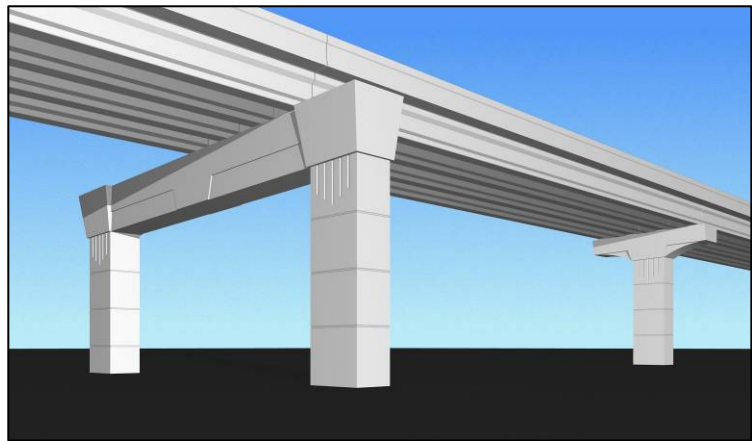


FIGURE 12 – STRADDLE AND HAMMERHEAD BENTS

Abutments and Retaining Walls

All bridges classified as aesthetic structures have vertical abutment walls (i.e., no sloped riprap). To set wrap-around Mechanically Stabilized Earth (MSE) abutment walls on this project apart from standard TxDOT construction, aesthetic corner elements were developed that replicate the detailing in the bridge columns. These corner elements are proportional in size to the columns, have the same horizontal reveals at joints, and also incorporate the vertical southwestern style reveals at the top (Figure 13). MSE abutment wall panels below aesthetic bridges have a smooth finish, distinguishing the walls below bridges from those along the roadway, and facilitating the installation of metal art pieces or murals that can be selected at a later date. During design, the use of large scale metal cutouts depicting a cattle drive scene (Figure 14) was suggested for the FM1431 Overpass, which is considered a gateway to the City of Cedar Park. During the final landscaping stages, a sand-blasted and painted mural was in fact created. MSE walls along the roadway feature a custom ashlar stone pattern on the nominal 5 ft by 10 ft precast wall panels

over the full height of the wall, topped by a standard 2 ft tall coping (typically precast) with a smooth finish. The use of form-liners for the pre-cast wall panels is cost-effective and ensures a consistent pattern from location to location.

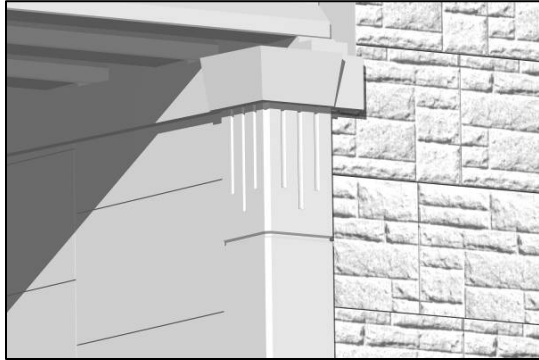


FIGURE 13 – ABUTMENT CORNER ELEMENT



FIGURE 14 – WALL ART CONCEPT

The Park Street Bridge features an additional aesthetic abutment treatment that is unique to the project. Natural limestone veneer proved to be a better solution for the retaining wall fascia than a form-lined concrete alternate, since it accentuates the “man-made limestone canyon” created by the deep cut at the bridge location, enhances the signature quality of the bridge, and was actually more cost-effective than the concrete in this case since a special set of form-liners would have been required for the large wall surfaces.

Sign Structures and Toll Gantries

Aesthetic concrete columns are designed to accommodate standard TxDOT galvanized steel sign bridge or cantilever trusses. A precast enclosure tops each column, concealing the truss ends and providing a sophisticated appearance (Figure 15). The toll gantry concept for this project essentially uses a pair of typical aesthetic overhead sign bridges connected with additional planar trusses to accommodate the electronic toll equipment (Figure 16). The reveals on the columns and the canted surfaces of the precast enclosures replicate features of the bridge substructures.



FIGURE 15 – SIGN SUPPORT CONCEPT



FIGURE 16 – TOLL GANTRY CONCEPT

Noise Walls

Noise walls that present a pleasing appearance to both the toll road users and the property owners behind the walls help to make these walls acceptable to residents, potentially mitigating negative impacts usually associated with the installation of sound walls near existing neighborhoods. Plantings in front of the noise walls further mitigate the impact of traffic-generated noise and integrate them into the landscape.

Where needed, at-grade noise walls ranging from eight to twelve feet in height utilize a precast post and panel structural system. On the traffic face of noise walls, form-liners similar to those used to construct typical MSE retaining wall panels create texture on the lower noise wall panels; the remaining height has a light textured surface and the top is trimmed with a precast concrete coping with smooth finish that is also consistent with the MSE walls. Vertical reveals on the traffic face at the top of the precast posts replicate detailing used on interior bridge bent columns and abutment corner elements for a consistent effect. Posts are topped with a classic pitched precast concrete cap (Figure 17). Adjacent property owners had the opportunity to vote for one of three different texture finishes for the residential side of the noise walls.

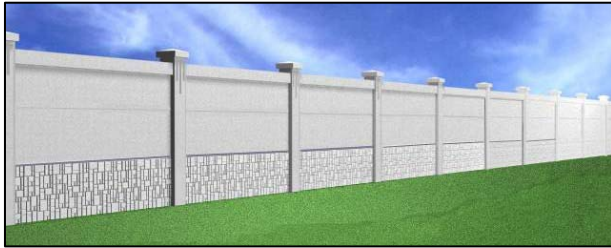


FIGURE 17 – NOISE WALL CONCEPT

DESIGN-BUILD EXPERIENCES

The CTRMA elected to use the design-build delivery method to ensure seamless integration of the design and construction phases of the project. URS assembled a team of engineers with expertise in the design-build delivery method to meet the aggressive schedule of the project. Design-build offered transparency and accountability throughout the process. From a structural engineering standpoint, there are many aspects of the design-build environment that are appealing, and, when properly executed, lead to a successful project.

Accessibility and Collaboration

During the design phase, the majority of active participants in the project (the Design Team, the Contractors, the Design Quality Assurance Firm, the Mobility Authority's GEC) were all co-located in a central office, providing immediate and effective access to information, interface and collaborative effort. In the authors' opinion, this is an ideal environment for the design process, and it fosters accountability, responsiveness, efficiency and coordination, although the fast pace and being continuously on-demand can be intense. It also provides a tremendous opportunity for learning – and applying knowledge to practice. Designers gain a deeper understanding of the construction process; likewise contractors develop additional insight into the driving factors behind engineering decisions. Design engineers in multiple disciplines – structures, roadway, drainage, traffic - also benefit from daily contact and interaction working side by side,

Design Deliverables – Schedule, Review and QA/QC Process

The traditional submittal schedule (30%, 60%, 90%, Released for Construction (RFC)) was modified to accommodate the construction schedule. “Early Release” grading and bridge substructure packages allowed the contractor to begin while detailed design continued, and the overall design schedule was synchronized with the intended construction sequence. A formal and systematic review process was key in moving the design forward to meet the construction schedule and ensuring a set of checks and balances for the design process. Design Coordination Reviews (DCR) between disciplines, Construction Reviews (CR) by the contractor, Independent Technical Reviews (ITR) by senior engineers not involved in the day to day design, Over the Shoulder Reviews (OTS) by the owner’s reviewers, Design Quality Control Manager (DQCM) Audits to enforce the QC process, Design Quality Assurance Firm (DQAF) Reviews, CTRMA and TxDOT Reviews all preceded the delivery of RFC documents to HCC Construction. The “Over the Shoulder” reviews, in which the engineering team had an opportunity to walk the reviewers through the design assumptions, constraints and the development of solutions prior to milestone submittals, were particularly effective in saving time (and oftentimes frustration!) and creating a forum where meaningful exchange of ideas could occur.

Post-Design Services

Accelerated procedures to resolve any Requests for Information (RFI’s) and Non-Conformance Reports (NCR’s) and to issue Notices of Design Change (NDC’s) worked effectively to minimize delays during construction. HCC Construction personnel would propose solutions for issues raised in the field after initial informal contact with the responsible Engineer. Likewise, members of the design team were always available to work with the contractor and Construction Quality Control personnel in the field to quickly and efficiently resolve any issues without holding up construction progress.

Results

A compressed schedule was achieved, enabling the toll road to be opened to traffic and collecting tolls ahead of schedule. The success of the project has garnered regional attention, having been awarded the 2008 Texas Council of Engineering Companies (CEC) Gold Award for Engineering Excellence. The new toll road has been well-received; toll revenues for the first year were nearly double predicted levels. That revenue is helping to fund and accelerate future enhancements to mobility in this growing region.



FIGURE 18 – THE 183A DESIGN-BUILD PROJECT - PEOPLE WORKING TOGETHER