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Strategic Research

PROGRAM

PROCEEDINGS OF A WORKSHOP ON ACCELERATED ROAD AND BRIDGE CONSTRUCTION

September 2016

Texas A&M Transportation Institute

Proceedings of a Workshop on Accelerated Road and Bridge Construction

Report

by

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WORKSHOP ON ACCELERATED ROAD AND BRIDGE CONSTRUCTION

Workshop Description

Justification

Rehabilitation and reconstruction of roads is the largest component of most department of transportation (DOT) budgets. These activities usually take place on active roadways, and the work zones pose a safety risk to the road users and construction personnel. Rapidly establishing a work zone with adequate room for construction operations, moving in, completing the construction, and moving out in as little time as possible will help to substantially reduce the risk. Accelerated construction of these facilities includes a design with a constructability review to keep as much material in place as possible and as much simplicity as possible while ensuring a long-life design, innovative ways to incentivize the contractor to complete the work quickly, optimizing lane closures to minimize impacts on the road users, maximizing the productivity of the contractor, minimizing worker fatigue, and providing enough publicity to allow motorists to avoid the affected area.

History

A previous study, "Considerations and Case Studies in Rapid Highway Construction Using Asphalt Pavement," was co-sponsored by the Texas A&M Transportation Institute (TTI) and the National Asphalt Pavement Association. In this study, several key factors for accelerated construction of pavements were identified including: 1) isolating the work zone from traffic, 2) using as much of the in-place material as possible, 3) maintaining lane closures as long as possible to improve productivity, 4) allowing contractors as much control as possible over work zone activities, and 5) developing innovative approaches to moving traffic in and around work zones.

This report is the end product of a follow-on project, sponsored by TTI, to hold a workshop comprised of presenters, Texas Department of Transportation (TxDOT) representatives, pavement and bridge contractors, the Federal Highway Administration (FHWA), design consultants, and TTI researchers. A list of attendees is given in Appendix A and included 15 industry, 12 TxDOT, 2 FHWA, 13 TTI, 1 Washington State Department of Transportation (WSDOT), and 1 University of California Davis (UC Davis) representative. This provided a good balance of interests and perspectives on accelerated construction.

Objectives

The objectives of the workshop were to: 1) identify what is known to effectively accelerate road and bridge construction, 2) identify elements needing research or implementation efforts, and 3) develop a list of research and implementation needs. The workshop was held July 25 and 26, 2016, and spanned approximately a day and a half. The agenda is given in Table 1 and was organized so that the initial presentations by contractors, TxDOT, TTI, WSDOT, and UC Davis provided useful information concerning the realities of accelerated road and bridge construction. Next, the participants were divided into discussion groups around some scenarios for accelerated construction to initiate the thought processes and help identify what is known and what is not. The meeting was adjourned for the day and the next morning was spent in identifying research and implementation needs. These were presented in a final plenary session that was followed by TxDOT and the industry's views of the path forward.

Table 1. Agenda for Workshop on Accelerated Road and Bridge Construction.

Date/Time	**Speaker**	**Topic**	**Comments**
July 25, 2016			
9:00–9:15	Jon Epps-TTI	Welcome and Overview of Issues	Self Introductions
	Dave Newcomb-TTI	Workshop Expectations	Facilitator Why we are here Not just more equipment and people Workshop products
9:15–9:30	Randy Hopmann-TxDOT	TxDOT's Interest	Existing activities Strategic importance Customer considerations
9:30–9:40	Jim Breland - Barriere Construction	Contractor's View-Asphalt Pavements	Experiences Opportunities Barriers Concerns
9:40–9:50	Mark Hilderbrand – Kiewit Infrastructure South	Contractor's View-PCC Pavements	Experiences Opportunities Barriers Concerns
9:50–10:10	David Ellis-TTI	Economics of Rapid Construction	User costs Non-user costs Construction costs Selecting cost effective projects Case history (IH-10 Houston)
10:10–10:25	Break		
10:25–10:45	Tim Lomax-TTI	Congestion Mitigation in Work Zone	Lane closures, weekend shutdowns, short duration (weeks/months) Alternatives for handling traffic Public survey to inform decisions Speed/Volume data availability Event calendar activities Context sensitive strategies/alternatives
10:45–11:05	Jerry Ullman-TTI	Work Zone Safety	Public and workforce issues Geometrics Equipment/Hardware Workforce
11:05–11:25	Stuart Anderson	Contracting and Construction Methods	Alternative contracting methods Construction methods-game changers Start contractor input early
11:25–12:00	John Harvey-UC Davis	Case Study I-710	I-710 project Other projects

			Software available
12:00–12:45	Lunch		
12:45–1:15	Jed Bingle- WSDOT	Accelerated Bridge Construction	Promising techniques Case histories Future
1:15–1:30	Dave Newcomb	Charge to Breakout Groups – See Descriptions of Scenarios for Breakout Groups Below	Formation of groups Breakout group meeting locations Description of projects to be considered Expectations Accelerated construction strategies Summarize and report
1:30–3:30	Group Facilitators	Breakout Group Meetings	Discuss example projects Identify choke points What is needed to overcome choke points How to accelerate construction Summarize results
3:30–3:45	Break		Break refreshments available at 2:45 Groups take break at any time
3:45–4:45	Group Facilitators	Summarize Breakout Group Discussions	Provide notes from discussion Flip chart/white board notes
4:45–5:00	Dave Newcomb	Day 1 Summary	
5:00–6:30	Reception	TTI State Headquarters Research Building	
July 26, 2016			
8:00–8:15	Dave Newcomb	Charge to Breakout Groups on Day 2	Summarize Day 1 Expectations for Day 2
8:15–9:30	Group Facilitators	Breakout Group Meetings	How can productivity be improved Safety impacts-public and workforce How can contractor and public agency risk be reduced What needs to be improved
9:30–10:15	Group Facilitators	Breakout Group Meetings	Research and Implementation Needs (traffic, bridges, pavements, economics, safety, construction methods-techniques/equipment), contracting methods, reducing risk
10:15–10:30	Break		Break refreshments available at 9:30 Groups take break at any time
10:30–11:30	Group Facilitators	Summarize Breakout Group Discussions	Productivity improvements Safety improvements Risk reduction to contractor/public agency Research/development needs Implementation needs
11:30–11:55	Jeff Smith – Smith & Co.	Accelerated Construction-Looking to the Future	What do we know What do we not know What is needed to move forward
	Randy Hopmann-TxDOT	Accelerated Construction-Looking to the Future	What do we know What do we not know What is needed to move forward

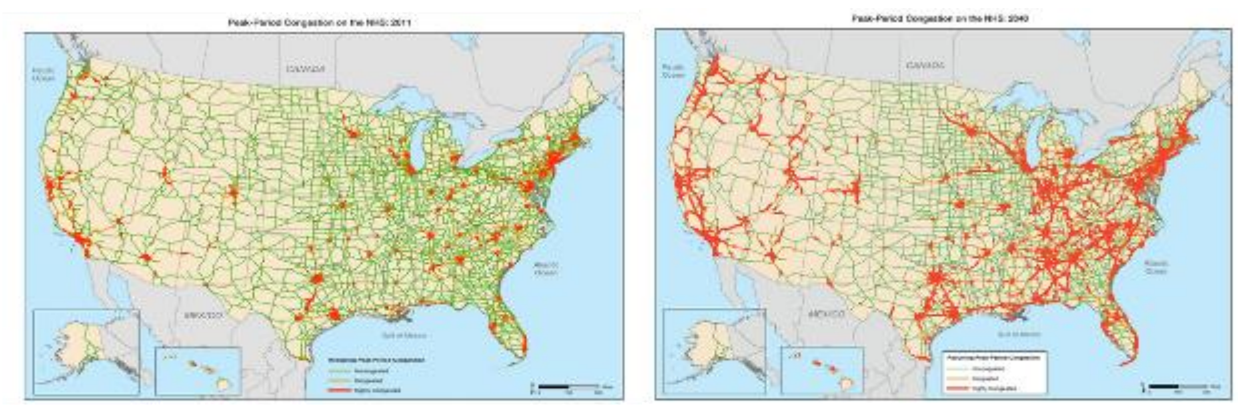
11:55–12:00	Dave Newcomb	Summary and Adjourn	

INTRODUCTION

Overview and Expectations for the Workshop

The construction zone is the visible and perhaps only connection between the driving public and the delivery of a roadway for public use. The driving public is very aware of and sensitive to the time it spends in delays in work zones. From the driver's point of view, any amount of time delay due to roadway activities is excessive and inconvenient. Significant public support and financial savings result when the speed of construction is increased on projects or construction on roadways is made unnoticeable to the driving public.

Blanchard et al. (2009) stated that, "Accelerated construction is about minimizing time impacts to the public," after reviewing successful practices in five states from Florida to California. The importance of speed of construction to the public can be illustrated by the maps of current and projected levels of congestion in the United States for 2011 and 2040, respectively, in Figure 1(a) and Figure 1(b). The current levels of congestion in Figure 1(a) center on major metropolitan areas. By the year 2040, a little over one generation from now, the congestion is projected to be as shown in Figure 1(b). The areas that are currently impacted by congestion will become worse, and areas that are not currently problematic will become congested. Although rapid construction techniques are currently in use, they need to be refined and further streamlined in the future just to keep up with the demands of the traveling public and the transportation of goods and services.



(a) Year 2011. (b) Year 2040.

Figure 1. Congestion Projected for National Highway System (FHWA, 2013).

The time required for a project to be delivered (inception to completion) is exceedingly long and unacceptable. Planning, financing, scoping, development, bidding/letting, and construction typically require 8 to 15 years. The planning, development, and contracting usually can take as much as 8 years, and the construction can take up to an additional 7 years. If the time required for the various activities can be reduced, significant cost savings can result for the agency, user, and adjacent businesses. These costs saving can far exceed project construction costs. Although the agency costs are usually hard costs for the agency and the contractor, in the end the public bears these expenses plus those that are caused by excessive congestion, additional accidents within the work zone, delayed deliveries, and missed opportunities for local business. Although these latter costs are difficult to forecast or determine they are, nonetheless, real.

Accelerated construction encompasses a wide variety of activities that must take place on roads and bridges, including capacity improvements, reconstruction, rehabilitation, major maintenance, and minor maintenance. Capacity improvements would include such items as road and bridge widening. Reconstruction might entail removing a large portion of the pavement structure and rebuilding it, and for bridges it could include bridge or bridge component replacement. Rehabilitation for roads generally means providing a structural capacity improvement, and for bridges, it could be strengthening an existing structure. Major maintenance could entail a thin overlay for a pavement and deck repair for a bridge. In a pavement minor maintenance would mean crack sealing, and for a bridge, it might include painting. Regardless of the activity, significantly accelerated construction would mean reducing the overall time for the work zone by 50 percent or more.

In order to accomplish the goal, all aspects of construction need to be reviewed including materials, equipment, quality control/quality assurance (QC/QA), traffic management, workforce concerns, economic incentives, and safety for both construction and traveling public. This will take a multidisciplinary approach that will entail material suppliers, contractors, equipment manufacturers, public agencies, human resources, financial and business interests, public affairs, and the public itself. If accelerated construction is successful, then all parties including the public, the agency, and the contractor should reap the benefits. The mantra for accelerated road and bridge construction is, “Get in, stay in and get out, stay out!”

The intent of this workshop was to allow a holistic discussion of issues so that as many ideas could be generated as possible. Thus all the interests and issues mentioned above were on the table and could be a part of the ideas for implementation and research. Some innovative construction practices from Europe were used to illustrate out-of-the-box ideas. For example, a two-layer paver (Figure 2) is used in Germany is capable of placing a binder course and surface course at the same time. Not only does this save time by placing two different materials in one pass, but it also allows complete bonding between the surface course and binder course, and it provides a better opportunity to achieve density. A competition for both concrete and asphalt paving contractors to build quiet pavements quickly was held in the Netherlands. In one example, precast concrete pavement sections were placed on beams on grade (Figure 3) and in another, an asphalt layer was unrolled onto an existing pavement layer like a carpet (Figure 4[a]), which was then bonded to the lower layer by a microwave generator (Figure 4[b]).

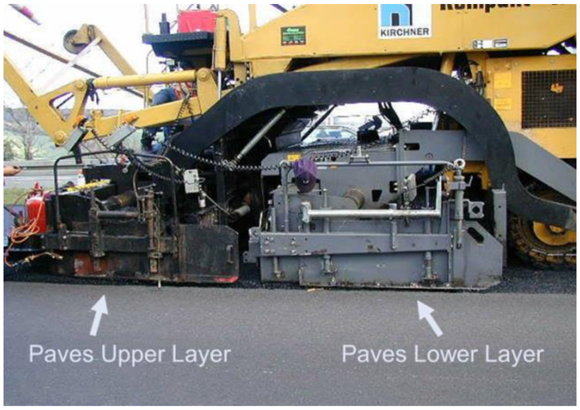


Figure 2. Two-Layer Asphalt Paver.

Figure 3. Modular Concrete Pavement.

(a) Asphalt Pavement Layer Being Unrolled.

(b) Asphalt Layer Being Bonded by Microwave Unit.

Figure 4. Asphalt Pavement Being Unrolled and Bonded to Existing Layer.

The outcomes for the workshop were to identify issues, research needs, and implementation needs. The identification of technology and institutional barriers was important in order to understand how to mitigate the barriers. The development of research needs helped to identify items that need to be defined and quantified as well as those items that would be known to help but have not yet been developed. The implementation needs covered the knowledge and tools that are known to exist but are not being effectively used. Thus, implementation may cover changes in policies and developing and delivering training.

Stakeholder Interests

TxDOT – Randy Hopmann

TxDOT interests in accelerated construction include existing activities, strategic importance, and customer considerations. The recent approval of Proposition 1 and Proposition 7 highlights two important considerations: 1) the voters want improvement in the transportation infrastructure and 2) there is public trust in TxDOT to provide that infrastructure. There is a need for TxDOT to identify better ways to accelerate construction and consider the overall situation in terms of cost not only to TxDOT but to the citizens and businesses as well. For instance, there are delay costs to the businesses impacted by the road construction projects and their customers. In the end, the user costs can end up being larger than the actual construction cost. There are also safety issues associated with long construction time to TxDOT personnel, contractor personnel, and the public.

It would benefit TxDOT and the state of Texas in general to examine what other agencies are doing to identify better construction materials and adopt better traffic control techniques such as complete shutdowns and continuous 24-hour work schedules to finish the job earlier. TxDOT and its industry partners need better strategies and tools to accelerate our construction activities where it is warranted and turn over projects to the public. This applies not only to metropolitan areas but to rural areas in some instances.

Asphalt Contractor Perspective – Jim Breland and Daniel Donahoe, Barriere Construction

Founded in 1949, Barriere Construction is a fourth-generation, family-owned industrial, highway and heavy civil construction Company headquartered in Metairie, LA, with interests in both asphalt and concrete paving. Their work is spread among five separate work groups across southern Louisiana and consists of approximately 70 percent public and 30 percent private contracts.

In 2014, the Louisiana Department of Transportation and Development (LADOTD) let an A+B+C (construction + time + time incentive) contract to reconstruct the pavement at the intersection of I-10, I-12, and I-59 north of New Orleans located in Slidell between Lake Pontchartrain to the south and the Pearl River Swamp (Figure 5). The project was bid with alternate designs for asphalt and concrete pavements. Barriere bid asphalt pavement had a construction cost of more than $2 million above the next bid, which was concrete. However, Barriere bid 360 total days for construction while the next bid had 675 days. This resulted in Barriere having a bid that was over $2 million lower than the next competitor. In the end, this project took 125,000 man-hr, during which over 90,000 tons of concrete was removed to be recycled and over 285,000 tons of asphalt mix was placed. Of this, 65,000 tons was reclaimed asphalt pavement. The job was completed 71 days ahead of Barriere's schedule, which resulted in the maximum amount of an early completion bonus.

Figure 5. Reconstruction of Intersection of I-10, I-12, and I-59 in Louisiana.

The project came with several challenges for the construction team including safety, schedule, project fatigue, laterally confined work zones, summer traffic, and completion within one hurricane season. It was important for the company to have employee buy-in for the importance of safety. Safety concerns included the potential for work zone intrusions, worker fatigue, and adequate supervision to cover all shifts. Proper lane closures and openings had to be ensured through traffic management plans and of particular concern was the potential for long queues and high truck volumes. These safety concerns were addressed through site specific safety meetings and training for employees, subcontractors, and delivery trucks. A service was hired to document and clear 3rd party accidents from the travel lanes.

The schedule of 360 total days presented considerable challenges in that there were multiple lane closures and laterally confined areas in which the contractor could only work for 72 to 76 hours at a time. For these laterally confined sections, a time penalty of $15,000/lane-mile/hour was imposed with no limit on the damages. Weather was also a major consideration for the schedule since critical decisions on construction had to be made on the basis of 24-hour forecasts. The execution of Barriere's operations was ensured by the presence of asphalt plants on either side of the project, although it was rare that more than one plant at a time was used.

Since this was a fast-paced and demanding project, worker fatigue needed to be monitored and addressed by scheduling consistent time off for work crews and supervisors and monitoring shift times and durations. Cool-down areas were designated for breaks during construction. Potential safety and morale issues needed to be addressed since the pace of the project created a lot pressure at all levels. To mitigate this risk, there were contingency plans for additional crews and supervisors during critical times. Material suppliers and equipment mechanics were also on-call during critical periods.

The partnering between the LADOTD, Volkert, Inc., and Barriere was key to the success of this project. Developing a strong partnership involved collaboration early in the planning process, and the group chose an independent moderator to help. Defining and developing lines of communication early were important to obtain a clear method of conflict resolution. Weekly site meetings and quarterly progress meetings were held. Transparency of the progress schedule and honesty were very important to the successful completion of this accelerated construction plan.

Portland Cement Concrete Contractor Perspective – Mark Hilderbrand, Kiewit Infrastructure South

Kiewit Infrastructure South has been involved in a number of accelerated construction projects for concrete pavements including Hartsfield International Airport in Atlanta, GA; the Dallas-Fort Worth Connector in Grapevine, TX; I-95 in Cocoa Beach, FL; and I-229 in Sioux Falls, SD. Through these experiences, opportunities, identification of project delivery methods, barriers and concerns have been identified.

The reconstruction of a main runway at Atlanta Hartsfield was a $94 million bid-build project constructed in 2006 (Figure 6). In this project, 260,000 square yards of runway had to be removed and replaced in a 60-day time period with liquidated damages assessed at $225,000 per day. There was 24-hr access to the work area at all times, and two taxiway crossings were required to be open at all times for vehicles and planes. Kiewit placed 180,000 cubic yards of concrete in 45 days during this project. In order to accomplish this, they used double shifts for all operations with constant coordination with airfield operations. Dedicated concrete plant and paving equipment ensured non-stop operations. To maintain schedule control, the prime contractor performed all excavation, subgrade preparation, base construction, and paving. The flow was helped through the use of optimized aggregate gradation, wireless grade control, and concrete maturity meters.

Figure 6. Reconstruction of Main Runway at Atlanta Hartsfield International Airport.

The DFW Connector was a design-build/comprehensive development agreement project for a $1 billion multi-interchange freeway and reconstruction of SH 114 and SH 121 (Figure 7). This American Concrete Pavement Association award-winning project consisted of 1.6 billion square yards of continuously reinforced concrete pavement (CRCP) placed on 227 lane miles in a 39-month period. Lane closures and access to certain work areas could only be done in off-peak traffic times only. A dedicated concrete plant and three dedicated paving spreads ensured that resources would be available. Kiewit elected to perform the excavation, subgrade preparation, and paving, and use a subcontractor for the base only. Innovation and cooperation was encouraged for all parties involved. This resulted in refinements to the pavement section and attention to detail in the scheduling. A method for real-time tracking materials, billing, and payment was instituted. Specifications were developed to use intelligent compaction technology on the job in addition to wireless grade control, optimized aggregate blends, and the use of maturity meters. Another important feature of this project was the relocation of utilities during construction to save time.

Figure 7. Construction of DFW Connector.

The project to build 10 miles of widening on I-95 in Cocoa Beach was a $170 million design-build job. By examining the project plans, a reconfigured technical solution was found for eliminating the need for wetland permits and embankments. Again, a dedicated concrete plant and wireless grade controls on subgrade, base, and paving equipment was crucial to saving time. In the end, the design of the project took 7 months and the construction was 15 months long.

In Sioux Falls, SD, Kiewit reconstructed 6.9 miles of I-229 in 2001. This $33 million design-build project lasted for 14 months, which included 5 months for the design phase and 9 months for construction. The design called for the placement of 353,000 square yards of 10.5-inch CRCP and the reconstruction of two 435-ft by 78-ft 4-span bridges over the Big Sioux River. Accelerated construction was facilitated by a dedicated on-site batch plant, dedicated earthwork, and paving equipment.

Kiewit views accelerated construction as consisting of opportunities, barriers, and concerns. The opportunities involve employing innovative technology to speed the construction process along. Wireless equipment for grade control and 3-D machine controls allow for continuous and accurate paving. Maturity meters provide timely information on when it is safe to cut joints and remove forms as well as move equipment and traffic onto concrete pavement surfaces eliminating the need for overly conservative time limits. Optimized aggregate blends are useful in delivering the desired workability, strength, and durability for concrete paving. The use of precast panels for pavement repairs allows for work to be accomplished at night for rehabilitation and reconstruction, which reduces user delays and disruption to local businesses.

A key aspect of accelerated project delivery is the need for dedicated resources. Both personnel and equipment must remain with the project for its entirety to provide the maximum benefit for production. The project personnel must be identified in preconstruction planning along with the coordination of supervision and personnel updates.

The barriers presented by accelerated construction include the investment required for new technology and equipment. Equipment must be kept busy in order pay for itself so there needs to be an expectation that any new innovations will become common-place within a short period of time. Also, the training to use new technology needs to have a long-term value so that workers do not have to be retrained each time it is used.

One large concern that contractors have is that accelerated schedules must have a balance between risk and reward. In other words, incentives for accomplishing projects must be lucrative enough to balance any disincentives. There also needs to be an acceptance of products developed and delivered in an accelerated schedule so that each project does not become a unique case with unique solutions that will not be applied in the future.

Allowable project durations should be determined according to the levels of user costs they impose either through construction-related delays on existing facilities or denial of access for new facilities. If contractual monetary incentives/disincentives are used to accelerated schedules it encourages contractors to maintain the proper levels of staffing and equipment availability to meet those schedules.

The contracting and project mechanisms for accelerated construction should result in increased partnering and communication between the contractor and the agency to resolve issues that threaten the timely delivery of the project. The use of A+B bidding, design-build contracting, construction manager-general contractor approach, and practical designs are all tools that effectively allow rapid construction.

STATE-OF-THE-PRACTICE/ART

Introduction

This part of the workshop focused on what is understood about accelerated construction. The economic considerations were presented by Dr. David Ellis of TTI. The need for congestion mitigation in work zones was addressed by Dr. Tim Lomax of TTI. Dr. Gerald Ullman discussed the aspects of work zone safety, and Prof. Stu Anderson of the Civil Engineering presented the construction considerations. These presentations were followed by two case studies, one involving roadway reconstruction in southern California by Dr. John Harvey of the UC Davis and another on accelerated bridge construction/replacement in Washington State by Mr. Jed Bingle of WSDOT.

Economics of Accelerated Construction – David R. Ellis, TTI

In order to present the economic case for accelerated construction, the example of the Katy Freeway in Houston, TX, was used. Some of the benefits of accelerated construction include time savings, fuel savings, and economic returns for the citizens. Time savings come in the form of rapidly delivering a project that can improve traffic flow for motorists, delivery of goods, and delivery of services. Fuel savings are directly realized as congestion is mitigated, which would also save in the amount of pollution generated from vehicles idling. The economic returns are tied to the time and fuel savings but could also include such items as prompt delivery of goods to various destinations. With these benefits come costs to achieve the goals of the construction in an accelerated time frame. For instance, utilities may need to be relocated, incentives paid to the contractor to finish within a shorter time frame, the need to pay employees for overtime, and traffic management would all increase the cost of construction. The question then arises, do the economic benefits justify the added expense?

Figure 8 shows the economic case for the Katy Freeway just in terms of wasted fuel and delay. This graph shows the cost of wasted fuel and delay plotted for the years of 2003 to 2028. The red line shows the no build or do nothing option would result in costs ranging from $100 million in 2003 to $1.2 billion in 2028. The black line shows these costs once the expansion of the freeway is complete. If normal construction procedures were used, the freeway would have been opened in 2015, where the black vertical line shows a drop from about $320 million to $140 million. Since accelerated construction was used, the facility was opened in 2009 (green vertical line) and user savings were realized 6 years earlier at a savings of about $200 million. Over the span of time from 2009 to 2028, the estimated savings by using accelerated construction were on the order of $1 billion.

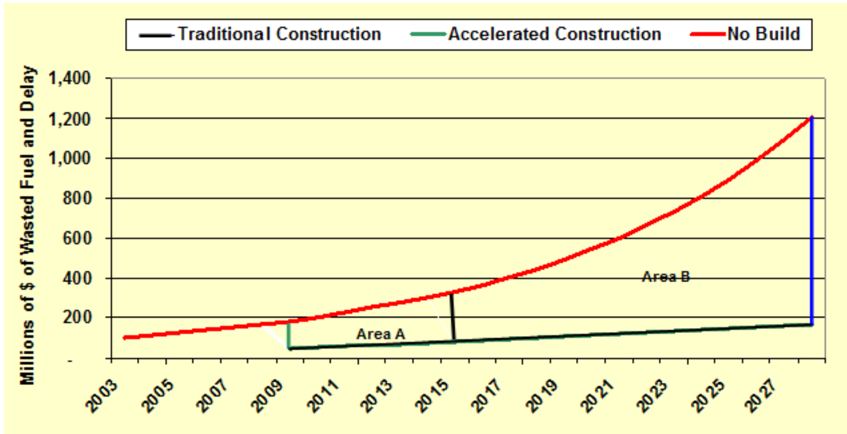


Figure 8. Cost of Wasted Fuel and Delay on the Katy Freeway for Traditional and Accelerated Construction.

Figure 9 presents the economic case in terms of the benefit/cost ratio. The cost of improvements including construction, right-of-way acquisition, utility relocation, design and project management, and administrative costs totaled $2.421 billion. The cost of accelerating the construction was $0.309 billion and the benefits, which include the amount of inflation saved, totaled $2.767 billion or a benefit/cost of 9.0. The inflation savings, which is not always considered in accelerated construction justifications, can be considerable as illustrated in Figure 10, which shows the highway construction index (HCI) moving average versus the consumer price index (CPI) from 1990 through June 2015. The HCI began to outpace the CPI around 2005 and has continued to accelerate at a greater rate since then.

Costs of Improvements:		
Construction	$ 1,402	
Right of Way	$317	
Utility Relocation	$325	
Design and Program Management	$266	
Administrative Costs	$111	
TOTAL	**$2,421**	
Costs of Accelerated Schedule:		
Cost of Utility Relocation Associated with Accelerated Construction		$75
Cost of Contractor Incentives Associated with Accelerated Construction		$61
Cost of Funds		$173
TOTAL COSTS OF ACCELERATED SCHEDULE		**$309**
Benefits from Accelerated Schedule (2009-2015):		
Time Savings		$789
Fuel Savings		$289
Returns to the Economy (calculated at 12% return based on FHWA study)		$1,810
Construction Cost Inflation Saved		$168
TOTAL BENEFITS OF ACCELERATED SCHEDULE		**$2,767**
TOTAL BENEFITS OF ACCELERATED SCHEDULE LESS COSTS		**$2,458**
Benefit/Cost Ratio		**9.0**

Figure 9. Costs and Benefits of Accelerated Construction.

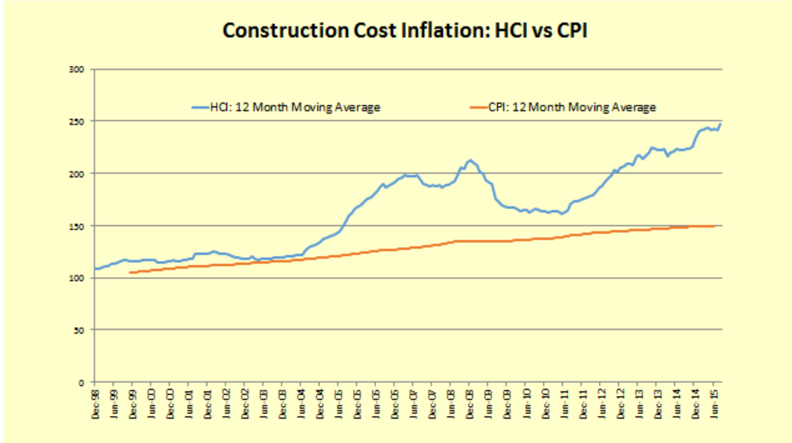


Figure 10. Construction Cost Inflation: HCI versus CPI.

The economic case for accelerating construction can be made if there are substantial savings in time lost and fuel wasted due to congestion under normal construction practice. For the Katy Freeway, the reduction in user costs was over $1 billion. Furthermore, according to FHWA, the returns to the economy are on the order of 12 percent or over $1.8 billion just due to the improvements made. A further consideration should be made to account for the time value of money (inflation) saved for accelerating construction versus normal construction times.

Congestion Mitigation in Work Zones – Tim Lomax

Economic growth is desired to maintain a prosperous society and that growth generally occurs with increasing demand for facilities to carry people, services, and goods from one point to another. Roads and bridges provide the transportation for the vast majority of passengers and freight. However these facilities need to be repaired, replaced, and upgraded with sufficient funding to continue providing efficient movements. Without funding, deteriorating roads and insufficient capacity can lead to increased crashes, congestion costs, and vehicle damage eventually leading to a functional failure of the transportation system especially in metropolitan areas. However, if funding is not used efficiently or if the repairs and construction require prolonged periods in busy corridors, public support for infrastructure improvements becomes jeopardized. Although infrastructure improvements typically cost anywhere from hundreds of thousand dollars to billions of dollars, the amount borne by individuals must be put in perspective. For instance, where the average Texan pays around $130 per month for internet, phone and cable TV and $140 per month for cell phone service, they typically pay $22 per month for highways.

Accelerated construction is one part of the solution to taking care of roads and bridges while minimizing the disruption of peoples' lives, but it requires a strategy. Public engagement is a key component to getting buy-in by explaining the long-term benefits of closing down more of the road and reducing the overall time for work zone. Designing the project and scheduling the work to accomplish this takes careful planning and review to remove obstacles and achieve the desired quality. Careful planning of the congestion mitigation will entail examining multiple scenarios and making sure that the benefits outweigh the potential costs. During the execution of the work, plans need to incorporate monitoring programs so that congestion and other negative effects are properly addressed.

Engaging the public from the preconstruction planning through the execution must be done frequently to maintain support for the project. The public needs to understand and support the improvements and the benefits of an accelerated construction schedule even if there are periods of greater inconvenience. Meetings and communications need to take place in communities, on social media, and in the local press. Frequent public meetings allow the community to express its feelings about the project and provide a forum to receive input and ideas at all levels including decision makers, community and business leaders, residents, and travelers. All need to understand the expectations and how success will be measured.

The variety of methods used to engage the public needs to include a full-spectrum of media and levels of interaction. For large projects, having a project website with updates and alerts, as shown in Figure 11, allow travelers to check on conditions before they use the road and updates on social media alert them while they are at work, shopping, or leisure. Going to neighborhoods and workplaces allow a greater involvement by reaching out to those who may not be able to attend public meetings. The messages need to be simple and easy-to-understand by most users. The engagement needs to fit all sizes of meetings and all demographics. The outcomes need to be the focus and having some measure of progress will resonate with people. These can include percent completion, products and services delivered, project changes, and customer satisfaction.

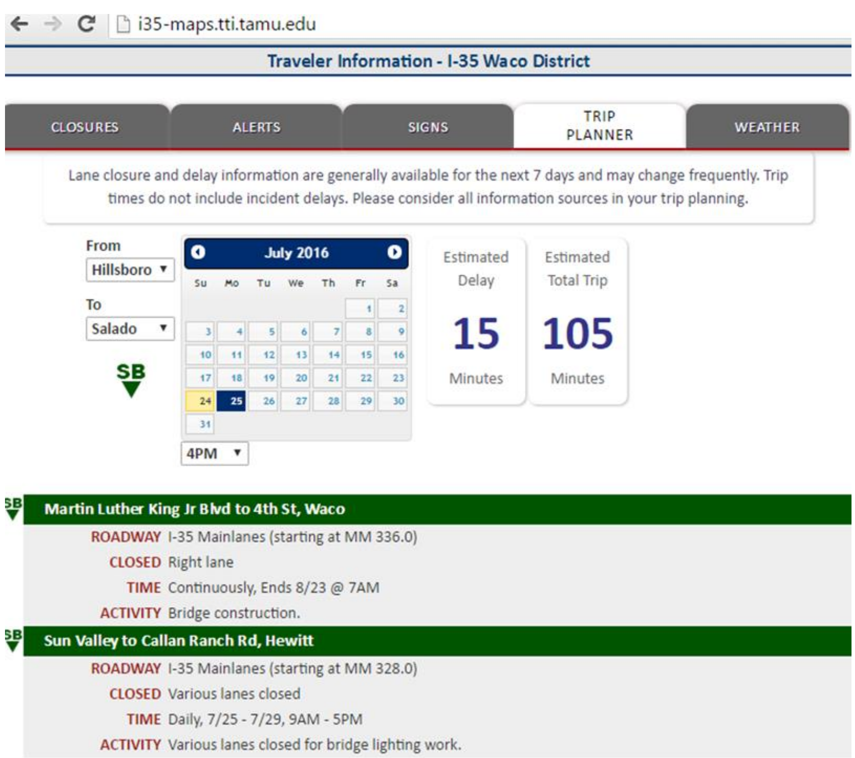


Figure 11. Page from Project Website for I-35 Corridor.

For large, complex projects, the engineering design and construction scheduling must be done simultaneously. A constructability review and operational traffic analysis of the project should follow to ensure an optimal flow of work to increase production and minimize user inconvenience. At this stage, the public should be made aware of the justification for the project, the proposed design, the timeline and milestones for each phase and the total project, and the expected outcome. The cost of the project to the community should be discussed in terms of the impact of accelerated construction versus conventional construction on users, businesses, neighborhoods, commuters, and shippers. Compelling input from the public should be used to modify scheduling of various phases recognizing that there may be diverse opinions on the outcomes. In the end, the discussion should identify risks relative to community effects, safety and cost, and the features of the project, which will mitigate these.

An example of accelerated construction with congestion mitigation was the reconstruction of I-64 in St. Louis. Using conventional means, the project was scheduled to last from 6 to 15 years, but with a design-build approach, it was completed within 2 full years. In order to accomplish this, the work zone closed one-half of the corridor length in each year. Congestion was eased, relative to initial expectations, because the regional network had an excess of traffic capacity. The traffic management plan included contingencies for incident responses, the use of a traffic management center for monitoring and adjusting traffic flow, and public outreach. The project was completed $11 million under budget and several weeks ahead of schedule.

The traffic management plan during construction must account for the construction schedule by arranging methods to improve detours ahead of time so that excess capacity will exist to handle traffic. The project planning and design must account not only for the construction of the facility but also all the supporting facilities that may be needed. Alternative designs need to be considered in terms of their impact on the scope, scale, and phasing. During construction, constantly monitoring speed and volume data on the project and adjacent roadways will allow for real-time displays and reports to inform travelers of conditions and options. Measures of traffic performance are necessary to adjust work zones and timing. These include project completion updates and lengths of lane closures, queue lengths and duration, travel delay and travel time, excessive queues, and percent of travelers encountering queues. These should be reviewed regularly and help to make informed decisions concerning adjustments during construction.

Each construction project is unique and requires its own congestion mitigation plan, but in the end, it all comes down to ensuring demand, capacity, and expectations are aligned. Depending upon the site and local conditions, there may be limited opportunities to increase capacity, but some strategies could include:

- Adding lanes to adjacent roads.
- Using managed lanes and pricing elements.
- Improving transit operations and fares.
- Increasing the use of telecommuting, flexible work hours, ridesharing, and other trip reduction strategies.
- Improving intersections and removing bottlenecks.
- Maintaining efficient construction access to work zones.
- Using temporary reversible lanes or shoulders.
- Considering parking, land use, and other influencing factors.

The goals should always be to improve safety and reliability. These can be accomplished through collaboration between the agency, contractor, businesses, commuters, and neighborhoods. Some of the key strategies to consider are having a rapid incident response, changing signal operations, establishing traveler information systems, maximizing the potential of travel and work options, maintaining queue warning and dynamic merge control, and accounting for special events.

Resources to help with work zone traffic management include:

- FHWA: www.ops.fhwa.dot.gov/wz/about/about_us.htm.
- National Operations Center of Excellence: www.transportationops.org/.
- TTI Policy Center: tti.tamu.edu/policy/congestion/how-to-fix-congestion/.
- *Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*, National Cooperative Highway Research Program (NCHRP) Report 574.
- Several state DOTs including Minnesota and New Hampshire.

Work Zone Safety – Gerald Ullman, TTI

Work zone safety is closely tied to the traffic management used on road and bridge construction projects. Conceptually, the effects of accelerated construction are illustrated in Figure 12. Typically, one of the outcomes of road construction is the reduction of crash rates, such that the after-construction rate becomes lower than the before-construction rate. However, during construction, there is generally a risk of increased crash rates, and doing nothing more than accomplishing the construction faster will reduce the total number of additional crashes that occur.

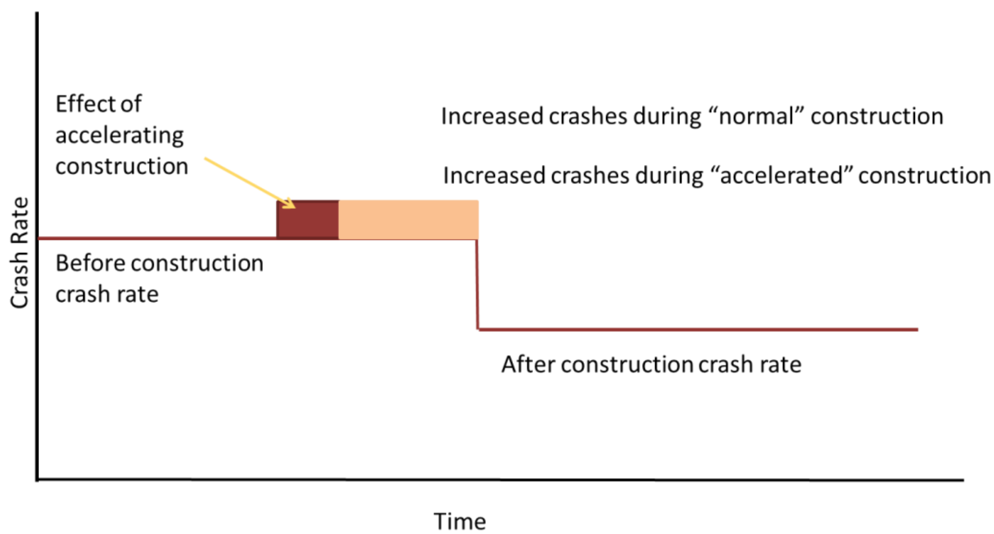


Figure 12. Illustration of the Potential Impact of Accelerated Construction on Crash Rates.

The impact of various types of work zones on the traveling public is shown in Figure 13 where the increase in crash risk is relative to the absence of work zones. There is a general increase in crashes going from inactive work zones to active work zones without lane closures to work zones with lane closures for either daytime or nighttime conditions. Nighttime closures result in greater risk than daytime closures except in the case of active work zones with lane closures. In instances where the work zones create traffic queues, there is a much higher incident of crashes as shown in Figure 14. The implication of these graphs is that the effect of accelerated construction upon safety depends not only on the reduction of time achieved but on the traffic handling strategy that is required to accomplish that reduction in time. For example, if techniques are used to simply reduce the number of inactive days that occur on a project, fewer crashes would indeed be expected to occur. However, if the reduction in time was achieved by closing a lane rather than maintaining the same number of lanes during construction, one would need to compare the relative increases in crash risks between the no-lane closure versus lane closure strategies *and* the change in duration achieved, since a work activity with a lane closure condition results in a greater increase in crashes than a work activity without a lane closure condition.

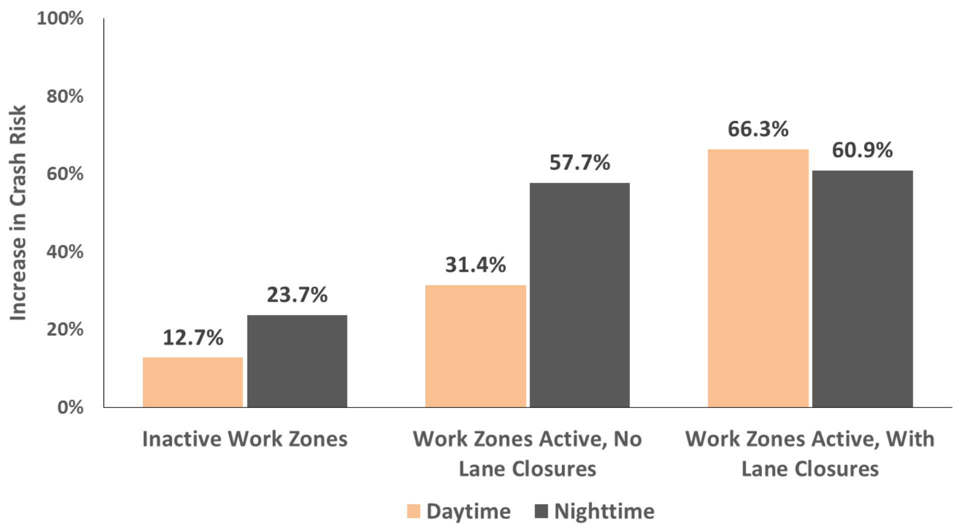


Figure 13. Impacts of Various Types of Work Zones on Crash Risk.

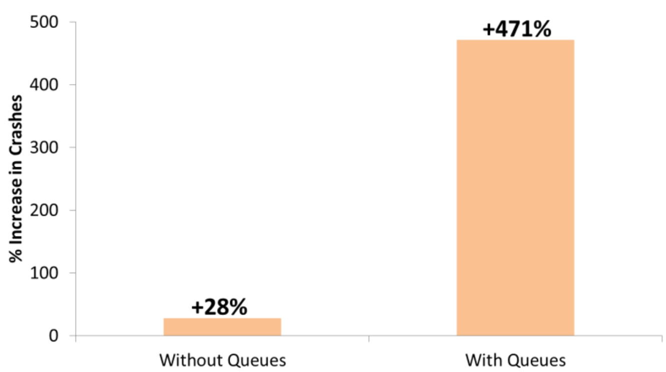


Figure 14. Impact of Lane Closures on Crashes.

Accelerated construction is also likely to have a safety impact upon worker safety. Highway worker fatalities generally varied between 100 and 170 per year on a national level and between

8 and 20 per year in Texas. While the causes of these deaths vary, Figure 15 shows that half are due either to motor vehicle crashes or being hit by a motorist. In fact, the latter cause was the single largest responsible for worker fatalities.

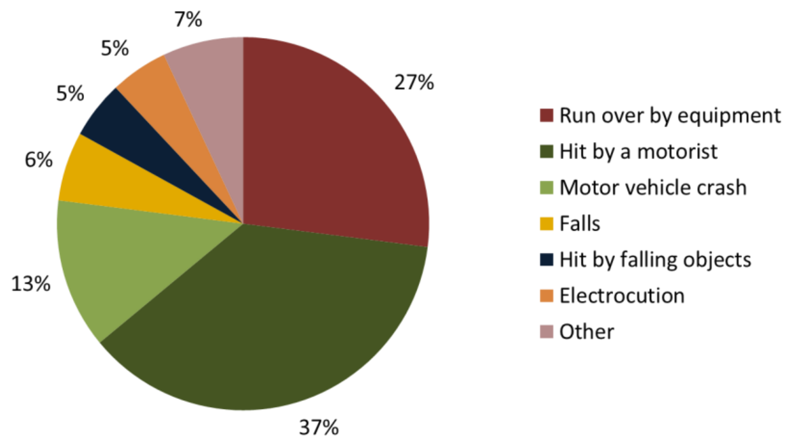


Figure 15. Types of Worker Fatalities.

Accelerated construction poses additional risks to the construction workforce. Fatigue can occur due to working longer shifts and disrupted sleep patterns in the case of night work. In addition, construction workers find themselves trying to accomplish the same tasks at night with limited visibility as they would during the day. This takes greater concentration and care, and can result in even more rapid onset of fatigue, which is difficult to monitor and detect. There is also an increased reliance on monitors, sensors, and other electronic displays on equipment and handheld devices. The more complicated the readings and analysis of the information are, the greater the chances are for distraction, and the effects of this distraction could likely be the same as those of impaired driving.

Traffic management plans and contractor safety plans are of great importance in mitigating risks to workers and the motoring public. The traffic management is important in establishing separation of workers from traffic through timely lane closures and the use of positive protection, the use of traffic enforcement, and the use of technology. Contractor safety plans should include internal traffic control plans and worker training. The set up and repositioning of the work zone as the construction progresses help keep traffic flowing smoothly. The selection of barrier types is also important along with the caution that barriers reduce the severity of crashes, not the frequency. Active enforcement may be warranted in situations where excess speeds have been noticed in the work zone. Traffic calming enforcement uses a parked law enforcement vehicle to remind motorists to obey the speed limit and drive more safely. The ability to position the enforcement vehicle to impact behavior is a key to effectiveness, and there needs to be an agreement between the project staff and enforcement on the expectations. The use of technology may take the form of real-time traveler information broadcast on a radio and signs warning of a queue ahead. New technology is expected to be available in the near future in the form of access point warning systems and intelligent intrusion alarms. Contractor internal traffic control plans (Figure 16) are important to keep operations moving and ensuring that adequate room exists to accommodate all operations. Work zone safety training is available to all through the National

Work Zone Safety Information Clearinghouse. This is an especially effective tool for raising awareness among workers and providing contractors with training resources.

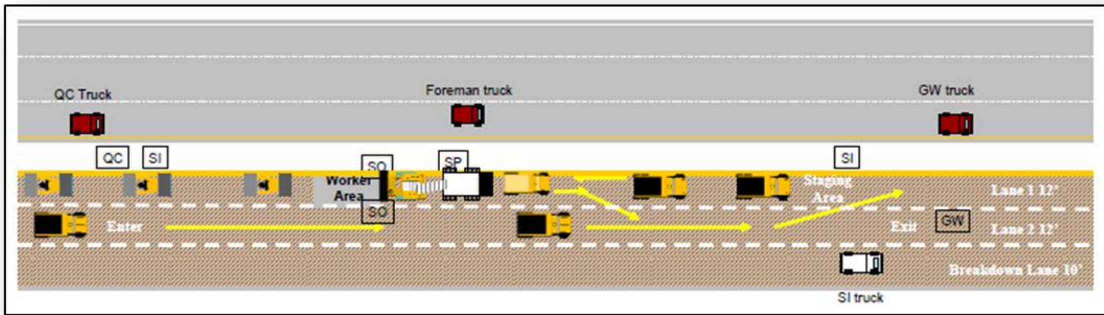


Figure 16. An Example of an Internal Traffic Control Plan.

There are gaps in the knowledge for work zone safety that need to be addressed. The effects of work zone traffic safety measures on non-freeway projects need to be measured. The relationship between available work space, work intensity, and worker injuries needs to be defined. A rational framework for balancing traffic space and work space needs to be developed. The effects of crash mitigation measures on detour and alternative routes need to be studied. Finally, there is a need for the identification and evaluation of distraction countermeasures.

Project Delivery and Construction Methods – Stuart Anderson, TTI

This presentation focused on how project delivery methods and construction methods influence the speed of construction. The project delivery methods include design-bid-build (D-B-B), construction manager/general contractor (CM/GC), and design-build (D-B). Construction practices can have a dominating influence on project duration, and the choice of tools and techniques is critical to accelerating the construction process.

The selection of project delivery method requires a number of considerations including the project goals, timing of delivery method selection, the degree of experience the parties have with the method, the tools available to execute the work, and appropriateness of the method. The availability of funding to use incentives for accelerating the pace of work also needs to be a factor in selecting the method used for project delivery. Figure 17 shows a comparison of the traditional D-B-B versus alternative CM/GC and D-B approaches.

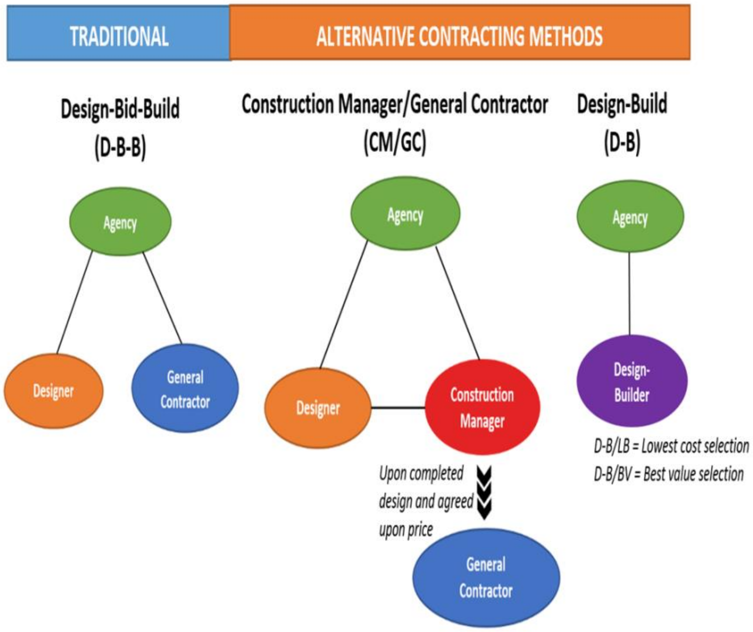


Figure 17. Comparison of Design, Bid, Build with Alternative Contracting Methods.

The D-B-B procedure has the agency either performing or directing the design of the project and then separately contracting for construction. In this approach, there is little opportunity for the contractor and the designer to communicate in order to discuss scheduling and constructability issues. Moreover, the sequence of design and construction is linear with no overlap. As a result, the D-B-B process usually requires the greatest length of time for project delivery, and the acceleration of construction can only be accomplished through a modification of the work periods available to the contractor, the use of aggressive milestones, and the use of incentives to finish the project early.

The CM/GC approach, sometimes known as Construction Manager at Risk, allows for an overlap of the design and construction, which shortens the delivery time. The agency contracts with a design firm to prepare plans and a construction manager to coordinate with the designer and contractor. The construction manager works with the contractor to identify and address constructability issues. As the design progresses, the planning and scheduling of the construction are done. After the design is substantially complete, the contractor delivers the project at an agreed upon cost. Communication is a primary focus in the coordination of the CM/GC approach, and incentives are traditionally used as a means of accelerating construction.

The D-B approach to construction is done either on the basis of low bid (D-B/LB) or best value (D-B/BV). Of these two, the best value method is used more often. As with the CM/GC method, there is an overlap between the design and construction, which shortens the delivery timeframe. Here the agency contracts directly with the D-B team, which is usually comprised of one or more engineering firms and one or more contractors. This is often done as a joint venture company set up specifically for the project at hand. The contractor and designer are in constant communications from the beginning of the project to the completion. Innovation is fostered as a result of the close working relationship and the integrated project team is very focused on delivery.

In the past, the vast majority of road and bridge construction projects were accomplished by the traditional D-B-B method, but recently this has changed. Figure 18 shows that D-B-B was used less than half the time in the 284 projects reviewed for a survey. D-B/BV was used 27 percent of the time and D-B/LB was used 14 percent of the time, meaning the D-B method was used in 41 percent of the projects. The CM/GC approach was used in 12 percent of the cases. Thus, it appears that the use of the alternative contract approaches is becoming more common.

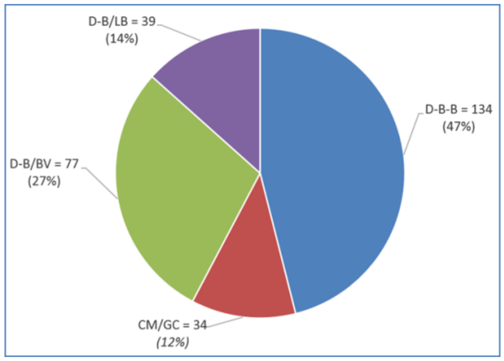


Figure 18. Results of Survey on Contracting Methods.

For projects where accelerated construction is one of the chief objectives, the schedule will dictate the construction practices. As discussed before, an integrated project team is crucial to communications and the resolution of conflicts. Detailed planning and updating is crucial to accomplishing milestones. From the beginning of design, the selection of materials and logistics of removal and delivery must be considered. The demolition and removal of existing structures is one of the most time consuming activities that occur in highway construction. Strategies that incorporate as much of the existing structures as possible should be considered. The methods for moving materials and components into the work zone, and, if needed, temporarily storing them should be integrated into the planning and design of the project. The work zone area needs to be large enough to accommodate movements into and out of the project without delays. This usually involves multiple lane shut downs and excellent coordination with traffic management, and a number of projects has shown that public awareness is crucial to successful traffic management and construction integration.

Personal interactions among the project team are important for good communication and cooperation to keep the schedule on track. Thus, efforts in partnering to gain commitment to the project from all team members are a necessity at the beginning of the project. During the project, it is important that all the participants are co-located near the project to facilitate communications. The goals must be the driving force for the commitment to partnering. Decision making and conflict resolution should be accomplished at the lowest possible level to avoid unnecessary delays.

While team communications are paramount in facilitating decisions and planning, others such as material suppliers, fabricators, and equipment manufacturers need to be constantly updated on the status of the construction and any changes in scheduling. Contingency planning should always be a part of project discussions and all members of the team should be aware of the uncertainties and remedial actions. Concurrent activities should be identified and planned to prevent cross-interference.

Traffic management and public awareness are very important to a successful accelerated construction project. Public and work zone construction traffic management must be properly handled so that the construction may proceed as smoothly as possible. Sharing the schedule for the construction and traffic control with the affected communities and publicizing times of restricted access will help alert motorists when they should avoid the construction area and possible detours they may take.

There are a number of delivery methods that may be used in the construction process, and while D-B-B has been used most of the time in the past, alternative methods such as CM/GC and D-B are becoming more commonplace. It is important to have a cooperative team approach to design and construction of accelerated construction projects. This allows for the greatest amount of innovation, communication, and speed in accomplishing the construction goals. The project team not only includes the designers and contractors, but also material suppliers, fabricators, and equipment suppliers. The public, community leaders, and motorists all need to be aware of the project goals, schedules, and traffic control methods. Each project is unique in its characteristics and objectives and requires its own planning. Accelerating project delivery requires a holistic approach to ensure success.

The following are suggested references on the topic of accelerated construction:

- NCHRP study on *Guidelines for Selecting Strategies for Rehabilitation of Rigid Pavements Subjected to High-Traffic Volumes*, 2002.
- FHWA study on *Traffic Management Studies for High Volume Roadways*, 2006.
- NCHRP study on *Selection and Evaluation of Alternative Contracting Methods to Accelerate Project Completion*, 2008.
- NCHRP *US Scan Report on Best Practices in Accelerated Construction Techniques*, 2009.
- FHWA study on *Quantification of Costs, Benefits, and Risks Associated with Alternate Contracting Methods and Accelerated Performance Specifications,* 2016 (publications in final FHWA review).
- NCHRP study on *Strategic Program Delivery Methods*, 2016 (on-going).

Case Study of Pavement Construction – John Harvey, UC Davis

The California Department of Transportation (Caltrans) has developed a multifaceted approach to the accelerated construction of long-life pavements. They use optimized pavement designs and thicknesses to minimize the construction time. Continuous closures and full-directional closures are used to maximize production and construction times. Detailed traffic planning is conducted ahead of the project, and constant traffic monitoring and adjustments are used during construction to minimize user inconvenience. These traffic control steps are used in conjunction with broad and frequent public updates and the use of alternative transportation to help the public during the disruption.

In general, long-life pavement design and accelerated construction may seem to work at cross purposes. Long-life designs are usually associated with the removal and placement of thick layers of materials, which would logically take longer to construct than thinner pavement sections. However, taking advantage of the existing material by leaving as much in place as possible and the advantage of advances in materials such as the use of polymers and quick setting cements, it is possible to reduce the time to build roadways. Construction operations are usually more efficient if short overnight work windows are avoided in favor of longer work periods such as 55-hour weekend or 72-hour weekday options. There needs to be good coordination between pavement design, construction engineering, and traffic engineering to make accelerated construction possible.

The Northridge Earthquake of 1994 provided the impetus for accelerated construction in California. The earthquake severely damaged four bridges on the Santa Monica Freeway. The loss of these bridges was estimated to cost the California economy approximately $1 million per day. The contract was let for $14.9 million with a completion time of 140 days. The contractor could earn a bonus of $200,000 per day for early completion, and the contractor finished 74 days ahead of schedule. The success of this project had to do with the application of innovative materials in the form of fast setting concrete for ramps, full closure that was unavoidable, and the schedule incentives that were justified due to the economic impact.

Caltrans has adopted three long-life pavement rehabilitation strategies for concrete and asphalt sections. For existing concrete sections, either a crack and seat of the concrete with a thick overlay or a remove and replace with concrete are used. The concrete rehabilitation option may be done with either a rapid setting (4 to 15 hr) concrete mix or precast slabs. There is also a remove and replace option with full-depth or partial-depth asphalt structure. Strategies that leave as much of the existing pavements in place have the greatest chance of being successful in accelerated construction.

An example of an accelerated project for concrete was a remove and replace project on I-10 east of Los Angeles in 2000 (Figure 19). The rehabilitation encompassed a 1.75-mile lane replacement in a 55-hour window over a weekend. Fast-setting concrete, a movable concrete crash barrier, a back-up concrete plant, and concurrent operations in the work zone were all features that allowed for quicker construction. At least 1-1/2 lanes were to be available for traffic at all times and the road needed to be opened within 4 hours if the traffic delay became too long. The lessons learned from this project were: 1) adequate trucking is needed, 2) each concurrent operation needs its own dedicated lanes, 3) traffic back-ups occur in both directions, and 4) materials need to be simple and predictable in their behavior.

Figure 19. Lane Reconstruction on I-10 in California.

Phase 1 of the reconstruction of the I-710 freeway in Long Beach is an example of accelerated road construction with asphalt. The existing pavement was 8 in. of jointed plain concrete pavement over 4 in. of cement treated base and 12 in. of aggregate base. For all portions of the freeway that were not subject to height restrictions due to overpasses, the existing concrete was cracked and seated, and for the portions with overpasses, the material was removed to the subgrade. The cracked, seated, and overlaid (CSOL) portions had an 8.2-in. thick asphalt pavement placed on top of the concrete. The full-depth asphalt concrete (FDAC) had 6 in. of new aggregate base followed by 12 in. of asphalt mixtures. Both sections had a 1-in. open-graded friction course placed on top that was underlain by 3 in. of a highly polymer modified mix. A standard dense-graded mixture was used below this. The FDAC section had a special fatigue-resistant mix at the very bottom of the asphalt pavement. If conventional materials and designs had been employed, the total asphalt pavement thickness would have been 21 in.

The construction operations of I-710 (Phase 1) employed some novel approaches. The MultiCool software, developed by the University of Minnesota, was used to estimate the rates of cooling for the asphalt lifts to establish when the mixtures would be stiff enough to support traffic. One of the important aspects of this construction was that the pavement design had two simple cross sections. This repeatability allowed the contractor to become more efficient with time on the job as illustrated in Figure 20, which shows that both the FDAC and CSOL construction productivity increased significantly over the eight weekend closures.

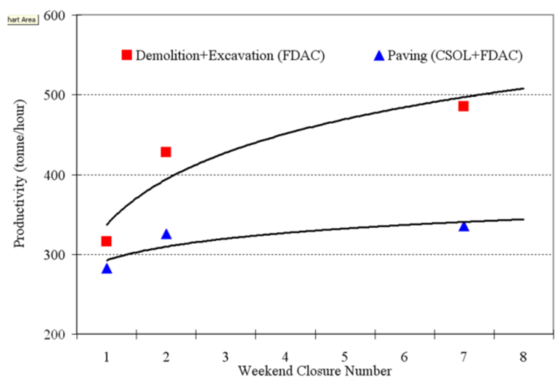


Figure 20. Construction Productivity Improvement on I-710 (after E.B. Lee).

During 55-hour weekend closures, the contractor had complete access to one whole side of the freeway (Figure 21). The shoulders were upgraded to allow traffic in two directions in the active roadway. This allowed two lanes in two directions during construction and, as with the I-10 project, a moveable concrete barrier was used to divide traffic on the active roadway portion. The contractor was eligible to receive a $100,000 bonus for each weekend less than 10 weekends and subject to the same level of disincentive for each weekend greater than 10. Additionally, there were hourly disincentives if the full freeway was not opened on time on Monday morning. The asphalt mixtures were subjected to performance testing for mix design and during construction gradation, asphalt content, and in-place density were used for pay factors.

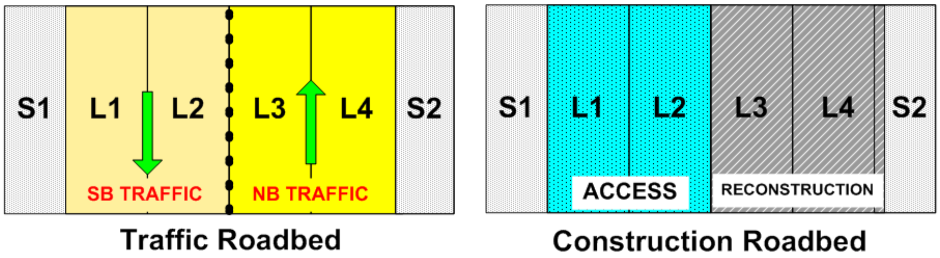


Figure 21. Full Closure Facilitated Construction Operations and Traffic.

The traffic management plan for I-710 was key in the reduction of traffic through the work zone during the eight-weekend duration of the project. A combination of adequate alternative routes and public awareness efforts provided information that local governments and road users could reference to ease congestion during construction. Because of these actions, the average daily traffic and peak hourly traffic flow on the freeway during the work weekends was reduced by 35 to 40 percent. An accelerated construction software tool, CA4PRS, was used to model the work progress and traffic flow. Using this approach allowed Caltrans to maximize the production, minimize construction time, and significantly reduce user impacts.

A number of construction related lessons were learned from Phase 1 of the I-710 project:

- The pre-bid conference should be mandatory for all interested bidders.
- New performance-related test procedures are now available, but work is needed to reduce the testing and reporting time and standardization is needed for consistency.
- Human resources need to be considered to avoid fatigue and other personnel issues.
- Contractor should select closure locations to allow for the best efficiency.
- Timely weather information is important for contractor operations.
- Contingency planning is extremely important to allow for unforeseen changes in materials, equipment, traffic, weather, accidents, work force, etc.
- Use of repetitious tasks in construction led to noticeable productivity improvement over the course of the project.
- Financial incentives are effective in accelerating the project completion.
- Pay factors are useful to encourage material quality and workmanship.
- The roadway is performing as expected.

Traffic management lessons from this project included:

- Allowing the contractor to provide recommendations for staging.
- Spending extra money to incentivize early completion and helping local governments make improvements on alternate routes.
- Working with local governments on issues such as:
  - Changing traffic light timing, restriping of lanes and intersection reconfigurations.
  - Increasing transit capacity.
  - Providing more police officers on parallel routes and at intersections.
  - Making arrangements with emergency services to maintain access.
  - Making arrangements with major employers for flexible hours, telecommuting, transit incentives, and communication.

- Having the contractor provide hour by hour scheduling.
- Maintaining a central traffic command during operations.
    - Use of continuous monitoring and messaging.
    - Providing daily teleconferences (all stakeholders, contractor, Caltrans, employers, public safety).
    - Providing 24-hour look-ahead and progress update.
    - Then giving the information to the media.

Summary

This portion of the workshop provided the participants with background information on how accelerated construction is affected by economic decisions, traffic control, work zone safety design, and contracting practices. Two case studies on road and bridge accelerated construction discussed construction methodology and highlighted technical innovations that contributed to minimizing user inconvenience. Common threads between these presentations and those in Chapter 2 from the concrete and asphalt paving contractors are:

- The economic considerations for accelerated construction must include the agency costs, user costs, costs to businesses, time value of money, and benefits of the completed construction. Incentives for early completion of projects may be justified by the reduction in public and business costs, and incentives are a primary motivator for contractors.
- Congestion mitigation plans will be unique to each project but the goals for traffic management should always be to improve safety and reliability. This requires collaboration between the agency, contractor, businesses, commuters, and neighborhoods. Advanced notice of work, public meetings to discuss construction phasing, real-time notifications, and clearly defined alternate routes will help minimize traffic disruptions.
- Work zone safety is closely tied to the traffic management used on road and bridge projects. During construction, there is generally a risk of increased crash rates, and doing nothing more than accomplishing the construction faster will reduce that risk. The use of moveable barriers has a proven benefit to adjusting work zones quickly to minimize mobilization time and react to unusual situations. There is a need to understand the relationships between traffic management, work zone access, safety measures, and construction speed.
- Alternative methods such as CM/GC and D-B are becoming more commonplace as rapid construction becomes more the rule than the exception. It is important for the construction team to have a cooperative and integrated approach to design and construction. To the extent possible, innovation should be encouraged along with communication and speed in accomplishing the construction goals. The project team not only includes the designers and contractors, but also material suppliers, fabricators, and equipment suppliers.
- The case study of the I-710 freeway in Long Beach, California, brings together many of the features discussed above. The use of project level software to tie traffic management and construction productivity provides useful information for optimizing the construction schedule. There is a need to better understand the causes and remedies for worker fatigue in accelerated construction schedules. It is also important to productivity to use repetitious tasks as much as possible to preclude constant learning curves on the project.

ACCELERATED AND INNOVATIVE BRIDGE CONSTRUCTION IN WASHINGTON STATE: PROMISING TECHNIQUES, CASE HISTORIES AND THE FUTURE – JED BINGLE

Accelerated bridge construction (ABC) provides the potential for a number of benefits. These include improvements in site constructability, total project delivery time, and work-zone safety for the traveling public. At the same time, ABC reduces traffic impacts, on-site construction time, and weather-related time delays. Several ABC techniques are available. These include:

- Prefabricated bridge elements/systems.
- Self-propelled modular transporters (SPMT).
- Lateral slide or slide in bridge construction.
- Geosynthetic reinforced soil – integrated bridge systems (GRS-IBS).

Precast bridge elements and systems are sometimes described as LEGOs® for bridge engineers. These precast elements include girder/slab elements that can accelerate bridge superstructure construction. Precast deck panels have been gaining popularity with the use of ultra-high performance concrete (UHPC) connections. For example, full width precast deck panels that are shop fit-up and then longitudinally post-tensioned in the field are being used. The use of UHPC (up to 25 ksi) allows reduction in the width of connector regions due to improved bond. Modular beams with precast deck elements are also be used to accelerate bridge construction. These prefabricated elements can include beams, diaphragms, deck, and traffic barrier elements. They are constructed off-site with survey control, erected, and then closure joints are cast. Bridge bents, which include the columns and crossbeams (or bent caps), have also been precast, along with footing, pier, and abutment elements. Precast substructure elements used by WSDOT include precast column segments with grouted ducts and precast crossbeams elements with grouted ducts or a pocket connection for each supporting column. The column-to-cap beam connection using a grouted duct for each individual longitudinal column bar was developed by the University of Washington (UW) and University of California at San Diego for Seismic Design Categories A, B, C and D. The same universities developed a pocket connection detail that uses a single void created by a corrugated pipe in the cap beam to encase all the column bars extending into the cap beam. Additional research recommendations developed at UW has been adopted for precast footings and shafts.

SPMTs have a number of useful features for ABC. SPMTs typically have a remote controlled—self-leveling—multi-axle platform. They are able to transport several thousand tons of weight, while moving laterally (rotating 360°) and with a vertical stroke of 18 to 24 in. This allows contractor to build bridge spans off-site, which can have several benefits including minimizing traffic disruption, improving work zone safety in the bridge staging area, and improving constructability in the bridge staging area. An appropriate staging area location with access to the bridge site is very critical to the success of using SPMTs to move the bridge spans into place.

Lateral slide or slide in bridge construction refers to an ABC technique where a new bridge superstructure is constructed adjacent to the final bridge location on temporary supports, the existing bridge structure is demolished, and the new bridge is moved transversely into place. An example project is the lateral slide of the Northeast 8th Street Bridge over I-405.

A geosynthetic reinforced soil–integrated bridge system is typically a single span bridge. The superstructure consists of a precast voided or slab superstructure with an asphalt overlay having a subsurface on the slab and approach. The superstructure is supported on the soil with a spread beam. The abutments can include modular block facing with soil reinforcement, a precast fascia with structure earth wall, or a cast-in-place (CIP) or precast fascia with a geosynthetic fabric wall. The benefit of this system is that it is simple to build.

Recent WSDOT ABC projects include 16 projects during 2000–2015. Among them are several precast crossbeam projects, several precast column projects, and a precast shaft cap/coffer dam. The I-5/US 12 Grand Mound Bridge included precast column segments with grouted ducts supporting a precast crossbeam with a grouted duct connection to each column.

SR 433 Lewis and Clark Bridge is a $27M truss bridge rehabilitation project that took place in 2003. The project used SPMTs and a specially design lifting truss to remove a section of old deck panel and then replace with new deck panel sections. The construction included three weekend closures, 120 8-hour night closures, and 200 single lane closures (SLCs). In addition, incentives and disincentives were used to drive the construction schedule. The incentives included $100,000 if all closures were complete by a specific date, $55,000 per weekend bridge closure (WBC) less than four (the contractor used three), $4,000 per total bridge closure (TBC) less than bid, and $1,000 per SLC less than bid. Disincentives included $16,000 per TBC more than bid, $4,000 per SLC more than bid, $1,700 per 15 minutes beyond time specified for TBC and WBC, and $900 per 15 minutes beyond time specified for SLC. The contractor earned a bonus of $185,000 for early completion.

Two WSDOT lateral slide bridge projects were highlighted. In 2013, the I-5 Skagit River Bridge had a span collapse occur due to vehicular impact with a lateral sway frame. The solution included erection of a temporary span consisting of a side-by-side dual lane modular truss span. A 27-day closure with detour was required prior to opening the temporary span. The temporary span was in place for 208 days. The permanent span was constructed adjacent to the temporary span and consisted of a prestressed deck girder span with lightweight concrete. The temporary bridge was laterally slid off the supports and then the permanent bridge was laterally slid into position. This operation required a one-day closure. During closures, 71,000 vehicles were detoured through the local city streets. The SR 167 Puyallup River Bridge involved replacing a Warren Truss with a conventional bridge. The truss was laterally slid and then used as a temporary bridge during construction of the replacement bridge.

Ongoing research related to ABC was also highlighted. Concrete filled steel tubes are being studied at UW, including ABC connections. The steel tube eliminates the need for formwork and a reinforcing cage and self-consolidating concrete can be cast on site. This approach can be used for both columns and shafts, is lighter than precast columns, and can be integrated with other precast bridge elements.

UW and Washington State University are developing wide flange deck girders with UHPC connections. The girder depth can be up to 8 ft 7 in., having a top flange width ranging from 4–8 ft and a top flange thickness of 3 in. or 6 in. This wide top flange allows a side-by-side arrangement of the girders that can include a welded/grouted connection between 6-in. flanges and a 1.5-in. concrete overlay for low Annual Average Daily Traffic (AADT roads, or a UHPC connection with 6-in. flanges for ABC projects. The 3-in. flange can be joined with a welded/grouted connection and then a 5-in. CIP concrete topping is added for typical projects. Span capabilities can be up to 225 ft (or 250 ft with lightweight concrete) for a 4-ft wide flange having a 3-in. thick top flange and a 5-in. CIP topping.

Additional areas of current research noted include development of precast rocking columns at UW using unbonded post-tensioning strands. The intent is to enable rocking to reduce damage and improve serviceability. In addition, the University Nevada-Reno is developing shape memory alloy and engineered cementitious composites materials for columns. The materials are intended to improve the seismic resilience of and serviceability of columns by minimizing residual drift, reducing plastic hinge damage, and dissipating energy.

Resources that provide additional information about accelerated bridge instruction include:

- Accelerated Bridge Construction – University Transportation Center.
    - Project and research database.
    - Monthly webinar (case studies, research, etc.).
    - National Accelerated Bridge Construction Conference, including archives (2014 and 2015) and upcoming conference in Miami (December 7 and 8, 2017).
    - Website: abc-utc.fiu.edu.

- FHWA Publications – can be downloaded online.
    - *Accelerated Bridge Construction Manual* (FHWA-HIF-12-013).
    - *Manual on Use of SPMT to Remove and Replace Bridges* (FHWA-HIF-07-022).
    - *Connection Details for Prefabricated Bridge Element Systems* (FHWA-IF-09-010).
    - *Precast Bent Systems for High Seismic Regions* (FHWA-HIF-13-037-B).
    - *GRS-IBS Interim Implementation Guide* (FHWA-HRT-11-026).
    - *Design and Construction of Field-Cast UHPC Connections* (FHWA-HRT-14-084).

- Industry and WSDOT.
    - SOAR on Full-Depth Precast Concrete Bridge Deck Panels.
    - WSDOT Bridge Design Manual Ch. 14 Accelerated and Innovative Bridge Construction.

INITIAL BREAKOUT SESSION

Introduction

In order to get the participants thinking in terms of accelerated construction, they were divided into groups to discuss particular road and bridge construction scenarios. The groups were provided information on the objective of the project, traffic conditions, right-of-way characteristics, and structural features. Their charge was to identify choke points in the project, discuss how to overcome these, and how to accelerate the schedules. After meeting in individual groups, the participants gathered for a general discussion of all the scenarios. The scenarios and ideas are presented below.

Exercise A: Pavement Strengthening – Moderators Lisa Lukefahr and Chuck Fuller

Problem Description

In this exercise, the focus was on rapid rehabilitation. There was an existing 11-in. thick asphalt pavement on a high volume (2-direction, 4-lane, 48,000 AADT), urban freeway in good structural shape that needed surface defects removed to a depth of 3 in. and either a 4-in. asphalt overlay or 6-in. white topping. Shoulders were to be brought up to grade and include a 10-ft outside and 4-ft inside shoulder. There was a 30-ft wide grass median. Current distresses were limited to top-down cracking and minor wear in the wheel paths. The peak traffic hours will be Monday–Friday 6:30 a.m.–9:00 a.m. and 4:00 p.m.–6:30 p.m.

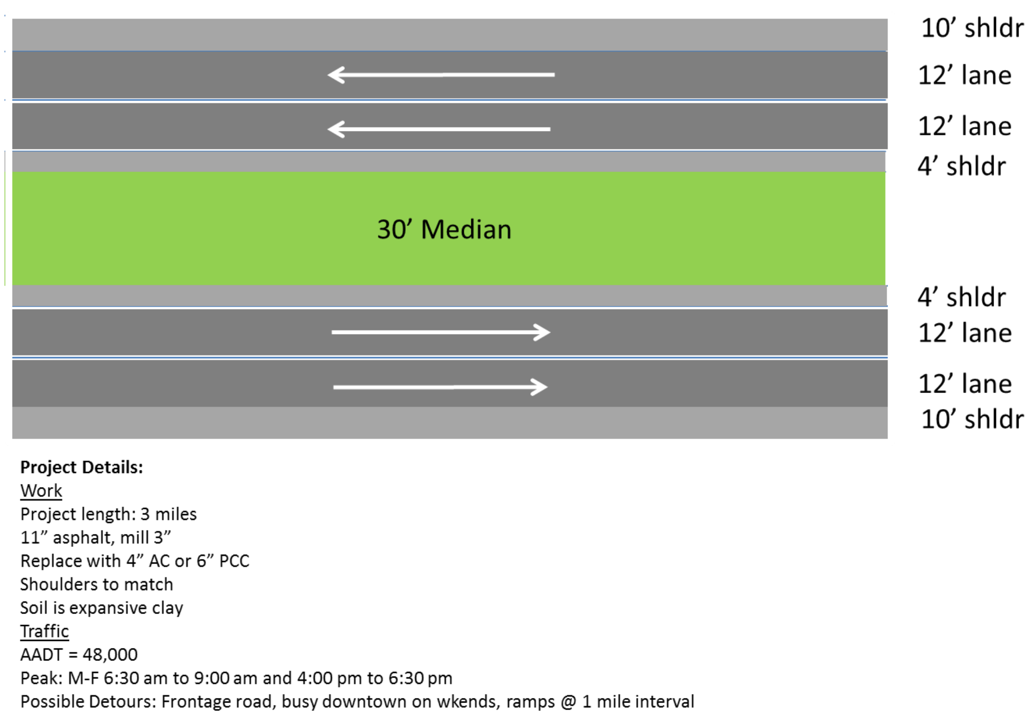


Figure 22. Workshop Exercise A: Pavement Strengthening.

Discussion

The group considered accelerated construction for this pavement strengthening according to the following strategies: 1) better materials, 2) better design, and 3) better traffic control plan. The key issues were that preconstruction engineering evaluations should be conducted, contractors needed incentives to complete projects quickly and that better communications were needed between different TxDOT offices (e.g., pavement, construction, and traffic).

They believed that an extensive preconstruction site investigation is warranted to include a ground penetrating radar (GPR) evaluation in order to identify subsurface conditions. If the existing pavement had been Portland cement concrete, the GPR would not be as effective and another means would be needed. Group A stated that the GPR surveys are not used as widely as they should be, especially in rural districts.

Incentives to contractors to finish early were seen as a prime motivator for the industry. However, disincentives were not considered to be as effective. They recommended that agencies consider incentives any time that the cost of delays are greater than the cost to the agency. The calculation of user delay cost could be the index for screening projects.

Better communications are needed between the various agency divisions involved in the construction project. For instance, the traffic engineer needs to know from the construction engineer the number of lanes to be occupied by the contractor during construction. This helps establish the work hours to maximize production and minimize user impacts. The pavement engineer needs to coordinate the design with the construction engineer in order to ensure that the design is simple and straightforward, and the construction engineer needs to understand the impact of construction procedures on pavement quality to ensure long life.

Possible barriers to rapid construction were discussed. The organizational inertia to keep doing what has always been done could prevent venturing into accelerated construction. An overly complicated design could nullify acceleration efforts. A lack of alternative routes would also be a hindrance in that more lanes would need to be open on a continuous basis. Also the presence of critical services of hospitals could be affected by continuous shut-downs.

The group offered other suggestions to speed up the construction of the rehabilitation. One of these was to mill to a deeper depth so that drainage and overhead clearances could be maintained along with removing the need to adjust the height of the shoulders. Another possibility was reducing the amount of surface milling depending upon the depth of the surface distresses and adjusting the thickness of the overlay accordingly since the scenario indicated that the damage was minor wear and top-down cracking.

If nighttime closures were used for this project (9:00 p.m. to 6:00 a.m.), then the milling and overlay could have a production rate of 1 lane-mile/night. However, issues that might occur would be that the asphalt mixture might cool too quickly leading to lower density than daytime placement, and if unforeseen issues occur, there would be a limited amount of time to deal with these before opening to traffic. Some options that could occur would be to close one direction and provide a temporary crossover, move all traffic to the frontage road (time reduction approximately 50 percent), or widen the shoulder and use it as an additional lane.

Traffic control could be the deciding factor for speeding up construction. Agencies tend to be overly cautious with the traffic control plan where some calculated risk and careful planning could result in faster construction, shorter risk exposure, and save money. If the incentives are great enough the contractor may be able to devise innovative traffic control plans within some set guidelines. Better communications with the public can lead to a better through-flow of traffic by discouraging short trips through the work zone. Safety studies need to be conducted because while shorter work windows might reduce the number of accidents within single windows, the total number for the construction might be increased.

Exercise B: Pavement Widening – Moderator: Jon Epps

Problem Description

This was capacity-building on a suburban interstate. In this case, the existing pavement was an 11-in. jointed plain concrete pavement over 4 in. of asphalt base with concrete shoulders. The additional lane was to be added to the inside of the roadway to avoid having to rework the ramps. After the widening, there would be no room for further lane additions to the inside of the roadway. Trucks would be prohibited from using the inside lane. A minimum pavement thickness of 8 in. of asphalt over 6 in. of flex base or 8 in. of concrete over 4 in. of asphalt base could be used. The existing road is a 2-direction, 4-lane facility with an AADT of 50,000 vehicles. Peak traffic hours are Monday–Friday 6:00 a.m. to 8:30 a.m. and 5:00 p.m. to 7:30 p.m. Weekend traffic tends to be heavy but not congested.

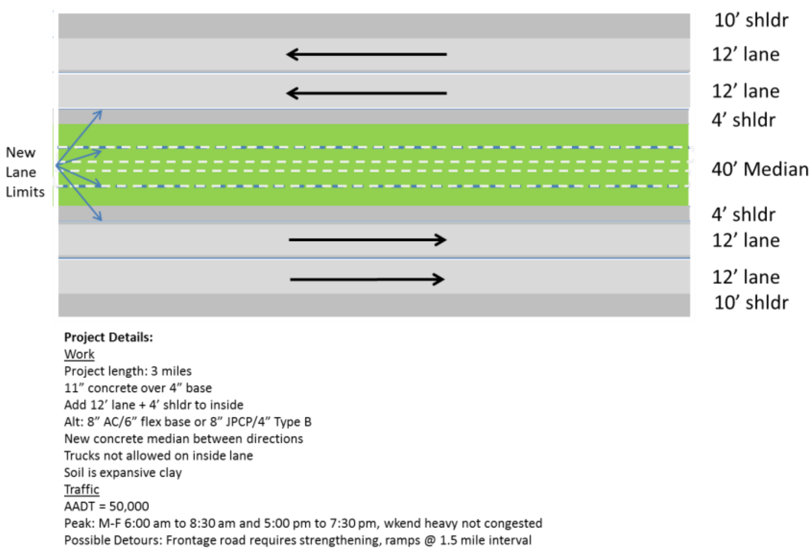


Figure 23. Workshop Exercise B: Pavement Widening.

Discussion

There are a number of risks inherent in accelerated construction beginning during the planning and continuing through the project completion. Careful evaluation of the project needs to be done to ensure that it lends itself to rapid construction. Realistic goals need to be set for the project scope in terms of time. Identifying any potential phasing needs to be done at this point so that it can be included in the design. Possible disruptions, such as weather events like hurricanes or manmade events such as social or sports activities, need to be accounted for up front.

The decision to use accelerated construction should be made during the planning phase and carried through design and construction. A central command/management war room should be established for a presence from each of the major parties in order to make timely decisions and adjustments. A recovery plan needs be in place at the start of construction and revised frequently to reflect detailed scheduling by day and week. This would help identify potential problems and solutions ahead of time rather than reacting to circumstances.

The best approach to contracting was the A+B+C method for incentivizing contractors to complete the project ahead of schedule. The contractor needs to understand the time implications in terms of the existing workforce and the availability of resources. It should be understood whether utilities will be moved prior to construction or during construction. The expectations for working days needs be clearly defined (e.g., 3-weekday 24-hour shutdowns versus night work versus 55-hour weekend closures). Public information should be used to the fullest extent possible to minimize traffic during the construction work windows. The impact of contracts should be evaluated in light of the bonding and insurance required.

Communication is a key component to the success of the project from the beginning. A careful constructability review ahead of bidding should be conducted to help identify and potentially fix problems early. The construction sequencing should be as simple and repetitive as possible. This allows a learning curve to build and the construction to become more efficient. The agency needs be open to value engineering as a way to bring innovation and greater speed to the project. For accelerated projects, it was essential to have high quality, error-free design documents. Thus, the amount of money spent on the design should reflect the expected cost and importance of the project.

Cost considerations include the type of traffic, structural section, and vertical and horizontal controls. Computation of user costs needs include the impact of construction on freight traffic and passenger vehicles. The total cost of the project needs to be considered in terms of the construction plus user and non-user costs. Although it would add cost to the construction, the added lanes, although exempt from truck traffic, should have the same structural capacity as the rest of the road in case more widening is needed in the future. Another issue affecting the cost of the construction is whether the existing overhead bridges have the needed vertical and horizontal clearance to allow the added lanes. The use of 3-D modeling with machine control should be used to aid in ensuring the proper elevation and alignment of the resulting pavement.

Exercise C: Rural Intersection Reconstruction – Moderator: Charles Gurganus

Problem Description

This was an at-grade intersection of a 4-lane divided highway and a 2-lane road with a traffic signal. The speed limit was set at 60 mph. The intersection was 4 in. of asphalt over 6 in. of flex base. Investigation has revealed that the reconstruction needed to include removal of the existing surface and flex base to a depth of 8 in. and replaced with 8 in. of concrete or asphalt. Detours would result in an additional 15 miles of travel around the work zone. The road had an AADT of about 20,000 vehicles on the 4-lane road and about 5,000 on the 2-lane road. Peak traffic occurred from 6:30 a.m. to 7:30 a.m. and from 6:00 p.m. to 7:00 p.m. on weekdays. Traffic was increased on the 2-lane road during the weekend as a popular lake was located on it.

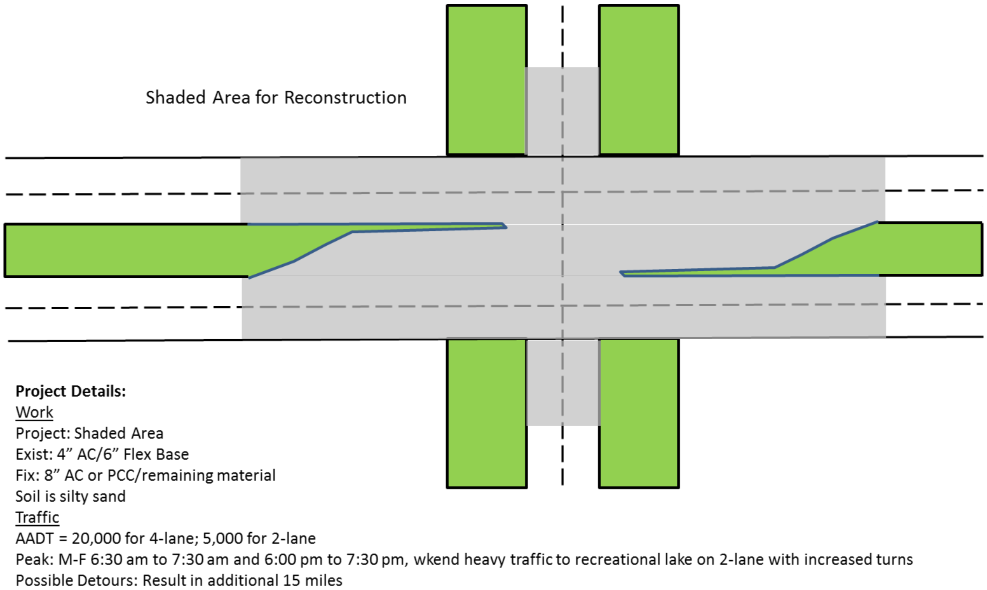


Figure 24. Workshop Exercise C: Rural Intersection Reconstruction.

Discussion

Three different methods of accelerated construction were considered for the reconstruction of the rural intersection:

1. The use of precast concrete for intersection construction.
2. Shift traffic to one side, reconstruct the closed side, flip traffic and do the same to the other side.
3. Never move traffic, but close an entire side and reconstruct. Once complete, close the other side and reconstruct.

The group settled on Option 3 as the option with the best constructability, minimal impact to traffic, better safety advantages, and most likely the technique that could complete the intersection most quickly. Each option is briefly discussed below.

Option 1: Precast Concrete Intersection Construction

The use of precast concrete panels to reconstruct the intersection initially seemed to be an attractive option. The panels could be constructed offsite, so there would be no impact to traffic. One issue with this type of construction is the amount of subgrade preparation required. While the use of concrete panels might eliminate the need for subgrade stabilization, leveling of the underlying layers would be necessary for an acceptable finished product. The group felt that the amount of leveling required would be similar to the amount of work for subgrade stabilization. Furthermore, traffic handling during leveling and concrete panel installation was possibly more challenging than pursuing a flexible option.

Option 2: Shift Traffic and Build in Phases

The type of construction described for Option 2 is very similar to the construction for Option 3, the primary difference is in the traffic handling. In Option 2, traffic is shifted to one side of the roadway so that the intersection remains completely open. One side of the intersection is rebuilt, then traffic is switched onto the new construction and the other side of the intersection is rebuilt. The traffic switches require a detour that could be built with minimal impact to traffic. Construction of the pavement section requires stabilization of the subgrade, followed by multiple lifts of hot mix asphalt (HMA) placement. All parties need to be in agreement on when the stabilized subgrade could be trafficked with construction equipment. This is particularly important for acceleration. The chemical stabilization quantity needs to be such that the construction of the HMA overlay could begin almost immediately following stabilization. Allowing this quick turnaround and working 24 hours per day allows the intersection to be rebuilt in a work week. The drawbacks to this method are safety and traffic related. The primary safety concern comes with taking rural high speed traffic and placing opposing traffic adjacent to each other. This could be offset with the use of barrier between traffic, but that would consume time and slow construction. Traffic switches also consume time that would be better spent working on the pavement. It is likely the traffic switches would take the better part of a day, essentially creating 1 to 2 days of traffic impact that could be avoided with Option 3.

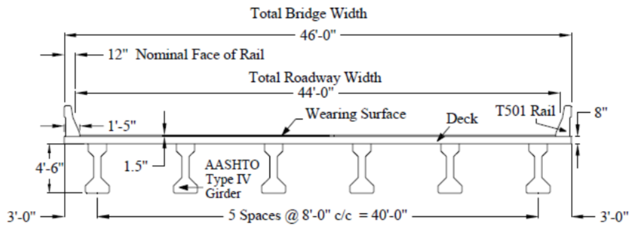
Option 3: Close One Side and Rebuild in Phases

The construction is the same as Option 2, but in this case, one direction of traffic is completely closed. When this is done, the group felt one side of the roadway could be completed in two days. Therefore, each direction of travel is impacted for only two days. This is accomplished by avoiding a traffic switch, which also presented safety advantages by not changing traffic patterns and behavior in a rural setting. The drawback to this is the long detour, but the group felt that with adequate public relations and the knowledge that using the detour will be minimized to a couple of days, this option is the safest and fastest.

Exercise D: Standard Bridge Overpasses – Widening Medium Span Bridges and Solutions for Replacing Short- and Medium-Span Bridges – Moderator: Mary Beth Hueste

Problem Description

The first part of this exercise focused on widening an existing bridge to add more lanes for increased capacity. The setting was a suburban area where some detours may be needed. It was assumed that peak hours were Monday–Friday 6:00 a.m.–8:30 a.m. and 4:30 p.m.–7:00 p.m. The existing bridge consisted of medium-span lengths (80–120 ft) with simply supported prestressed concrete I-girder construction. The deck is CIP reinforced concrete with precast concrete stay-in-place forms and an asphalt overlay. The discussion was expanded to discuss alternatives and challenges for full replacement of short- and medium-span bridges.



Project Details

The first part of this exercise focuses on widening an existing bridge to add more lanes for increased capacity.

- Setting
  - Suburban area.
- Existing bridge
  - Medium-span lengths (80-120 ft).
  - Simply supported prestressed concrete I-girder construction. See figure for typical transverse section (girder type can vary).
  - Deck: reinforced concrete with precast concrete stay-in-place forms and an asphalt overlay.
- Traffic
  - AADT = 15,000
  - Peak is M-F, 6:30 - 7:30 am and 6:00 - 7:30 pm.

The discussion will be expanded to discuss alternatives and challenges for full replacement of short- and medium-span bridges.

Figure 25. Workshop Exercise D: Standard Bridge Overpasses – Widening Medium Span Bridges and Solutions for Replacing Short- and Medium-Span Bridges.

Discussion

Currently for TxDOT, a major impediment is considering rapid construction too late in the process. This limits the solutions available. TxDOT rehabilitates, replaces, or builds about 600 bridges per year, and this number is expected to increase to 750 in the coming years. However, it was suggested that filling out decision matrix forms may be too cumbersome if TxDOT only uses ABC 10 percent of the time. Note that 70 percent of TxDOT bridges are currently designed by consultants. TxDOT makes ABC tools available for contractors, such as precast bent caps (a current research project being conducted by TTI). TxDOT uses a decision matrix early on in the project to determine whether ABC methods should be used. WSDOT uses a planning tool developed by Oregon DOT.

Several issues were considered to accelerate construction in the case of a bridge widening project. The first was whether a total closure would be a feasible approach to reduce the construction time. TxDOT has typically been reluctant to consider total closure, but this could be an acceptable option if the total construction time is reduced. Public engagement would be useful to determine preferences. The current approach is often focused on informing versus engaging. The question came up as to how to best engage the traveling public? Some techniques include early warning of closures with signage and posting information at DriveTX.org. WSDOT has an app that is available to the traveling public.

Typical bridge replacements in Texas tend to include replacement of the substructure and foundation elements. In many cases, longer spans are required due to the need to increase traffic capacity for the lower roadway, which is being widened. In the case of deterioration, the foundation is often replaced because it is commonly affected by deterioration. On the other hand, most SPMT projects have been just to replace the superstructure.

Bridge widening projects typically include a CIP foundation with drilled shafts or piles and a CIP abutment wall. The substructure may be installed from the bridge, when the bridge is over water or when there is limited access at grade. The time required to complete a widening project in Texas is approximately nine months (50 percent for substructure and 50 percent for superstructure). With regard to actual widening, some specific steps include:

- Installing a temporary barrier connected to the deck with dowels.
- Breaking off the existing rail along the bridge edges.
- Installing foundation elements, columns, and bent caps. New bridge bents are connected to existing bent cap in the case of a single column addition.
- Setting girders, which are typically precast.
- Adding bedding strips to level the girders for installation of precast concrete deck panels.
- Completing the CIP deck, asphalt overlay, and installation of permanent barriers.

One area where time could be saved was in the removal of the existing rail. Typically the deck is partially cut near the centerline of the exterior girder to remove the rail. The existing concrete is removed and the deck bars remaining are cleaned and left in place to tie into the new deck pour for the expanded deck. This is a time consuming process and not having this demolition step could save significant time. It could be possible to remove only the rail by cutting the dowels at the base of the rail and leaving the deck in place.

An additional area to consider is the connection between the existing and new bridge deck for a widened bridge. Potentially UHPC could be used in the joint between the new and existing decks.

Precast full depth overhangs have also been researched by TxDOT in the past, including two demonstration projects. Precast full width decks have been used on the east coast. Both of these options could save time for both widening and replacement projects.

Current WSDOT developments include UHPC connections between flanges of side by side wide flanged girders. They are working on UHPC mixes with local materials that can be batched on site with a design compressive strength (f'_c) around 10 ksi (versus 25 ksi for true UHPC mix). WSDOT has also been conducting research on 103 in. deep decked precast girders. These girders can span up to 240 ft and are designed to be simply supported for dead load and continuous for live load. Going deeper with girders is not always an option; 54 in. and 62 in. are typical maximum girder depths for conventional bridges in Texas. Transportation limits are not typically is not an issue for girders, but curfews on shipping in the city limits and on toll roads cause difficulties in transportation.

Columns in TxDOT bridges are currently CIP concrete. In discussing whether precast columns would be feasible, some attributes of the WSDOT precast columns were summarized:

- Drilled shafts have reinforcement cages that extend above the shaft with an additional sleeve.
- Precast column with roughened concrete (notches) are placed in the sleeve of the drilled shaft and concrete is poured around it to connect the two elements. Note that a larger crane is typically required for placing precast columns.
- Concrete filled steel tubes can also be used for columns and drilled shafts. Research is currently being sponsored by WSDOT.

Crane operations are an important consideration because the cost of mobilization and time at the site can be significant. SPMTs offer an alternative for moving large loads, even bridge spans, into place with the possibility of a 360° turn. The number of SPMTs is based on the weight that needs to be distributed during transport. In addition, a staging area is typically required near the bridge site to construct large elements and then move them into place.

Conventional construction methods were considered versus innovative construction. If total closure time is less, then indirect costs can be significant. An additional approach is to use alternative contracting methods that promote an accelerated construction schedule. Risk to the owner can be reduced through contracting methods. Design/build allows contractor to innovate on how to accelerate the project. Currently, this method is limited in TxDOT to $250M per year of design/build contracts with not more than six projects per year.

There are examples of ABC in Texas. In Fort Worth, the West 7th Street Bridge kept the existing bridge in place during staged construction. Limited total closure was used and arches were moved into place using SPMTs.

The group discussed reducing risk and how to limit exposure. Comments included that safety risk increases with more people on site and heavier equipment. Also, when using total span replacement there is one closure versus multiple closures, which is less confusing for drivers. Finally, eliminating the need to contain traffic reduces risk.

Some areas for improvement included planning and education. The planning process should consider accelerated construction early in the project. Typically this needs to be determined at the district level. For ABC education, the Bridge Division has knowledge available, but information needs to get to district level where the early decisions should be made about whether to accelerate a project.

Some possible research needs for TxDOT were discussed. These include developing UHPC mixes. One application could be for overlays to improve durability. Life cycle costs may show that this is more economical despite the initial cost. UHPC could also be used for precast girders including pre-topped I girders (similar to pre-topped double Ts in commercial construction). This could eliminate deck panels. Thicker flanges could be ground down at the site, similar to what is done in New York. In addition, self-consolidating concrete could be investigated for use in CIP decks. The recent Precast Concrete Institute Summit identified needs for innovation and new product development, including cross-sections that lend themselves to ABC.

Exercise E: Major Interchange Construction Requiring Long-Span Bridges – Moderator: John Mander

Problem Description

This exercise focused on the addition of overpasses to improve traffic flow in areas where several major roads were intersecting. An example was the High Five north of downtown in Dallas, where US 75 and I-635 intersect, with a five-level interchange now constructed. Assume that peak hours are Monday–Friday 6:00 a.m.–8:30 a.m. and 3:00 p.m.–7:00 p.m. Access was limited due to the urban setting and high traffic volume. Potential bridge types and construction approaches, along with other measures needed to address quality, mobility and safety were discussed.

Project Details

This exercise focuses on addition of overpasses to improve traffic flow in areas where several major roads are intersecting. An example is the High Five north of downtown in Dallas, where US 75 and I-635 intersect, with a five-level interchange now constructed. Potential bridge types and construction approaches, along with other measures need to address quality, mobility and safety will be discussed.

- Setting
  - Urban area
  - Access is limited due to the urban setting and high traffic volume.
- New Bridge Spans
  - Medium Spans (80-140 ft) and Long Spans (180-240 ft)
  - Girder types can vary depending on radius of bridge and span length
- Traffic
  - AADT = 50,000
  - Peak is M-F, 6:00 - 8:30 am and 3:00 - 7:00 pm.

Figure 26. Workshop Exercise E: Major Interchange Construction Requiring Long-Span Bridges.

Discussion

The discussion of research needs for ABCs for larger viaducts principally centered around two inter-related research questions:

1. How to reduced or completely remove certain time-consuming construction activities from the job site in the field so they can be conducted off-site in factory-like conditions?
2. How can certain other activities be removed or avoided entirely from the on-site construction process?

The discussion focused from beneath the ground and upward in the order a bridge would normally be constructed.

Deep Foundations

Most foundations for large bridges in Texas and elsewhere consist of deep drilled shafts. The holes for the shafts are normally augured. While this exercise is difficult to speed up, what is built within and above the shaft may vary considerably depending on the soil conditions.

- Status quo method. A rebar cage is placed within the drilled shaft cavity and concrete poured.
- Potential future alternative approach. Is the rebar cage really necessary? Perhaps not. As an alternative way to speed up the construction, it may be possible to use a steel tube as a shaft liner, which is infilled with concrete. Only a limited amount of reinforcing may be necessary near the very top. Some reinforcing may be a necessity near the head of the shaft to connect into the foundation footing/pile cap system.

Footing/Pile Cap Placement of footings can be laborious and time-consuming due to the construction of formwork and the installation of rebar cages.

- Status quo: Construction methods mostly use formwork, followed by placement of a rebar cage and the casting of concrete. If stiff soils exist, the formwork need not be used and the concrete may be cast directly against the soil.
- Potential future alternative approach: Use a hollow reinforced or prestressed concrete shell system. The structural concrete shell is fabricated off-site, then shipped to the construction site and placed around the protruding heads of piles/shafts. Infill concrete is then poured within the cavity. In this way, the site placement of the rebar and formwork removal can be avoided.

Bridge Columns

This is one of the slowest and most laborious construction site activities for the entire bridge structure, especially for tall bridges and flyovers.

- Status quo: Construction methods for most short and tall bridge columns consist of reinforced concrete. There are normally four key tasks for this activity: First, tie and place the rebar cages. Second, install the formwork. Third, cast the concrete [note several lifts may be needed for tall columns]. Fourth, remove the forms. Furthermore, there is normally a one-month stand-down period until the CIP column concrete strength can be certified as conforming to contract specifications. Overall, for most bridges, the duration of this activity is in excess of three months.
- Potential future alternative approach: One of the most promising prospects for accelerating bridge construction is to take the column construction activity to an off-site location. Precast columns may be used; this presents the opportunity of using higher strength/performance materials, leading to further economy. Moreover, the pre-certification of the concrete prior to its arrival on site is a key factor in the construction acceleration process.

When precast columns are used, they may be constructed using either reinforced (RC) or prestressed concrete (PSC). Whether the columns are RC or PSC depends on the nature of the column-to-cap (or footing) connections. RC lends itself to wet concrete or grouted joints where a limited amount of site concrete is cast within the wet column-to-cap connection.

On the other hand, PSC lends itself to having partially pretensioned prestressed concrete columns with post-tensioned connections that form a dry jointed column-to-cap connection. While this class of bridge pier may be built very expeditiously, it relies on tight precision at the location of the connecting elements. Such a prefabricated system may be intolerant of accidental misalignment. Therefore, special care is needed in developing adjustable connection details that are cost effective.

For tall bridges, the gross weight of precast column units becomes a limiting factor. To mitigate the dimensional limitations due to weight, two approaches may be adopted. First, hollow columns may be used, leading to a weight saving in the order of 50 percent. However, for large or tall columns this may not be sufficient. Therefore, segmental column construction may be used whereby column units are stacked and then post-tensioned together.

Another alternative for accelerated column construction is to use concrete filled steel tubes. However, that considerable concrete volumes may still need to be poured with the only saving in the placement and removal of the formwork and some rebar cages.

A significant concern for tall columns is the aesthetics. One advantage of pre-casting is that aesthetic treatments can be embodied within the purpose-built formwork used at the pre-casting plant.

Cap Beams

The existing precast systems commonly use wet joints in the form of either grouted ducts or larger diameter concreted pocket connections.

- <u>Status quo:</u> Bent caps have historically been, and predominantly remain, CIP. However, in recent years there has been a partial move to using reinforced concrete cap beams. Currently, there is a desire to change from precast reinforced concrete caps to using some of the advantages of pretensioned prestressed concrete.
- <u>Potential future alternative approach</u>: One method to further speed up construction would be to use post-tensioned dry joints. While this has already been conceptually verified with some limited laboratory tests dating back some 20 years, there has be little uptake due to perceived difficulties. This topic remains a fertile area where progress can be made through further research and development.

Superstructure

Although improvements have been made to the installation of bridge decks there remain numerous opportunities for speeding up the deck construction process.,

- <u>Status quo:</u> When compared to former times where total CIP construction prevailed for bridge decks in Texas and elsewhere, there now exists a reasonable degree of accelerated construction. For example, bridge girders are either fabricated steel girders, or precast prestressed concrete. When concrete girders are used, the deck commonly consists of stay-in-place half-depth precast prestressed concrete panels. Only the upper half of the deck slab is reinforced and CIP.
- <u>Potential future alternative approach</u>: A key approach to further speeding up superstructure construction is to improve the details by removing entire trade activities. One approach would be to use pre-topped decks such as double-tee systems. A drawback of such an approach is the significant weight that is added in the process of adding a full

top flange to each individual girder. This limits the long span lengths presently possible when shipping girders alone.

An alternative approach is to modify the pre-casting of the deck-slab units. Instead of using small half-depth panels that are prestressed transverse to the bridge axis, longitudinal prestressing could lead to much longer deck panels, especially if they are thickened. Therefore, by using thicker full-depth panels, 55-ft (or longer) units could be developed that also embody all required deck reinforcement, both longitudinal and transverse. By using longitudinally prestressed panels, the transverse reinforcement that is required over the top flange of the prestressed concrete girders can be cast into the panels. In this way, a normal 18-wheel truck could be used to ship the full-depth prestressed concrete units. No further rebar need be placed on site, only a final wearing surface be poured that integrates the deck-panels with the girders. This approach negates the need for any on-site steel placement, removing a laborious and slow construction activity from the bridge site. This concept has already been explored, by design, by Texas A&M researchers.

Another area where time and cost savings can be made is to move away, wherever possible, from using wet joints that are used to join together precast concrete elements. Instead, dry jointed assemblies that are connected by applying an appropriate measure of PT prestress should be adopted. Naturally, there will be additional costs associated with precision of unit manufacture by the precaster, but it is considered that these costs would be by far outweighed by the on-site savings in time and effort. The dry jointed approach has successfully been implemented in segmental box-girder construction and could be extended to other precast connection types such as cap-to-column, longitudinal splicing of girder segments, and transverse splicing of deck segments.

Exercise F: Below Ground Level Grade Separation – Moderator: Tim Lomax

Problem Description

Constructing an underpass below a railroad presented an additional challenge to typical rapid grade separation construction—excavation while minimizing impact on railroad operations. This is the case at the intersection of George Bush Dr. and Wellborn Rd. in College Station, Texas. Right-of-way is limited and traffic volumes are relatively high (55,000 AADT with over 60,000 vehicles during school year) and special events with as many as 110,000 people occur periodically, so the opportunities for full closure during construction are diminished and the community impact is increased. It was assumed peak traffic hours were two hours in the morning and evening, there was some unused capacity on alternate routes, and traffic volumes were lower during the summer and the Christmas holiday period. The underpass will carry four lanes of traffic with a pedestrian/bicycle path. The intersection plays a key role in the local economy, serving many nighttime and weekend special events. What combination of design, equipment, personnel, contracting, traffic mitigation, demand management, and construction procedures can be used to construct this needed improvement while minimizing impacts to the traveling public, local community and railroad?

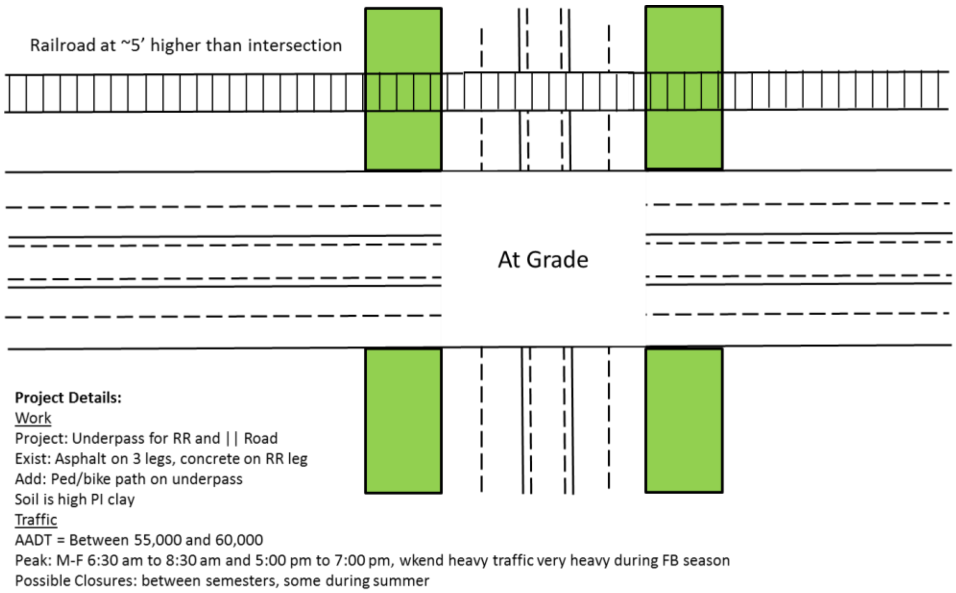


Figure 27. Workshop Exercise F: Below Ground Level Grade Separation.

Discussion

Long term, there is a need for grade-separation due increased vehicle, bicycle, and pedestrian traffic at this intersection. Also, special events around this intersection cause sudden surges in the traffic volume, which can take hours to dissipate.

Other construction projects needed prior to grade separation: improve capacity on alternate routes of FM 2818 and Penberthy.

Could a 3rd party design-build contract be used where Texas A&M would contract for DB? This would be similar to the intersection of Old Main and Wellborn where TxDOT signed an advanced funding agreement with a maximum amount. Time incentives are key to minimizing the construction time although it is a complicated construction process. If the project is accelerated, then it is unlikely that the preliminary plans will be kept.

For going under the railroad the staging operations would include:

1. Clear the right-of-way and deal with the utilities.
2. Build the north-south thoroughfare and shift Wellborn traffic
3. Dig north-south (Wellborn) ditch to George Bush.
4. Construct single-point urban interchange on Wellborn (elevated).

Elevated Options/Issues

- Phase 1: Construct Wellborn Rd. thoroughfare in the middle or outside of its existing path or as an elevated roundabout?

- Phase 2: On George Bush drill columns outside of the street to support overhead beams. Place the beams at night. Start near the middle and work outward until a 13.5-ft clearance on both sides of Wellborn. Use precast caps.
- Phase 3: Close George Bush and connect tie-ins to ramp up from ground level to already constructed elevated section

Design needs to address frontage roads and U-turn's on George Bush. Pedestrian ADA requirements need to be addressed. Maybe a diagonal crossing for the intersection would be the best choice since this is the expected route for most pedestrian traffic.
The benefits of an elevated interchange are:

- Time – likely a shorter amount of closure time.
- Less utility adjustment.
- Precast elements are easier to use.
- Less railroad interaction
- Lower user cost during construction.
- Can afford more aesthetics.
- Pumps are most reliable if they are not there.

Contractor will need to drill shafts for the retaining wall if the road goes under the railroad tracks, but still looking at spending three months to dig the hole.

RESEARCH AND IMPLEMENTATION NEEDS

Introduction

After the groups discussed their scenarios with the whole workshop, they reconvened to develop ideas for research and implementation needs. These ideas were combined and categorized as general, planning, contract methods, design, materials, construction, traffic management, work zone safety, and public awareness. These are presented below in a brief description along with an assessment of the urgency, timeframe, whether it is research or implementation, and the estimated cost. Table 2 in Appendix B presents a summary of all the research ideas.

General

Title: Develop Policy Roadmap for Rapid, Durable, Safe, and Construction

A policy roadmap needs to be developed to facilitate a cultural shift toward accelerated constructions. The roadmap will identify the current state and the goals, how fast we want to reach these goals, what might be the gaps and challenges, and how these challenges can be overcome. Thus, this will be a flagship research that will potentially open the door for more research studies. One of the aims will be to help the agency (TxDOT) develop some criteria for selecting projects eligible for accelerated construction based on economic and/or safety considerations. For example, Caltrans criteria for accelerated construction eligible projects were: ADT>150 000, truck>10 percent, and pavement costs>50 percent of the total project cost.

Urgency: Immediate
Timeframe: 1 year
Type: Implementation
Estimated Cost: $250,000

Title: Decision Tool for Accelerating Highway Construction

Accelerating the construction of road projects is useful in certain circumstances but may be overly costly in others. This effort would create a design-build guidance document and decision tree for properly selecting construction projects for accelerated scheduling. Accelerated construction is not simply using standard designs with shorter time frames. General guidance needs to be developed for traffic, design elements, contractor issues, materials, and resources. Using the project goals, a planning and design path needs to be developed that would result in the best strategies for completing the construction and minimizing user costs.

In the end, the decision for using accelerated needs to be based on economics. The question of how to make the case for selecting alternative finance methods would hinge on quantifying construction costs, the cost of inflation during construction, and user costs. The use of local tax increment reinvestment zones, local tolls, or other funding mechanisms might be more likely if the project could be finished sooner—the effect of improvements and early benefits.

Urgency: Immediate
Timeframe: 1.5 years

Type: Implementation
Estimated Cost: $150,000

Title: Best Practices and Benefits of Accelerated Construction Case Studies

This effort would result in a report that documents case studies for accelerated construction. The report would describe key elements and benefits, and its primary audience would be planners and designers.

These elements would be captured in the report:

- Early and consistent public engagement.
- Design charrettes that bring everyone together to discuss project scope and desired outcomes.
- What elements and aesthetic treatments are important?
- Realistic scheduling – more details are needed to show work flow and describe projects. AC attributes should include construction phasing; contractors should not be bidding liquidated damages into the job just because designers did not do their job.
- Material/methods/soil types and effect on schedule.

Urgency: Immediate
Timeframe: 1 year
Type: Research
Estimated Cost: $150,000

Title: Construction Engineering and Inspection (CE&I) Needs and Other Inspection Needs Associated with Unique Contracting

The expansion of CE&I use in TxDOT is rapid and growing. The training and expectation of the CE&I firms is not always well defined or carried out. The chain of command within the project and where the buck stops is not always clear. The decision-making timeframe is typically quite long. The expectations with testing, inspection, and payment are not always clear, particularly with bonus/penalty type items. The change order process is very slow.

This should be a research effort that starts with a synthesis of what is currently being done within TxDOT and highlights the differences that occur from project-to-project. There is a need to examine what is being done contractually and how it is being applied in the field. This needs to extend to what is being done nationally and how the decision-making process occurs. Further, there is a need to identify best practices and develop some standard operating procedures. This could evolve into a training opportunity for inspection services for CE&I firms. Additionally, is there a long-term research opportunity to compare TxDOT inspected projects with CE&I projects. This comparison should take place at multiple levels. One is the performance of the roadway, but another is the cost associated with the inspection.

Urgency: Immediate
Timeframe: 1 year
Type: Research and Implementation
Estimated Cost: $300,000

Title: Training and Knowledge Base for Construction Details

With turnover in TxDOT staff and the greater use of consultants the local and institutional knowledge is becoming more difficult to maintain. There is a need to create a way to capture this knowledge and pass it along. In order to accomplish this, a strategy for training young engineers and consultants on TxDOT processes needs to be developed first. Afterward, a training effort needs to begin and needs to be required of engineers working in TxDOT planning, design, and construction whether they are within TxDOT or with a consultant.

Urgency: Immediate and long term
Timeframe: 1 year for development
Type: Implementation
Estimated Cost: 250,000 for development, $100,000/year for training

Title: Introducing Innovation

There are disruptive technology ideas involved in accelerated construction, and there are ways to get these types of new processes into practice. There is a need for identifying and developing innovative elements and approaches that are not currently used but could be advantageous to accelerating construction. Ideas are needed for innovation and incentives are needed for their development. Approaches that could be used include contests, construction demonstrations, open houses, and vendor displays at conferences. A strategy needs to be developed; ideas need to be identified; interested manufacturers and contractors need to be identified; and suitable venues or projects need to be found.

Urgency: Intermediate
Timeframe: 1 to 2 years
Type: Implementation
Estimated Cost: $250,000 for initial effort

Title: Skilled Worker Labor Market Study

This is a more general topic that is equally pertinent to normal and accelerated construction. The education and qualifications of workers needs to be studied. Currently, most construction jobs involve equipment specific training, some safety training, and minimal educational requirements. As the sophistication of construction and inspection increases, so must the training efforts for workers. In order to create a better trained workforce, the educational resources need to be itemized and methods need to be developed to get the workers to attend construction related training.

Urgency: Immediate to Intermediate
Timeframe: 12 months initially, on-going afterward
Type: Development and Implementation
Estimated Cost: $150,000 initially, and afterward $250,000 per year

Planning

Title: Development of Framework for Accelerated Construction Projects

This effort would entail identifying lists of future project for accelerated construction, developing ways to encourage partnerships, identifying the equipment and labor force necessary, determining the economic justification, publishing a list of design-build projects, and determining the level of acceleration appropriate for different tiers of projects (i.e., rural, intersections, urban, freight corridor, or energy sector). In order to grow this initiative, there needs to be cultural change to planning, and this could be facilitated by holding workshops co-sponsored by TxDOT, the Associated General Contractors, the Consulting Engineers Council, and TTI.

Urgency: Immediate
Timeframe: 1 year
Type: Implementation
Estimated Cost: $200,000

Title: Best Practices in Partnering

Description: This implementation effort is directed toward providing guidance and structure to partnering efforts within the construction team and with the public and local governments. Guidance will be given on meeting topics, structure, and schedules and how these should be advertised. This guidance should be developed for the various stages in planning and design with how much information is needed, how much time to allot, standard agendas, and how to receive input.

Prebid meetings allow information exchange at a point when timely decisions could be made about planning, design, and construction phasing. This often constitutes a constructability review.

The pre-project partnering occurs during the design phase where contractors are engaged to assist with the constructability of design.

The post project award partnering deals with the interaction between TxDOT and the contractor and extends to subcontractors. Most of the issues at this point revolve around communications and timely decisions. It is important to minimize the decision-making time by resolving issues at the lowest possible level. Types of decisions need to be identified and the hierarchy for decisions should be developed to determine the best level for resolution. For instance, resolving segregation problems could probably be done at the inspector and paving crew level, problems with design would need to be resolved at a level of project manager and project engineer at a minimum, etc.

There needs to be a standardization of both pre-project and post-award project partnering. For accelerated construction, constructability is going to be a high priority, so contractors need to be involved on the front end. In the post-award process, expectations, time frames, and definitions of things like substantially complete must be made very clear.

Guidelines need to be developed for pre-bid and post-bid partnering and dispute resolution. The schedule of regular meetings and agenda items, the warrants for special meetings, and a dispute resolution chart need to be developed so that communications among the parties is treated as a priority.

Urgency: Immediate
Timeframe: 12 months
Type: Implementation
Estimated Cost: $75,000

Title: ABC Best Practices for Planning and Design

This effort would provide training to help determine which projects are suitable for ABC. A two-day education program with TxDOT bridge engineers, engineering consultants, general contractors, and precast engineers would be held. The workshop would include planning (determine which projects are suitable for ABC), contract methods, designing with ABC considerations, materials (pros and cons of materials used in ABC), construction methods, traffic management considerations, work zone safety, and public awareness strategies for ABC.

Urgency: Immediate
Timeframe: 1 year
Type: Implementation
Estimated Cost: $30,000. The Precast Concrete Manufacturers' Association of Texas noted an interest in organizing the workshop and that it would be possible to get sponsorships from other interested organizations.

Contract Methods

Title: Development of Contract Methods for Accelerated Construction

Guidance needs to be developed for the selection of contract types and conditions. Usually accelerated construction contracts are D-B or A+B+C. Design-build contracts are usually reserved for large, complex and time-sensitive projects where initial plans and schedules are developed to begin construction and then detailed plans are more fully developed for phases ahead of construction. For these projects, a time-frame is set by the owner with incentives for early completion and disincentives for late completion. Because the design is left to the D-B team, innovation can be used to accelerate construction and the designers and constructors can work closely on achieving the project goals in a timely manner. However, this approach also requires that much of the risk be borne by the D-B team.

A+B+C contracts usually have plans that have been developed by the agency with an anticipated schedule that has a dollar per time lane rental rate and incentives and disincentives for finishing the project either early or late. The incentives and disincentives can be very large in some cases, and there are questions on how to determine an appropriate payment schedule what type of cap should be placed on incentives.

In order to bid on D-B or A+B+C projects, contractors usually need to secure high-cost bonding due to the risk of not meeting schedules. This can reduce the contractor's ability to bid on other work as much of their bonding capacity is tied up in the large project. A study needs to be conducted to see how risks can be lowered in order to minimize the impact of large projects on the bonding capacity of construction companies.

Urgency: Intermediate
Timeframe: 1 year
Type: Implementation
Estimated Cost: $100,000

Design

Title: Develop Guidelines for Environmental Impact Abatement during Accelerated Construction Projects

Comprehensive guidelines for the design of temporary environmental treatments need to be developed for erosion and runoff control, air quality features, noise reduction, required permits, and portable plants.

Urgency: Intermediate
Timeframe: 2 years
Type: Implementation
Estimated Cost: $100,000

Title: Preconstruction Site Investigation and Documentation

Projects are sometimes let with relatively little information available on the existing conditions, which may have large impacts on time and change orders. The paucity of information often occurs due to the age of the project and lack of information. Project information concerning the existing pavement or bridge conditions are important considerations during bidding and a lack of information translates into increased risk. Information such as the depth of the water table, traffic characteristics, existing geometrics, pavement cross-section, and available workspace all need to be documented and available at the time of construction. This effort would result in the development of information to include in bid packets in order for contractors to make more informed decisions and possibly reduce their risks.

Urgency: Immediate
Timeframe: 1 year
Type: Implementation
Estimated Cost: $100,000 for initial effort

Title: Improved Precast Traffic Barrier

This effort will develop standard traffic barriers to connect to precast superstructure elements in bridges (deck/precast girder).

Urgency: Intermediate
Timeframe: 5 years

Type: Research
Estimated Cost: $300,000

Title: Superstructure Design for Accelerated Bridge Construction

Placement of precast deck panels can add significant time costs to construction of a bridge, particularly compared to the time for placement of girders. Research is needed to develop superstructure designs that can accelerate speed of construction. One example would be the use of deck bulb beams. Work should include (1) workshop with industry stakeholders to identify constraints for construction and design, (2) identification of efficient shapes for beams, (3) materials and construction method for connections and joints, and (4) experimental testing.

Urgency: Short-term
Timeframe:
Type: Research
Estimated Cost: $1,000,000

Title: Developing Dry-Jointed Superstructure Connections

Present CIP girder-to-girder splice connections are defined as wet connections. While effective, they are quite slow and difficult to implement and construct. A dry-jointed rendition of the girder-to-girder connection should speed up girder erection and remove concrete placers off the job site. Phase 1 would be to develop design models and guidelines, and then perform laboratory proof-of-concept validation experimental tests. Phase 2 would conduct a demonstration field project to identify conceptual difficulties.

Urgency: Immediate
Timeframe: 4 to 8 years
Type: Research
Estimated Cost: $600,000 (Phase 1); $1,200,000 (Phase 2)

Title: Precast Foundation and Substructure Elements

Pile/foundation and bent caps, along with pier columns all have the potential for being precast off-site as a turnkey system that could be rapidly assembled at the bridge site. Two contrasting systems could be developed. The first, which builds on successes in other states, uses wet joints. The second, which builds on successes in the commercial building construction industry, uses dry joints. Both the wet and dry approaches should be phased in two stages: Phase 1 would be to conduct design models, guidelines, and laboratory proof-of-concept validation experimental tests. Phase 2 would be to conduct a demonstration field project to identify conceptual difficulties.

Urgency: Immediate
Timeframe: 5 years
Type: Research & Implementation
Estimated Cost: $1,200,000 (Phase 1); $1,800,000

Title: New and Existing Deck Construction

Bridge widening requires construction of nominal connection between new and existing bent caps and bridge decks. Research is needed to establish connection designs that provide the necessary shear and flexural strength, yet can be constructed quickly in the field. Lightweight concrete has had minimal use in Texas bridges due to the limited savings in weight of the current family of TxDOT girder shapes and current bridge geometry restrictions preventing increase of girder depth. Changes to everyday designs are needed to allow efficient use of lightweight concrete that may lead to longer spans of the use of smaller cranes on construction sites. Possible design changes include (1) smaller cap beams enabled by pretensioning, (2) inverted T bent caps, or (3) changes in girder shapes.

Urgency: Short- to long-term
Timeframe: 5 years
Type: Research
Estimated Cost: $600,000

Title: Developing a Full-Depth Deck Panel System That Avoids Steel Placement

The present half-depth panel system remains relatively laborious. Moving to a full-depth system whereby all required deck steel is embodied within the precast panels has promise in dramatically speeding up superstructure construction. As above, this research should be conducted in two phases. Phase 1 would be to develop design models and guidelines, and then perform laboratory proof-of-concept validation experimental tests. Phase 2 would conduct a demonstration field project to identify conceptual difficulties.

Urgency: Immediate
Timeframe: 4 to 8 years
Type: Research
Estimated Cost: $800,000 (Phase 1); $1,400,000 (Phase 2)

Title: Design Strategies for Accelerated Construction

Guidelines for designers would be developed to ensure that the designs are as uncomplicated and repetitive as possible in order to allow contractors to develop learning curves during construction so that production could be increased. Other strategies for accelerating construction such as minimizing the amount of demolition and using optimized work zone traffic strategies would be developed and presented in the guidelines and during training which could be in the form of classes or webinars.

Urgency: Immediate
Timeframe: 3 years
Type: Implementation
Estimated Cost: $150,000 for development; $50,000/year for training

Materials

Title: Stabilization of Base and Subgrade

This is an immediate research opportunity, particularly from an educational perspective. Specifications and expectations differ from district to district within TxDOT. There is an immediate need to synthesize expectations and best practices for base and subgrade stabilization. For accelerated construction, the biggest issue that needs to be addressed is the magnitude of the initial subgrade and base work, decisions on when trafficking can occur, and how QA testing and acceptance could be accelerated.

Urgency: Intermediate
Timeframe: 1 to 5 years
Type: Implementation
Estimated Cost: $300,000

Title: Development of Non-Proprietary Ultra High Performance Concrete Mixes for Use in Accelerated Bridge Construction

TxDOT needs non-proprietary UHPC mix designs that could be used for ABC. Mixes would be used for connections, decks, overlays, and perhaps full-depth girders.

Urgency: Immediate
Timeframe: 2 years
Type: Research
Estimated Cost: $250,000

Construction

Title: Develop Database on Accelerated Construction Operations

When planning and designing accelerated construction projects engineers need reliable and usable information concerning construction operations in order to make their estimates as realistic as possible. Data on productivity rates for various operations (concrete removal, paver rates, etc.) are available but different sources give a very wide range of values. Using site specific information including closure times, work zone areas, traffic flow, etc., improved estimates of productivity need to be developed. Also, information on skilled labor needs and demands, trucking availability and reliability, and the location of resources need to be considered.

Urgency: Immediate
Timeframe: 1 to 5 years
Type: Research and Implementation
Estimated Cost: $250,000

Title: Application of Accelerated Construction on Small Scale Projects

The nature of small scale accelerated construction could become problematic to a contractor's overall operations. It is likely that such items as the reconstruction of rural intersections could be completed in 4 or 5 days, but there would be a lag time for crews to recover that would affect other projects. If, for instance, it is necessary to reconstruct the section by stabilizing the base and overlaying, two milling machines would be required for removal, two mixers for stabilization, and two lay down machines for HMA. This would exhaust the equipment and labor resources for a portion of the contracting community. For some districts in Texas, the accelerated location areas would be isolated and be very short in timeframe. There is a need to develop criteria specifying either a minimum size project for accelerated construction or to develop criteria for small project characteristics where accelerated construction could be justified.

Urgency: Medium-term
Timeframe: 5 years
Type: Research
Estimated Cost: $150,000

Title: Quality Aspects of Accelerated Construction

As accelerated construction becomes more common, features that allow for quality work and quality monitoring need to be updated to ensure the longevity of pavements and bridges. For instance, the ability to use materials in-situ is often compromised by their lack of uniformity or strength. Improved treatments that impart the needed level of quality for in-place materials will reduce time significantly. Construction features such as improved lighting and night vision aids will improve the ability of crews to direct work and inspect the construction. Real time measurements of temperature, smoothness, thickness and other attributes will lead to the ability to address issues on the fly rather than waiting for hours to receive data from testing. This effort will be directed toward a review of technology and a survey of agency and contractor personnel to identify accelerated construction needs.

Urgency: Immediate
Timeframe: 5 years
Type: Research and Implementation
Estimated Cost: $150,000 for the initial effort

Title: Equipment Needs for Accelerated Construction

Construction equipment could play a very important role in accelerated construction. As an example, improving equipment reliability and reducing repair time would reduce the need to have redundant equipment sitting at the job site. The integration of 3-D models with machine controls on paving and other equipment would allow more precise placement of materials, and avoid issues such as string lines during construction. Remote control of machinery would allow operators to control construction away from the work zone and potentially improve quality by removing distractions and improve safety by removing the operator from the traffic area. Portable asphalt and concrete mix plants already exist, but their designs could be improved to allow for faster assembly. By using portable plants in accelerated construction, a more reliable flow of materials could be developed by reducing the traffic between the plant and the paving.

Urgency: Immediate
Timeframe: 5 years
Type: Research and Implementation
Estimated Cost: $100,000 for initial effort

Title: Balance between Accelerated Construction and Quality

The goal of this project is to provide a broad overview of innovative contractual, material, and construction methods are used and how they are inspected and accepted. Of particular interest is how might QC change when using accelerated techniques and how should QA change for accelerated construction.

Urgency: Immediate
Timeframe: 3 years
Type: Research
Estimated Cost: $300,000

Traffic Management

Title: Improved Traffic Characterization for Accelerated Construction

There is a need for better current and predicted traffic (ADT and percent trucks) data with understanding of impacts of closure windows (not just traffic control plan) with full stakeholder involvement (traffic engineer participation in meeting). The traditional work flow of traffic design → pavement design → construction needs to be replaced with an approach where all three parties come together and collaborate. Also, traffic engineers need to have support from the agency enabling them to take/accept certain degree of risk with traffic design. Operationally, the ability to track delivery trucks and traffic conditions in real time is critical to making decisions concerning the work zone activities. A useful tool at TxDOT's disposal is the CA4PRS software developed by the University of California, which can be used to model the effects of lane and roadway closures by inputting traffic and construction parameters. The software is free of charge to TxDOT as the agency was part of the pooled fund effort that supported its development. As part of this effort, guidelines and training on the use of CA4PRS would be developed and delivered to TxDOT divisions and districts.

Urgency: Immediate
Timeframe: 2 years
Type: Implementation
Estimated Cost: $400,000

Work Zone Safety

Title: Safety requirements and protocols for accelerated construction

Safety is always a challenge in construction work zones but accelerated construction brings a set of conditions beyond normal construction. In accelerated construction, the work zones need to be designed to maximize production while maintaining a safe working environment. This means that more equipment and trucks will be traversing the site possibly trying to serve multiple operations. Moving normal traffic as far from the work zone as possible is the first step to improved safety, but other considerations need to be addressed in the work site. For instance, multiple lanes may be needed so that trucks can serve separate operations will improve traffic flow. Workers visibility could be enhanced with improved and more reflective clothing, and perhaps even flashing lights. Improved lighting within the work zone would improve the safety and the quality of the project. It may be desirable to have a prequalification for bidding based upon a contractor's safety record. This project would identify required and desirable safety features for accelerated construction and result in a safety check list that can be updated during construction.

Urgency: Immediate
Timeframe: 1.5 years
Type: Implementation
Estimated Cost: $200,000

Public Awareness

Title: Public Awareness for Accelerated Construction Projects

The public must be an active partner in the highway construction process, especially for accelerated projects. Outreach to the public must: 1) occur early to get buy-in for the need of the project, 2) educate people on accelerated construction and the benefit to them, 3) keep them updated on progress and travel alternatives, and 4) alert them to any changes in schedule or traffic restrictions. The message of "give us two months and we'll give you 30 years" needs to be a part of the public's consciousness. Effective media campaigns, work zone message signs, and the availability of alternatives such as public transportation should all be a part of the toolbox. In addition to the general public, local officials should be consulted early in the process as well as businesses that may be affected. Their input could result in minimizing impacts on the community by avoiding construction during certain events or holidays and making provisions to route traffic to local businesses. This implementation effort will result in the development of a public outreach toolbox that could provide a checklist of actions and contact information for media for use during accelerated construction projects.

Urgency: Immediate
Timeframe: 1 year
Type: Implementation
Estimated Cost: $100,000

WORKSHOP CLOSURE

The workshop concluded with remarks from Randy Hopmann of TxDOT and David Casteel representing the construction industry. A summary of their presentation is given below.

TxDOT: Randy Hopmann, Director of District Operations

TxDOT's interest in accelerated construction involves three aspects: existing activities, strategic importance, and customer considerations. The recent voter approval of Proposition 1 and Proposition 7 highlights that the voters want improvements to the transportation infrastructure, and there is public trust for TxDOT to do its appointed work.

There is a need to identify effective methods of accelerating construction that may be put into practice. The cost of accelerated construction needs to consider the benefits to society by reducing delays and impacts on businesses in the vicinity of the work. We also need to be conscious of the fact that the user costs during construction may be much greater than the construction cost. As always, there is a need to consider the safety impacts of long construction time on TxDOT personnel, contractor personnel, and the public. Proper selection of accelerated construction projects can reduce time, user costs, and accidents.

In preparing TxDOT for more accelerated road and bridge construction, there are areas that need to be thoroughly researched. An examination of other states' practices for speeding up construction needs to be conducted. Improved construction methods, materials, and monitoring techniques need to be proven and implemented so that materials delivery and quality can keep up with the pace of the project schedule. Improved methods of traffic modeling need to be developed to optimize lane closures to maximize production and minimize user inconvenience. Finally, the applicability of accelerated construction to rural projects needs to be assessed and the warrants need to be established.

Industry: David Casteel, Williams Brothers Construction

The industry is very interested in helping TxDOT pursue accelerated construction projects. One of the best ways to accelerate is to provide a clear ROW and clean utility project before starting construction. Next, involving contractors early to provide feedback on design, schedule, and construction is crucial. There are good examples of districts who work with contractors on major projects. Partnering needs to be an established practice with a commitment from TxDOT decision makers and a willingness to consider out of phase and project benefiting change orders. Design alternates need to be incorporated where possible to see what real costs and time savings are available.

D-B is an appropriate contracting practice in some situations but not all, and if it is used, there is a need to factor in procurement time to total time comparison. Additionally, the roles and control of testing firms involved with D-B need to be reviewed. Currently, the quality assurance firm and owner verification firm functions are redundant. The QA firm should be the judge of the materials and work. TxDOT needs to be more open to alternate technical concepts that could reduce time and/or cost and should develop a more reasonable risk sharing strategy.

TxDOT needs to make it clear that consultants providing construction engineering and inspection are to focus on completion as well, and TxDOT needs to provide every day oversight of their activities and schedules. TxDOT should avoid prescriptive specifications and check that consultants are using the right standard methods and materials for the area they are working in.

The use of incentives at certain milestones and substantial completion will garner attention from contractors as long as they are meaningful, as was the case for the Katy Freeway. A+B and A+B+C are appropriate in cases when time is really important and the engagement of the industry is needed to participate in phase development, as the Barriere Construction example showed. However, not all projects need to be accelerated as it may not be worth the costs in some areas, projects, or even some phases within projects. Caution needs to be exercised so that fewer projects are built because too much of the budget is spent to accelerate too many.

Consultants need to be part of the discussion on continuous improvement program for better plans. While accelerating work on some projects is important, the schedules need to be realistic or there will be failure before the project begins. Quality needs to be as big a priority as time. Rapid methods for testing and feedback, continuous inspection, and contingencies for correcting quality issues need to be considered throughout planning, design, pre-construction, and construction.

The discussion of accelerated construction must continue and include TxDOT districts and divisions, construction company CEOs, equipment manufacturers, material suppliers, and consultants in order to understand the impact, answer questions, and get more ideas on the implementation.

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APPENDIX A.
LIST OF ATTENDEES: ACCELERATED ROAD AND BRIDGE CONSTRUCTION WORKSHOP

First Name	Last Name	Affiliation
Mary Beth	Hueste	TAMU/TTI
Jim	Breland	Barriere Construction Co., L.L.C.
John	Barton	Texas A&M Engineering
Anna	Birely	Texas A&M University
David	Casteel	Williams Brothers Construction Company
Lonnie	Gregorcyk	TxDOT
Jon	Epps	TTI
Brian	Merrill	Wiss, Janney, Elstner Associates, Inc.
Al	Alonzi	FHWA
Dave	Newcomb	TTI
John	Mander	Texas A&M University
Lisa	Lukefahr	Texas Concrete Pavement Association
Robert	Adamson	Longview Bridge and Road, Ltd.
Rudy	Polselli	James Construction Group
Todd	Mansell	Caterpillar Paving
Danny	Donahoe	Barriere Construction Co., L.L.C.
Steve	Helton	APAC – Texas
Bill	Stockton	TTI
Randy	Hopmann	TxDOT
Robert	Hall	R.K. Hall Construction, Ltd.
Letty	Von Rossum	TxDOT
Kyle	Hammon	Roadtec, Inc.
Jed	Bingle	Washington State DOT
Clint	Henson	Jordan Foster Construction, LLC
Ryan	Detry	The Levy Company, L.P.
Lonnie	Gregorcyk	TxDOT
Jason	Estes	Zachry Construction Corporation
Chuck	Fuller	Txapa
Lance	Simmons	TxDOT
Valente	Olivarez, Jr.	TxDOT
Eliza	Paul	TxDOT
Stan	Swiatek	TxDOT
David	Ellis	TTI
Tim	Lomax	TTI
Jerry	Ullman	TTI
Rachael	Sears	TTI
John	Harvey	UC Davis

Benjamin	Engelhardt	TxDOT
Rene	Garcia	TxDOT
Gregg	Freeby	TxDOT
Duane	Milligan	TxDOT
Stu	Anderson	TTI
Tracy	Cain	TxDOT
Thomas	Bohuslav	Thomas R. Bohuslav Consulting Engineers, PLLC
Harold	Mullen	Texas Asphalt Pavement Association
Chris	Lechner	Precast Concrete Manufacturers' Association of Tex
Mark	Hilderbrand	Kiewit Infrastructure Group
Jorge	Hinojosa	Bexar Concrete Works, LTD.
Kyle	Rodemacher	Webber, LLC
Jeff	Smith	Smith & Company
Abu	Faruk	TTI
Charles	Gurganus	TTI
Ben	Carroll	Lone Star Paving
Hala	Elgaaly	FHWA

APPENDIX B.
RESEARCH NEEDS SUMMARY: ACCELERATED ROAD AND BRIDGE CONSTRUCTION WORKSHOP

Table 2. Summary of Research Needs.

Group	Title	Urgency	Timeframe, yrs.	Type	Cost, $
General	Develop policy roadmap for rapid, durable, safe, and construction	Immediate	1	Implementation	250,000
	Decision tool for accelerating highway construction	Immediate	1.5	Implementation	150,000
	Best practices and benefits of accelerated construction case studies	Immediate	1	Research	150,000
	CE&I needs and other inspection needs associated with unique contracting	Immediate	1	Research/ Implementation	200,000*
	Training and knowledge base for construction details	Immediate/ Long Term	1*	Implementation	150,000*
	Introducing innovation	Intermediate	1.5*	Implementation	150,000*
	Skilled worker labor market study	Immediate/ Long Term	1*	Research/ Implementation	150,000*
Planning	Development of framework for accelerated construction projects	Immediate	1	Implementation	200,000
	Best practices in partnering	Immediate	1	Implementation	75,000
	ABC Best Practices for Planning and Design	Immediate	1	Implementation	30,000
	Development of contract methods for accelerated construction	Intermediate	1	Implementation	100,000
Design	Develop guidelines for environmental impact abatement during accelerated construction projects	Intermediate	2	Implementation	100,000
	Preconstruction site investigation and documentation	Immediate	1*	Implementation	100,000*

	Improved precast traffic barrier	Intermediate	5	Research	300,000
	Superstructure design for ABC	Immediate	5	Research	1,000,000
	Developing dry-jointed superstructure connections	Immediate	6	Research	600,000*
	Precast foundation and substructure elements	Immediate	5	Research/ Implementation	1,200,000*
	New and existing deck construction	Immediate/Lon g Term	5	Research	600,000
	Developing a full-depth deck panel system that avoids steel placement	Immediate	6	Research	800,000*
	Design strategies for accelerated construction	Immediate	3*	Implementation	150,000*
Materials	Stabilization of base and subgrade	Intermediate	3	Implementation	300,000
	Development of non-proprietary UHPC mixes for use in ABC	Immediate	2	Research	250,000
Construction	Develop database on accelerated construction operations	Immediate	3	Research/ Implementation	250,000
	Application of accelerated construction on small scale projects	Medium	5	Research	150,000
	Quality aspects of accelerated construction	Immediate	5	Research/ Implementation	150,000*
	Equipment needs for accelerated construction	Immediate	5	Research/ Implementation	100,000
	Balance between accelerated construction and quality	Immediate	3	Research	300,000
Traffic Mgmt	Improved traffic characterization for accelerated construction	Immediate	2	Implementation	400,000
Work Zone Safety	Safety requirements and protocols for accelerated construction	Immediate	1.5	Implementation	200,000
Public Awareness	Public awareness for accelerated construction projects	Immediate	1	Implementation	100,000

* Phase 1 effort