STRATEGIES OF ACCELERATED BRIDGE CONSTRUCTION PRACTICE IN CALTRANS

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ABSTRACT

The concepts of accelerated bridge construction (ABC) offers significant advantages over the conventional cast-in-place construction in minimizing traffic disruption, improving work zone safety, and reducing on-site environmental impacts. For these reasons, as one of the world leaders in infrastructure planning and construction, California Department of Transportation (Caltrans) has already embraced the ABC philosophy in bridge design and construction projects. In this paper, the ABC practices in California over the last five years have been reviewed, and presented. The new concept in developing an ABC project such as construction impact index, impact tolerance index and project delivery index are proposed and analyzed, and the design impact questions are developed for quantifying the index. Also, a pilot project implementing ABC technology is described.

Keywords: Accelerated Bridge Construction, Strategy Plan, Pilot Project, Caltrans

INTRODUCTION

In California more than 24,000 bridges support one of the world's most vibrant economies link the nearly 45,000 miles of pavement. In the current 21st century, this highway network massively built in 1950's has failed to meet the fast-paced traffic demands due to the population increase. Recent years the severe congestion in statewide has adversely affected the economic growth. Local, regional and state transportation partners grapple constantly with congestion relief strategies. The vast majority of structures constructed in California are cast-in-place concrete that require substantial construction effort and extended construction completion time. This conventional project delivery processes in place for decades, which include planning, design and construction, are no longer acceptable norms in congestion relief projects. The state-of-the-art concept, accelerated project delivery (APD) that towards delivering infrastructure projects sooner offers a feasible tool for transportation planners, engineers and contractors to reduce overall impacts to the motoring public while completing improvements quickly. Typical project delivery schedules are controlled by construction of bridges, which require the most time to complete. ABC, as a main component of APD, has been widely recognized as utilizing prefabricated bridge components in bridge planning and design to substantially reduce on-site construction time. The careful planning, design, and implementation for an ABC project offers significant advantages over onsite cast-in-place construction in lowering costs, improving safety in job site, and mitigating environmental impact due to minimized construction time.

The Federal Highway Administration (FHWA) has been actively promoting the advantages of accelerated bridge construction. A framework of decision-making in developing ABC project utilizing prefabricated bridges components has been established [1]. Caltrans continues to strive for innovative ways to expedite project delivery while maintaining stewardship of entrusted public funds. Over the last few years, working with academic institutions and industry, Caltrans initiated a practice development and implementation for accelerated bridge construction (ABC). Under the direction of the State Bridge Engineer, a special task force consisting of subject matter experts from design, construction, maintenance, material, environment, project management, and other relevant fields has been formed to investigate viable alternative engineering practices to achieve ABC. The progresses have been achieved in developing standards, guidelines, key policies, design criteria, and project management and performance assessment for ABC. Several projects utilizing ABC technologies, which provided a template and motivation for increasing widespread ABC practice in the future, have been successfully delivered. In order to further promote ABC in California, a number of design teams are working on the several Caltrans ABC pilot projects. This paper outlines the Caltrans ABC strategies, and presents challenges and solutions of ABC projects, including Caltrans ABC Strategic Plan, Action Plan, ABC Decision-making Strategy, design criteria, a pilot project in urban area.

ABC PROJECT DEVELOPMENT METHODOLOGY

Starting in 2008, Caltrans initiated a practice development and implementation for ABC, and has established a task force that is headed by an ABC Executive Committee and Advisory Council to develop standards, guidelines, and key policies for implementing structure design for ABC. The ABC task force has outlined a strategic plan to develop, implement, and promote ABC practice in California. The road map of developing a new project has proposed, and criteria for evaluating a project performance have been established for Caltrans review and use.

ABC PROJECT DECISION-MAKING

It is important, though, to understand that the success of ABC implementation rests largely on widespread acceptance of the associated techniques by project development staff (both internal and external), funding partners, and the contracting industry. The Caltrans' larger goal, as stated in its Mission/Vision statement, is "Caltrans improves mobility across California". The goal of ABC is to deliver projects earlier to the travelling public: to effectively reduce the impacts of on-site construction to motorists. Therefore, as stated precedent, ABC is viewed as a subset of a larger APD effort encompassing all aspects of project development through construction contract acceptance. Considerations related to lane rental rates should also be considered as part of this to address funding issues. This latter requirement stems from the fact that quite often new techniques involve unassigned risk that must be borne by the Contractor at a premium until the comfort level garnered from successes has been realized.

ABC means significantly reducing on-site construction time to mitigate traffic impact on public travelling, improving safety, and alleviating the effects on environmental sensitive area. The longer construction duration will induce the in-directed cost due o traffic delay or other impact, herein defined as impact cost (IC). Besides the Construction Cost (CC), in structural type selection, therefore, the IC should be considered in the decision making. Currently, Caltrans ABC Advisory Council suggests a cost objective criterion for total cost (TC) estimate as follows [2, 3]:

$$TC = CC + IC \tag{1}$$

As mentioned precedent, ABC can substantially mitigate the construction impact on the site to benefit the business, commerce and environment. The benefits due to ABC implementation should be taken into account, and the earned value analysis is suggested.

Eq. (1) suggests that, for any construction type, the IC should be included in the total cost estimate. In general the construction impacts consist of traffic and environmental impacts. The traffic impact includes all construction related traffic delay or interruption, and the environmental impact includes all environment damage in the environmental sensitive area due to bridge construction. To accurately quantify the IC, the construction impact index (CII) is defined by impact intensity, which consists of three levels, low or mild, moderate and severe. The details of the construction impact index are as follows:

Table 1: Construction Impact Index

Impacts	Intensity Level	Description
Traffic	T1-Low or mild	Reduce widths of lanes and shoulder, closure of 1-30% of total lanes and/or shoulder or lane realignment
	T2-Moderate	Closure of 31-66% of total lanes + shoulder
	T3-severe	Closure of 67-100% of total lanes + shoulder
Environment	E1-Low or mild	Site and structural type dependent. To specify the impact level, the environmental analysis is required
	E2-Moderate	
	E3-severe	

It is noted that, for a project, the longer construction duration, the higher impact will be. The impact induced by construction duration is defined as construction impact time (CIT). Usually the ABC has shorter CIT than that of the conventional construction. In determining the impact intensity, the ABC will have relative lower intensity level.

There are significant differences in tolerating an “impact” for different construction site. For a local street, a road closure may be acceptable, but for an interstate freeway, one lane closure in daytime can create unacceptable traffic impact. The Impact Tolerance Index (ITI) of the construction site is defined as the tolerance level that scales the capacity of a site to tolerate the impact.

Table 2: Impact Tolerant Index

Construction Site	Tolerant Level	Description
Residential community Local streets	High	For a reasonable period, road closure in day and night time may be acceptable
State routes, major city arties	Moderate	Partially lane closure in a day and night time may be acceptable
Interstate or State freeways	Low	No lane closure allowed in day time, partially lane closure in night time may not be acceptable

The two impact indexes can be quantified using score system in impact cost analysis. The Currently Caltrans ABC-Advisory Council is working on the establishment of the score system for each index. Conceptually, the total impact can be expressed as:

$$\text{Total Impact} = CII * ITI \quad (2)$$

The impact cost, then, can be estimated based on the total impact. It should be pointed out that the CII is structural type dependent. The prefabricated bridge type, for instance, will have relative less impact on the construction site.

For some emergence case, such as restoration of the traffic capacity interrupted by accident or incident, the project must be delivered in a very short time. In this case, ABC may be an only viable option to complete the project. For some project, the longer construction duration may be appropriate due to the cost considerations. In order to describe the degree of urgency of the project, the project delivery index (PDI) is defined, and is tabulated in the following:

Table 3: Project Delivery Index

Project Type	PDI	Description
Capacity restoration	High	Emergence response, to restore traffic capacity in a very short period (less than 30 day, for example)
Capacity improvement	Moderate	Severe congestion adversely affects the traffic and economical activity, increasing capacity become urgent
Safety improvement & rehabilitation	Low	Retrofit structure to meet updated codes

In order to quantify the impact indexes, based FHWA decision-making frame work [4], an ABC decision-making questionnaire has been developed to guide the engineers and management to evaluate the feasibility of using ABC alternatives in a project. The questionnaire prompts the designer to evaluate all the traffic, environmental, and other relevant impacts to the site based on the conventional bridge construction selection. The scoring system requires the engineer/designer to rate the impact intensity and importance level. The total scores will assist the project design team to assess the needs to have an accelerated bridge construction type so that the impact levels and intensity can be greatly reduced or eliminated. The questionnaire (Project Delivery: Design Impact Questions) is listed in the following Table 4.

Table 4: Project Delivery: Design Impact Questions

Structural type			
Questions		Scores	
General		Yes No 1 2 3 4 5	
Is this an emergency bridge replacement?			
Is bridge on an emergency evacuation route or over railroad/waterway?			
Is there a funding requirement to accelerated project delivery?			
Is rapid recovery from natural/manmade hazards or rapid completion of future planned repair/replacement needed for this bridge?			
Is the bridge construction a critical path of the total project?			
Are there significant economic benefits if construction/project is completed ahead of schedule?			
Traffic			
Bridge carries high ADT or ADTT?			
Bridge over existing high ADT or ADTT facility?			
Bridge construction significantly impact traffic? a. Does it have high user-delay costs?			
Can the bridge be closed during off-peak traffic periods?			
Will the traffic control plan be significantly impacted?			
Construction			
Do worker safety concerns at the site limit conventional methods, e.g., adjacent power lines or over water?			
Is the bridge location subject to construction time restrictions due to adverse economic impact?			
Does the site create problems for conventional methods of construction (falsework, concrete delivery, etc.)?			
Utilities			
Are there existing utilities that impact the construction window?			
Are there existing utilities that impact construction operations?			
Environmental			
Is the site environmentally sensitive area requiring minimum disruption (e.g. wetlands, air quality, and noise)?			
Are there natural or endangered species at the bridge site? a. Shorten construction window needed?			
Local weather limit the time of year for construction?			
Is the bridge on or eligible for the National Register or Historic Places, or a designated landmark structure?			
Total Scores			

ABC PILOT PROJECT

In 2008, the Division of Engineering Services (DES) at Caltrans started a pilot program that implemented ABC technologies. In this pilot program, the 10 projects were first selected. The bridge types cover most structural types currently utilized in ABC application, which included PC/PS concrete, steel I girder, spliced precast girder, and prestressed concrete segmental bridges. The objectives of this program are to improve the management process and coordination of Caltrans functional units, and develop design procedures and seismic details for ABC bridges.

I-10 HOV LANE WIDEN, LOS ANGELES

I-10 is a major east-west route that is used for interstate, interregional and commutes travel that links the Los Angeles and San Bernardino Counties. It is a part of the Federal Aid Interstate (FAI) system, which is a subset of the National Highway System. Near the project limits, the segment connecting Los Angeles Central city to San Bernardino County is currently an 8-lane freeway. The proposed Segment 2 (PM 33.4/37.1) project is to widen and restripe the I-10's eastbound and westbound directions, from Puente Avenue, City of Baldwin Park, to the Hollenbeck Avenue, City of West Covina, to facilitate the construction of High Occupancy Vehicle (HOV) lanes on each direction. The purpose of the project is to relieve existing congestion, improve safety, operations, and accommodate future growth. The project has been assigned as Project Development Processing Category 4A.

Within the project limit, I-10 is an 8-lane facility with four 12 feet lanes in each direction. The current lanes cannot accommodate the existing peak traffic volumes. Thus, heavy congestions and long delays occur daily. The proposed project adds 12 feet median HOV lanes in each direction of I-10. The freeway will also be widened on the outside shoulders to maintain 4 standard traffic lanes in each direction.

The proposed project requires six freeway bridges crossing local streets to be widened. In order to accommodate the median HOV lanes in each direction of I-10, new bridge structures need to be constructed on both sides of the existing structures. Figure 1 shows the project location map and bridge structure locations.

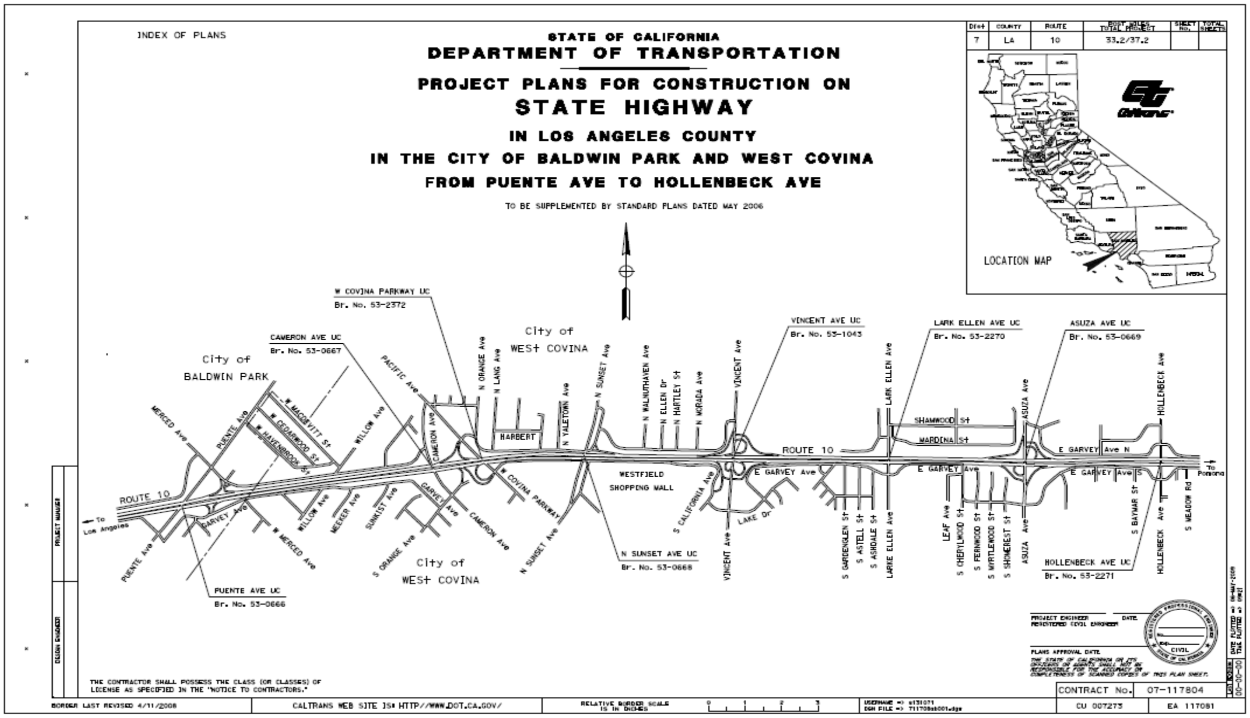

Fig. 1 Project Location Plan

ABC Structure Type Selection

The six bridge locations posed challenging and strict constraints on the structure depths, vertical clearances, and traffic detours during construction. The primary constraint is the severely limited vertical clearance available due to the existing profile grades. This constraint is further complicated by the cities' request to maintain full operation on all roads underneath the bridges.

The conventional CIP/PS box girder was initially considered since it was estimated to cost less to build. However, CIP/PS structures require falsework that would reduce the vertical clearance to a level below the standard requirements. The only feasible option for meeting the required temporary vertical clearance for CIP/PS would either to lower the existing roadway or to construct the structure at a higher elevation, and then lower it into position. After careful review, it was determined that reconstructing the roadway is not feasible because the construction would case significant traffic delays to the local public, which was rejected by the local cities and communities. Furthermore, the option of building the CIP/PS box girder high, and then lowering it into place was deemed impractical and difficult for multi-span structures. Therefore, the conventional bridge alternative is not feasible and an ABC structure type solution is needed to minimize the traffic impacts.

A precast/prestressed girder type is selected as the ABC solution for all the bridges on this project. The precast girder type would consist of precast Bulb-Tee and box beams. The multi-span structures would use Precast, Pre-stressed Box or Bulb-Tee girders, made continuous at bents with post-tensioning. All of the superstructure will be supported by column integral bents and seat type abutments.

The precast girders require no falsework and can be rapidly installed on-site, which satisfies the goals of accelerated bridge construction. The only cast-in-place operations are for deck, diaphragm, and substructure construction. Most importantly, casting the deck, bent, and diaphragms in place and then post-tensioning the integrated superstructure allows for depth-to-span ratios of less than 0.04. Thus, this results in the satisfaction of minimum vertical clearance of 15'.

Table 1: Bridge Structural Data

Bridge Name Bridge Number	Bridge Type		Proposed dimensions		Comments
	Span	Girder	Length (ft)	Width (ft)	
Puente Ave UC Widen (53-0666)	Single-span	PC Bulb-T Girder	116.32' (WB)	16.28' (WB)	Employ post-tensioning to resist live loads
			103.08' (EB)	14.43' (EB)	
Cameron Ave UC Widen (53-0667)	Single-span	PC Bulb-T Girder	73'-4" (WB)	15' (WB)	Employ post-tensioning to resist live loads
			73'-4" (EB)	16'-0" (EB)	
W. Covina Pkwy UC Widen (53-2372)	2-span	PC Bulb-T Girder	227'-6"(WB)	8'-11" (WB)	Employ post-tensioning to provide continuity over integral bent
			212'-11" (EB)	14'-2" (EB)	
Lark Ellen Ave UC Widen (53-2270)	3-span	PC/PS Box Girder	144'-6" (WB)	13'-6" (WB)	Employ post-tensioning to provide continuity over integral bent
			144'-6" (EB)	13'-6" (EB)	
Azusa Ave UC Widen (53-0669)	2-span	PC/PS Box Girder	163'-4" (WB)	12'-6" (WB)	Employ post-tensioning to provide continuity over integral bent
			163'-4" (EB)	6'-0" (EB)	
Hollenbeck St UC Widen (53-2271)	3-span	PC/PS Box Girder	144'-6" (WB)	13'-6" (WB)	Employ post-tensioning to provide continuity over integral bent
			144'-6" (EB)	13'-6" (EB)	

ABC Construction

The proposed construction sequence for the ABC structure type is summarized as follows:

1. Cast girder in the precast plant while the substructures are constructed on site

2. Erect temporary supports, and set girders in place.
3. Construct cast-in-place intermediate diaphragm
4. Cast deck starting at Abutment 1
5. Construct deck and end diaphragms starting from end abutment
6. Cast bent caps.
7. Post-tension superstructure, remove temporary supports, and complete construction of abutments
8. Construct closure pour

The proposed construction sequence diagram is shown in Figure 2 as follows:

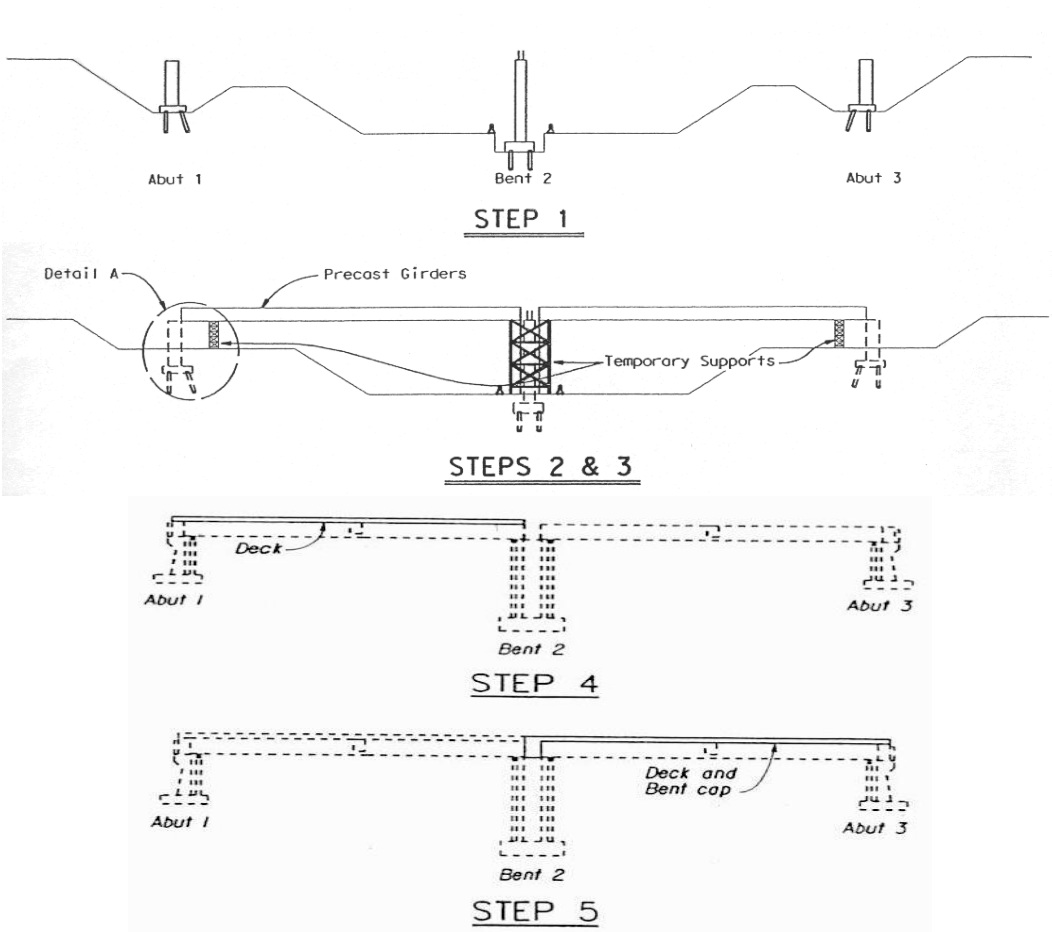

Fig. 2 Construction Sequence Diagram

The current structural construction cost is estimated around $20 million USD and the project bid date is targeted for December 2010.

Utilizing precast/prestressed concrete spliced girder bridge types is an effective method to achieve accelerated bridge construction. This unique structure type can eliminate falsework and allow rapid construction, and thus reduce congestion and traffic delays to the traveling public. In addition, the structure type will allow the usage of longer span lengths, minimizing bridge superstructure depths and rapidity of construction.

CONCLUSIONS

In California the economic and population growth, coupled with the decaying infrastructure, have led to the omnipresent need to rapidly replace, widen, and build new highway infrastructure and thus bridge structures and transportation planners are under increasing pressure to improve highway and bridge systems in accelerated time. ABC as an innovative design philosophy in infrastructure delivery poses some most challenges for the design, construction, and project management. In this paper, the new concept of the construction impact index, impact tolerant index and project delivery index have been proposed and analyzed. The development and application of this state-of-the-art concept requires interdisciplinary cooperation, such as structure, environment, planning etc. It can be anticipated that this design and management concept will play the more and more important roles in future ABC project.

REFERENCES

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