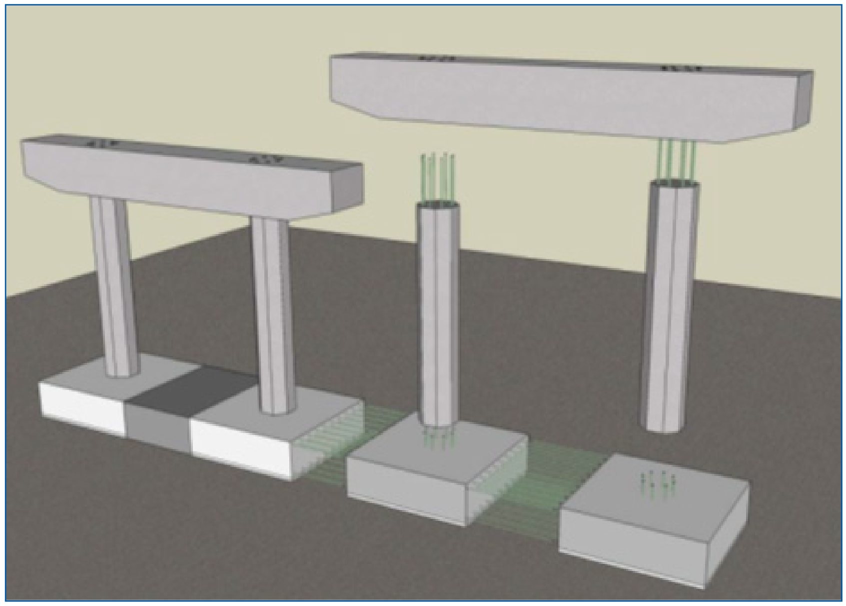
# MOUNTAIN-PLAINS CONSORTIUM

**MPC 17-331** | S. Pei, N. Wehbe, and M. McMullen

## Implementation Guidance for Accelerated Bridge Construction in South Dakota



MOUNTAIN-PLAINS CONSORTIUM REGION 8

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# Implementation Guidance for Accelerated Bridge Construction in South Dakota

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September 2017

## Acknowledgment

The authors would like to acknowledge the financial support of the Mountain-Plains Consortium (MPC) and the South Dakota Department of Transportation (SDDOT) for funding this study through project MPC-395.

## Disclaimer

## ABSTRACT

A study was conducted to investigate implementation of accelerated bridge construction (ABC) in South Dakota. Accelerated bridge construction is defined as construction practices that employ innovative techniques to reduce on-site construction time and interruption to traffic. The main objective of this study was to implement a systematic method for evaluating ABC techniques to determine their applicability to bridge construction and rehabilitation projects in South Dakota from a cost effectiveness standpoint. A comprehensive literature review was conducted to develop a catalog of ABC techniques and detailed profiles describing the use of these techniques. These tools were used in conjunction with the ABC evaluation tool to help the decision-making process for any given construction project. Currently, the S.D. Department of Transportation must (SDDOT) determine if ABC techniques will provide a more efficient use of construction funds than conventional bridge construction methods. Therefore, this research was geared toward developing the knowledge base and tool to evaluate if implementation of ABC techniques is beneficial to a particular project scenario, based on South Dakota local cost and experience data. Many other state DOT offices currently have evaluation tools for ABC. Some were used as references when designing the tool for SDDOT. Examples for using the developed tool also were included in this study to illustrate use of the evaluation tool for ABC decision making in South Dakota.

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| | |
|---|---|
| **ABC** | Accelerated bridge construction |
| **AHP** | Analytical hierarchy process |
| **BDO** | Bridge Design Office (located at SDDOT) |
| **Caltrans** | California Department of Transportation |
| **CIP** | Cast-in-place |
| **CMF** | Crash modification factor |
| **DOT** | Department of Transportation |
| **DRUC** | Daily road user costs |
| **FHWA** | Federal Highway Administration |
| **FRP** | Fiber-reinforced polymer |
| **GRS** | Geosynthetic reinforced soil |
| **LGAO** | Local Government Assistance Office (located at SDDOT) |
| **MnDOT** | Minnesota Department of Transportation |
| **ODOT** | Ohio Department of Transportation |
| **PBES** | Prefabricated bridge elements and systems |
| **SDDOT** | South Dakota Department of Transportation |
| **SPMTs** | Self-propelled modular transporters |
| **TxDOT** | Texas Department of Transportation |
| **UDOT** | Utah Department of Transportation |
| **WSDOT** | Washington State Department of Transportation |

# EXECUTIVE SUMMARY

Through its implementation in recent years in the United States, accelerated bridge construction (ABC), has been proven to improve work zone safety and reduce interruption to end-users, primarily through the use of prefabricated elements. The concept has been gaining momentum as a recommended practice for bridge work on existing routes, especially for bridges on heavily-travelled corridors. Several research and implementation initiatives have been set in action around the United States, including multiple projects in Utah (Ardani et al., 2010, Park 2011), Washington (Khaleghi 2005, Khaleghi 2010, and Marsh et al., 2005), and California (Chung et al., 2008), etc. These demonstrative projects on critical bridge sites had been successful in minimizing traffic interruption to a level not possible with traditional construction methods, e.g. removal and replacement of a major bridge in one week (Ardani et al. 2010). Several ABC applications are documented in Connection Details for Prefabricated Elements and Systems (Culmo 2009), published by FHWA. A summary of current ABC applications and experiences was presented in an “ABC Manual” (Culmo 2011) published recently by FHWA. Study on the application of ABC in seismic regions has also been initiated by identifying applicable ABC connection types for seismic loading (Marsh et al. 2011).

The ABC methodology is quite general and can also be applied to relatively small scale projects and typical highway bridge systems, as it was demonstrated in an Iowa DOT project (bridge over Keg Creek near Council Bluffs, Iowa)—part of the second Strategic Highway Research Program (SHRP 2). To achieve time savings, implementation of ABC will involve pre-manufacture of modular bridge components (PCI Northeast 2006) and need additional resources and special planning considerations during construction, such as special equipment (Rosvall et al., 2010 and Zhu, Ma 2010) and site management plan. These requirements tend to drive cost of the project up when compared to traditional −construction. On the other hand, reduced construction time will benefit end users and workers with reduced interruption and safety hazard. The benefit of ABC tends to be significant and worth considering when potential traffic volume affected by the project is high.

This study hypothesizes that, given the project condition and current viable ABC techniques, a set of influential factors exist that will control whether ABC is beneficial, such as site condition, material availability, and traffic volume, etc. Among these factors, the controlling factor will likely be related to traffic volume, type of road corridors, availability of immediate detour options, and material availability. For most areas in South Dakota, it is likely that some of the ABC techniques will not be economically beneficial due to low traffic volume. Thus the implementation of ABC in South Dakota should be planned carefully to ensure cost efficiency. Currently other DOTs use guidelines that assess the necessity of ABC (e.g., ABC rating system used by Utah DOT). These cannot be directly applied to South Dakota because the cost of implementing different ABC techniques differs based on location and resources−equipment and crew−available. The cost effectiveness of implementing these procedures in South Dakota has not been fully investigated. A systematic approach to support decision making on ABC implementation in South Dakota has not been developed.

In Section 1 of this report, the problem description is presented. The previous minimal use of accelerated bridge construction in South Dakota and the “Every Day Counts” initiative put into place by the Federal Highway Administration (FHWA) are discussed.

The three main objectives of the report also are explained. The objectives are: 1) To investigate previously used ABC techniques that have the applicability for use in South Dakota, and develop a catalog describing the use of these techniques, 2) To estimate potential costs and benefits of implementing ABC techniques over the use of conventional construction, and 3) To develop a cost-benefit analysis model to aid in determining feasibility of using ABC techniques in place of conventional construction.

In Section 2 of this report, the full findings and conclusions for the project are presented. Each section in this chapter explains different research methodologies used to obtain information required to meet the project needs. This chapter also presents information regarding sources used to obtain the necessary information and to design and populate with data the final deliverables required.

This project involved three objectives that achieve the goal of developing a decision-making process concerning using ABC techniques. The first objective was to develop an ABC technique catalog denoting techniques previously used in the United States. The second objective was to estimate associated costs and benefits encountered through the use of the researched ABC techniques. The third objective was to develop a cost/benefit analysis tool to evaluate potential projects where the ABC techniques could be applied. This section will summarize what was done, and present conclusions and recommendations regarding the three objectives.

The first objective involved development of a catalog of ABC techniques, which informed the user of what was used in the past and how techniques were implemented into construction of a bridge project. This catalog informed the user of what was done in the past, and related each technique to benefits, special requirements or problems pertaining to each technique. To accomplish this objective, an in-depth literature review was completed that familiarized the reader with current ABC techniques used across the United States to-date. Sources investigated throughout the course of the literature review provided a list of ABC techniques that have been used in practice across the United States. Information found throughout the course of this literature review was used to create ABC technique profiles. The ABC technique profiles are designed to inform the reader of applications of each ABC technique, and provide the source of the information, and—in some cases—an example project and visual aid are also given.

Additionally, several interviews were completed to structure and populate the ABC catalog. Interviews with the SDDOT were completed to determine priorities of importance to the Bridge Design and Local Government Assistance Offices to include in the ABC catalog. These interview results were also used to finalize the list of ABC techniques obtained from the literature review. Then, several interviews were conducted with employees of other state DOT offices that had previous experience with use of the ABC techniques researched in the literature review. The information obtained from these interviews was used to populate various cells of the ABC catalog.

The second objective of this project was to estimate costs and benefits associated with the use of ABC techniques. These costs needed to be South Dakota-specific estimates for information to be useful to SDDOT. To obtain this cost information, three sources were used. The first source was SDDOT itself, which provided conventional cost information regarding bridge construction projects completed in the past. The second source was South Dakota manufacturers and contractors, which provided information pertaining to the implementation and construction costs of using ABC techniques in the state. The third source was the SDSU Road User Cost Tool, which was obtained from Project SD2011-05, “Review of Road User Costs and Methods,” and through use of the empirical equation displayed in Equation. The empirical formula was used for the first stage of the evaluation tool procedure, while the Road User Cost Tool was used for the second, more rigorous stage of the evaluation tool procedure.

The third and final objective of this project was to develop a cost/benefit analysis procedure tool for purposes of evaluating applicability of ABC techniques for a given bridge construction project at SDDOT. This objective involved development of several inputs, based on reference tools used for creation of the evaluation tool for SDDOT. These three reference tools were: 1) the Accelerated Bridge Construction (ABC) Analytical Hierarchy Process (AHP) Decision Tool, 2) the UDOT ABC Decision Tool, and 3) The Iowa DOT ABC Decision Tool. These three references were used to develop a two-stage evaluation process determining if ABC techniques should be used for the purposes of given bridge construction projects in South Dakota. An output indicator is obtained from the inputs with their given predetermined weighting factors for the first stage of the decision-making procedure. This indicator is used with decision-making flowcharts generated from the reference tools to determine if a given project will move to the second stage of the decision-making procedure. If the project does proceed to the second stage of the decision-making procedure, new inputs are generated for the project to obtain a second output indicator used in conjunction with decision-making flowcharts to determine if ABC techniques should be used over a conventional construction approach.

First, the ABC catalog is to be used as a reference tool to determine which ABC techniques should be used on a given bridge construction project after the decision has been made that ABC techniques are applicable for the project (i.e., after the project has exited the second stage of the decision-making procedure with recommendation of implementing ABC techniques into the project design).

Second, the costs used for the generation of the second stage inputs should not be considered as project-specific cost estimates of ABC techniques. Lack of use of ABC techniques in South Dakota and costs for given ABC techniques can vary greatly from project to project, so exact costs were not able to be obtained for the use of ABC techniques. Therefore, a general estimation of the total cost of implementing substructure, superstructure, and placement ABC techniques was generated. These estimations should not be considered accurate estimations of the actual cost of implementing ABC techniques into a given bridge construction project. If a more accurate cost of implementing ABC techniques is desired, a South Dakota contractor would be contacted to obtain a bid price for the project, based upon the ABC techniques desired.

Finally, although the evaluation tool developed in this study laid out framework for a simplified assessment for ABC applicability in South Dakota, the available data related to actual ABC costs in South Dakota is limited. Through future use of the tool in realistic SDDOT projects, additional data should be collected and used to calibrate the evaluation tool's weighting factors. It will be beneficial to run realistic project scenarios through the evaluation tool to see if the indicator reflects realistic decision making conditions. Ideally, weighting factors should be adjusted using several clearly defined benchmark projects, so the calculated indicator will be representative for the actual measured benefits from these projects. As such data is currently unavailable in South Dakota, results from the proposed process remain partially subjective and should be used with caution.

# 1. INTRODUCTION

## 1.1 Project Description

Accelerated Bridge Construction (ABC) can be defined as construction practices that employ innovative techniques to reduce on-site construction time and interruption to traffic. It can potentially improve quality of construction and work zone safety. Less interruption on traffic also lowers agency costs associated with traffic control and road user costs from delays and detours. Currently, a significant portion of bridges in the United States are functionally obsolete or will soon reach the end of their service life and require major rehabilitation or replacement, making them potential candidates for ABC. As part of the "Every Day Counts" initiative, the consideration of ABC techniques in new bridge construction and existing bridge retrofit has been recommended at the national level.

The S.D. Department of Transportation's (SDDOT) experience with ABC is mainly limited to the use of pre-fabricated bridge elements, which are widely used in rural locations with limited access to construction materials. While other ABC techniques have proven beneficial in states with high traffic volumes, it is unknown whether they would be preferable when compared to conventional bridge construction techniques in South Dakota, where traffic volume is relatively low.

Currently, there is no systematic method for evaluating ABC techniques to determine their applicability to bridge construction and rehabilitation projects in South Dakota. Due to limited experience with ABC, uncertainty in agency and user costs associated with ABC implementation, and the inability of current cost analysis to account for work zone safety effects, the SDDOT is uncertain whether ABC techniques would provide more efficient use of construction funds than conventional bridge construction methods. As a result, research is needed to develop technical and economic guidance to identify ABC techniques applicable to South Dakota and to quantify potential costs and benefits of using them.

## 1.2 Objectives

The study covered in this report was undertaken to address the following three main objectives.
Develop a catalog describing ABC techniques and their applicability to South Dakota. The first task of this project was to develop a catalog that describes existing ABC techniques with information related to the implementation of each ABC technique into a bridge construction project. This catalog serves as a reference for use by SDDOT when assessing ABC applicability for a given project. All information in the catalog was obtained from practices of other state DOT and review of existing literature.
Estimate potential costs and benefits of using ABC techniques in South Dakota. The second main task was to estimate potential costs and benefits of using ABC techniques in South Dakota. This estimation was based on South Dakota local cost information. The estimated cost information was then used in comparison to current conventional construction cost information as a way to determine the cost/benefit of using a given ABC technique on a bridge construction project. This cost information was split into three categories: the agency costs and benefits associated with using ABC techniques or the change in cost of using ABC; the user costs and benefits associated with the conventional alternative that could be used for construction; and the alternative conventional costs that would be used in place of an ABC alternative.

Develop an ABC cost-benefit analysis model and procedure to determine applicability of ABC in South Dakota. The third task of this project was to develop an ABC cost/benefit analysis procedure and tool to assess effectiveness of implementing ABC in South Dakota. The main deliverable of the entire project was to develop an evaluation tool for use by the SDDOT prior to the start of a bridge construction project to see if implementation of ABC would be beneficial, and what the options were on techniques, if ABC is to be implemented. The cost comparison with conventional methods is to be used in conjunction with several other key project condition inputs, i.e., daily traffic, detour length, etc., to calculate a single output indicator that ranks ABC applicability. This indicator is then used with decision-making flowcharts to determine whether or not ABC will be used for the construction project.

# 2. FINDINGS AND CONCLUSIONS

## 2.1 Literature Review

A comprehensive literature review was completed for the purpose of this project. The main purpose of the literature review was to obtain a list of ABC techniques that currently used in practice in the United States. The information gleaned from this literature review was used to develop ABC technique profiles to aid in defining what each ABC technique is and how the use of each is employed to save time during construction. A catalog that outlines existing ABC practices was constructed based on literature review results. Also, an ABC technique profile document was compiled to provide detailed description of each technique. The ABC catalog is available in Appendix D and ABC technique profiles are available in Appendix A.

### 2.1.1 Literature Review Reports

The purpose of the extensive literature review performed for this project was to summarize current ABC techniques implemented across the United States to-date. Several reports were studied to obtain this information, and the findings from these reports are summarized in this section. Several state DOT offices have also published reports on the ABC implementation projects completed in the past, with experiences gained through these implementations.

The ABC Manual (Culmo 2011) published by FHWA and USDOT was one of the main sources from which catalog information was gathered. The ABC Manual includes a vast amount of information pertaining to the use of ABC techniques in bridge construction, analysis of the ABC and PBES implementations currently used in practice, and recommendations for determining which sites would benefit most from the use of ABC techniques, as opposed to conventional construction on bridge projects. In addition, the manual also analyzes construction details of implementing ABC techniques and long term durability assessments completed that evaluate extended effectiveness of using precast elements instead of cast-in-place components. The ABC technique components implemented into current bridge construction practice are broken down into four main categories: materials, superstructure elements, substructure elements, and foundations elements.

Other sources used for this literature review include several reports or articles published by individual state DOT offices regarding the ABC projects conducted previously in each state. The report titled "One-Weekend Job Rapid Removal and Replacement of 4500 South Bridge in Salt Lake City, Utah" (Ardani et al., 2010) discussed a rapid removal and replacement of a bridge in Salt Lake City, Utah. The article discusses how the superstructure of the bridge was prefabricated off-site on temporary abutments. Additionally, the report discussed how the structure was closed for only one weekend to deconstruct the old bridge structure, construct the substructure of the bridge without any substantial interruption to traffic flow, and move the new bridge superstructure into place using advanced jacking systems and self-propelled modular transporters (SPMTs).

Another report titled "Accelerated Bridge Construction Applications in California—A Lesson Learned" (Chung et al., 2008) focused on seven projects conducted by Caltrans implementing ABC techniques. Four projects required emergency replacement construction, and therefore, the needs of the project were well-suited for implementation of ABC techniques. Additionally, the report discusses three more projects that planned to utilize ABC techniques from the time the project was initiated. Implementation of ABC techniques into all of these projects were discussed in addition to the lessons learned through the process of implementing the ABC techniques. The lessons learned are presented so the process can be more efficient and streamlined in the future. ABC techniques implemented into the projects included in this report are: precast girders, precast abutments, precast bent caps, and horizontal skidding. This report was used to populate the ABC catalog with specific information regarding the ABC techniques used on the projects included in the report.

The Texas Department of Transportation (TxDOT) published a report titled "Texas's Totally Prefabricated Bridge Superstructures" (Freeby 2005) that denotes projects in which TxDOT fully prefabricated the superstructure of the bridge and used an advanced ABC technique for placing the superstructure on supports and substructure of the bridge. The report focuses on benefits experienced by implementing this advanced type of placement, which include, but are not limited to, increased long-term quality of construction materials, increased work zone safety, minimized environmental impact, and minimized traffic disruption. Aside from presenting benefits of the use of ABC techniques, the report also discusses implementation of both steel tub girder designs and pretopped U-beam design.

The Washington State Department of Transportation (WSDOT) published a report (Khaleghi 2010) annotating the to-date use of ABC techniques in bridge construction in Washington State and outlining a plan for future use of ABC techniques in Washington. This report portrays the use of precast bent caps in bridge projects and specific connections details that were implemented throughout the course of construction. The report also discusses the use of a decision-making matrix to aid in determining what ABC techniques, if any, to incorporate into a bridge construction project. This report denotes the use of precast girders and beams, which have been used in Washington State since the 1950s, and details regarding the connection of girders to piers. The WSDOT's plan for the future use of ABC techniques in bridge construction is based on several factors that would affect decision-making for projects that may use ABC techniques. These factors were considered when determining inputs for the evaluation tool for this project.

The WSDOT additionally published a report titled "Use of Precast Concrete Members for Accelerated Bridge Construction in Washington State" (Khaleghi 2005), which further discusses the use of ABC techniques such as precast columns, bent caps, and girders/beams. This report focuses on the seismic applications of these precast elements and specialized connections used to ensure that structure joints can withstand seismic forces the state of Washington experiences. While seismic analysis is not of as much importance to South Dakota as it is to Washington State, this report was useful in that it provided additional performance details relating to the ABC techniques discussed in the report. These performance details aided in populating the ABC catalog.

In addition to the reports reviewed from state DOT projects that have successfully implemented ABC techniques, several of the literature review reports covered alternate aspects of the ABC process. One of the additional reports published by the FHWA titled "Connections Details for Prefabricated Bridge Elements and Systems" (Culmo 2009), outlines the general connections procedures used for the implementation of different ABC techniques. This document aided in developing the Connections Details column of the ABC catalog. Though the specific connections details for a given ABC technique will change depending on details of the bridge project, this manual specifies general techniques used for several ABC techniques that are included in the ABC catalog. The manual also specifies that the suggested connections details should not be directly used in the design of a bridge construction project, but rather the general guidelines provided in the manual should be adapted to meet the unique needs of ABC techniques used in the bridge construction project design.

Two reports included in this literature review are called "Manual on Use of Self-Propelled Modular Transporters" (FHWA 2007) and "Induced Stresses from Lifting and Moving Highway Bridges with Self-Propelled Modular Transporters" (Rasvall, Halling, Lindsey 2010). These two reports analyze the use of an advanced method of transporting newly constructed or replaced bridge superstructures into place called self-propelled modular transporters (SPMTs). The manual outlines basic guidelines that must be met when using SPMTs as an ABC technique on a bridge construction project, and offers general instructions and suggestions for successful use of the technique to maximize construction efficiency and safety. The report involving induced stresses discusses tolerances that must be met when using SPMTs—more specifically, how the stresses in the bridge superstructure will change when picking up and placing the bridge. These stresses can cause damage to the structure before construction is complete, and therefore, the report presents useful information for the purpose of this project.

Several other reports relating to alternate aspects of implementation of ABC techniques are as follows: "Application of Accelerated Bridge Connections in Moderate-to-High Seismic Regions" (Marsh, et al., 2011), "Framework for Prefabricated Bridge Elements and Systems Decision-Making" (FHWA 2005), "Guidelines for Accelerated Bridge Construction Using Precast or Prestressed Concrete Components" (PCI Northeast Bridge Technical Committee 2006), and "Selection of Durable Closure Pour Materials for Accelerated Bridge Construction" (Zhu, Ma 2010). These reports were reviewed to obtain additional information related to the ABC techniques researched to develop ABC technique profiles and catalog. Each of the reports discussed was used and thoroughly reviewed to develop a knowledge base about the ABC techniques currently employed throughout the United States. In addition, these reports inform the reader of several alternate aspects relating to use of ABC techniques to maximize the successful implementation of the techniques into current bridge construction practices throughout the country, which is the goal of the "Every Day Counts" initiative put into place by the FHWA.

### 2.1.2 ABC Catalog Structure

The first step in creating the ABC catalog for use by SDDOT for decision-making purposes was to develop a list of categories of interest to SDDOT and relating to each ABC technique. The catalog is organized in table form with each technique as a row and different information related to the technique listed in each column (see Appendix D). Some categories of information related to each technique that were commonly available from the literature review include: typical duration, special equipment, special site requirement, etc. Some information was found in the reports published by other state DOT offices regarding the ABC techniques implemented in each state. Other information was found in the manuals specifying connections and general ABC technique details. All possible categories of interest were compiled using the literature review to help construct structure of the catalog.

To further organize the catalog structure, ABC techniques that were researched were broken down into the following categories: substructure, superstructure, and placement. These categories represent the three main components of bridge construction. Additionally, many ABC-implemented projects encountered in the literature review would include ABC techniques on the superstructure alone, superstructure and placement combined, or a combination of superstructure, substructure, and placement—if placement techniques are utilized for the purposes of the superstructure ABC techniques. The previously discussed manual for ABC techniques published by the FHWA was useful in developing the catalog's structure. Information in the manual was organized in a similar manner, breaking bridge construction components into superstructure, substructure, and placement groups (ABC Manual 2011). The ABC techniques researched were then organized into categories and subcategories shown in Table 2.1.

**Table 2.1** Organization of ABC Techniques

| Category | Subcategory |
|---|---|
| Substructure | Abutments |
| | Caps |
| | Footings |
| | Miscellaneous Elements |
| Superstructure | Decks and Panels |
| | Girders/Beams |
| | Spans |
| Placement | N/A |

The information categories of interest to SDDOT finalized during the SDDOT interviews are displayed in Table 2.2. The benefits column was deemed necessary because it informs the user of positive effects on time savings, safety, quality assurance, etc., that are seen when the ABC technique in question is implemented into a project. Special equipment, crew experience, and site requirement denote any extenuating circumstances that must be in place prior to the successful implementation of the ABC technique. Connections details specify any unique connections information found through the research and interviews that would affect the implementation of the ABC technique. The potential problems column discusses current implementation challenges encountered by other state DOT offices that have implemented the ABC technique. Existing experience and other comments denote where the ABC technique has been used and additional comments made about the ABC technique, not relating to the other categories.

**Table 2.2** ABC Catalog Columns

| Category of Interest | Description |
|---|---|
| Benefit | The benefit of using a given ABC technique as opposed to conventional construction |
| Special Equipment | Any special construction equipment required for construction |
| Special Crew Experience | Any special experience that may be required of the contractor's crew (welding, specialty equipment operation, etc.) |
| Special Site Requirement | Any special requirement of the job site necessary for the ABC technique (precasting zone away from job site, etc.) |
| Connections Details | Any specified connections details specified for the ABC technique |
| Typical Duration | The duration of the ABC technique, as compared to conventional construction |
| Potential Problems | Any potential problems that have been recognized by other crews who have used the ABC technique in practice |
| Existing Experience | Any example projects that have employed the ABC technique |
| Other Comments | Additional comments gleaned from literature review or interviewees |

### 2.1.3 ABC Technique Profiles

The ABC catalog is presented in a table format with limited information related to the ABC techniques. It provides a brief description of each ABC technique and catalog information categories. An ABC technique profile document was developed based on literature review results. The ABC technique profiles include a brief description of the technique, the source of the information, and, when applicable, an example project and/or visual aid for the ABC technique. These profiles are to be used in conjunction with the ABC catalog to aid in decision-making when determining which ABC techniques to implement on a given bridge construction project. Even though each ABC technique has a description and a profile, it is important to remember that a given ABC technique may have more than one application, depending on details involved with the project in which the technique is being implemented. The layout and appearance of a sample ABC technique profile can be seen in Figure 2.1.

**Precast Bent Caps**

**Description:** A bent cap is the top horizontal portion of a bent that supports the superstructure of a bridge. Precast bent caps simply provide a way of precasting portions of each bent without prefabricating the entire bent away from the bridge site. Instead, the portions are brought to the job site and assembled in place.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** Lake Ray Hubbard Bridge, Dallas, TX


*Precast Bent Cap*
*http://www.fhwa.dot.gov/publications/publicroads/03nov/02.cfm*
*Accessed 23 Oct 2012*

**Figure 2.1** Example ABC Technique Profile

Creating these ABC technique profiles during the literature review process was essential to become familiar with ABC techniques and their uses. While the profiles are necessary for use by SDDOT in conjunction with the ABC catalog and evaluation tool, they also serve as educational tools that can be used to further understand the process of ABC and the ways in which ABC techniques can help revolutionize the bridge construction process in the United States. In addition, when example projects and visual aids are available, the profiles provide the advantage of being able to understand how the ABC techniques are implemented differently than conventional methods—not just the theory behind the advanced construction technique. The ABC technique profiles are attached to this report in Appendix A and can be viewed on the FTP website for this project.

## 2.2 ABC Catalog

The ABC catalog is a valuable source of information that includes specific details pertaining to each ABC technique. This information is intended to be used in conjunction with the ABC technique profiles and ABC evaluation tool to aid in determining which ABC techniques should be implemented into a given bridge construction project, if any are applicable. Due to a relatively short history of ABC implementation, some information sought was not available. Furthermore, the use and benefit of a certain

ABC technique is highly project dependent, therefore, it is difficult to develop related entry for such technique in a generalized catalog. However, the resulted catalog still provides an informative reference when comparing the use of ABC techniques to the use of conventional construction. The process of obtaining information to construct the catalog is described in the sections below.

### 2.2.1 SDDOT Interviews

After the ABC techniques were organized into appropriate categories and subcategories in the ABC catalog, feedback from the technical panel and relevant employees of SDDOT was requested through interviews, as this department is the end-user of the resulted procedure/tool. In November 2012, five members of SDDOT were interviewed to gather the applicability and current practice of ABC in South Dakota. Two were from the Bridge Design Office (BDO) and three from the Local Government Assistance Office (LGAO) (see Table 2.3). Interview questions were focused on information required for the development of the ABC catalog. The first concern was completeness of the catalog structure. The catalog structure was shown to DOT personnel to see if all ABC categories and information categories were complete. In addition, the SDDOT contacts were questioned concerning the current conventional construction practices employed in South Dakota and what the typical durations of these conventional methods might be for any given bridge construction project. The interview questions can be viewed in Appendix B.

**Table 2.3** SDDOT Interview Contacts

| SDDOT Office | Contact |
|---|---|
| Bridge Design Office (BDO) | Hadly Eisenbeisz |
| | Kevin Goeden |
| Local Government Assistance Office (LGAO) | Noel Clocksin |
| | Ron Bren |
| | Doug Kinniburgh |

Each of the interviews was based around two main queries. First, the interviewees were asked to comment on the completeness of the list of researched ABC techniques, adding or removing techniques where he or she found necessary. Second, the list of categories of interest pertaining to the ABC techniques developed during the literature review was discussed, and input was obtained from each interviewee concerning any necessary changes or revisions. Aside from these two main queries, the interviewees were questioned about what ABC techniques were currently employed at SDDOT and which ABC techniques were being considered for future construction projects at SDDOT. Additionally, each interviewee was also questioned about the current conventional construction methods and what the typical duration for traffic interruption is for this type of construction. The information was compiled to aid in developing the final structure of the ABC catalog, which can be viewed in Appendix D.

Based on the interview feedback, it was found that current implementation of the ABC techniques for bridge construction in South Dakota is minimal. Some prestressed girders and beams are used for construction of the superstructure of interstate and state highway bridges, and precast box culverts have been used since the 1980s, but the majority of substructure bridge elements are still completed using conventionally cast-in-place concrete construction. The use of prestressed girders can be used on bridge construction projects in high traffic volume areas, or in extremely remote locations where transporting fresh concrete would be substantially more expensive than using precast girders and beams. In addition, it was found that the list of ABC techniques compiled through literature review prior to the interviews was complete to the knowledge of those being interviewed at SDDOT. Other topics discussed in these interviews included an analysis of the decision-making process involved with bridge construction projects. For example, one of the questions posed to the interviewees asked how construction and engineering affect the decision-making process. This information was used to determine which sources should be used to obtain information further along in the project.

The most important query posed in these interviews concerned the information categories of interest to SDDOT relating to the ABC techniques. The answers were used to determine which categories of interest would become one of the columns in the ABC catalog. Prior to the interviews, a list of categories of interest was compiled to present to each interviewee. Then, each contact was asked to evaluate the list of categories to determine which ones were relevant, which ones were not, and any additional categories that should be included when evaluating potential use of ABC techniques on a bridge construction project. The results of this query yielded the final list of categories of interest pertaining to the use of ABC techniques in bridge construction (see Table 2.2). Each of these columns gives pertinent information pertaining to the ABC techniques listed in the rows of the catalog.

### 2.2.2 Other State DOT Interviews

After the structure of the catalog was finalized as a result of the SDDOT interviews, the process of populating the catalog with information began. This was the most time-consuming portion of the project because the process required several sources to be identified and interviewed. Some of the information needed for the catalog was found through literature review, while others were only available through existing project experiences. This is the reason a series of phone interviews were conducted with different DOTs who have past experiences using the ABC techniques. Table 2.4 shows the other state DOT offices that contributed information to this project and the respective contact(s) from each DOT office.

**Table 2.4** Other State DOT Contacts

| **State DOT Office** | **Contact(s)** |
|---|---|
| Utah (UDOT) | Josh Sletten, Carmen Swanswick |
| Texas (TxDOT) | Michael Hyzak |
| Minnesota (MnDOT) | Paul Rowekamp |
| Ohio (ODOT) | Tim Keller |
| Washington State (WSDOT) | Bijan Khaleghi, Ron Lewis |
| California (Caltrans) | Dorie Mellon |

SDDOT's research office helped in arranging interviews with other DOT contacts. Prior to the phone interviews, the contact at each DOT office was provided with a list of questions that were to be addressed during the interview. This aided the contacts in familiarizing themselves with information prior to the interview and saved time on both sides of the call. The questions list for each interviewee is listed in Appendix C.

The questions t posed in the interviews reflected the layout of the ABC catalog. For instance, if the ABC technique in question was fiber-reinforced polymer (FRP) deck panels, the contact would be asked about the benefit associated with the technique, as compared to conventional construction. Each column of the ABC catalog would be investigated in a similar manner for every ABC technique investigated. By using this method, the interviews commenced efficiently by simply filling in the blanks left in the ABC catalog after literature review. A downside to this interview method was that some of the information desired was not readily available from the DOT office alone, as the information pertained more toward the contracting or manufacturer side of construction. However, each of the contacts gave information when available, and the remaining blank cells were either given the notation "N/A" representing Not Applicable or "INF" representing Information Not Available. The completed ABC catalog can be viewed in Appendix D and on the FTP website for this project.

The Utah interview contacts were Josh Sletten and Carmen Swanswick. The ABC techniques investigated for which UDOT had experience were: precast spread footings, full-depth precast deck panels, lightweight precast deck panels, precast approach slabs, self-propelled modular transporters (SPMTs), and longitudinal launching. The contacts were then questioned about various categories of the ABC catalog as they relate to the ABC techniques being investigated. After the ABC techniques with which UDOT had experience were discussed in the interview, the contacts were then questioned about any information the office had relating to the ABC techniques list that could not be assigned to a specific state DOT experience. This "catch-all" list was sent to each DOT office interviewed to obtain as much information as possible and consists of the following techniques: spill-through abutments, integral abutments, prefabricated full height wall panels, continuous flight auger (CFA) piles, partial-depth precast deck panels, steel grid deck systems, precast box culverts, and barge use in construction. Finally, the contacts were questioned about the Accelerated Bridge Construction Analytical Hierarchy Process Decision Tool produced by the FHWA (FHWA 2012). The contacts were asked to give feedback on effectiveness and use of this tool. UDOT had concerns about the use of the FHWA tool due to the numerous and time-consuming inputs process. Instead, UDOT has developed a tool separate of the ABC AHP Decision Tool for the decision-making purposes of their office.

The Caltrans interview contact was Dorie Melon. The interview was set up similarly to the UDOT interview. The ABC techniques investigated for which Caltrans had experience were: precast abutments, precast I-girders, precast bulb-T girders, and precast box girders. After the ABC catalog categories were covered and the catalog populated fully as possible, Mellon was also questioned about the "catch-all" list of ABC techniques mentioned previously. Feedback was offered where possible, and offered concerning the ABC AHP Decision Tool produced by FHWA. Caltrans had concerns about the decision tool, stating that the tool was advertised to be a quantitative analysis tool that seemed to be much more qualitative when used in practice. Caltrans also had the concern that the input process is subjective and different outputs may result from the input of different users.

The TxDOT interview contact was Michael Hyzak. The ABC techniques investigated for which TxDOT had experience were: precast bent caps, proprietary retaining wall systems, precast double-T beams, and pretopped U-beam design. Similar to the other interviews, each category of interest from the ABC catalog (see

**Table**) was investigated concerning techniques with which TxDOT has experience and the "catch-all" list of ABC techniques previously discussed. Available feedback obtained was added to the ABC catalog. When asked about the effectiveness of the ABC AHP Decision Tool, TxDOT did not have much feedback to offer, as TxDOT does not often need a process for deciding between the use of ABC and conventional construction. However, TxDOT is of the opinion that the tool has promising potential for the process of decision-making when determining whether or not to use ABC for a given bridge construction project.

The ODOT interview contact was Tim Keller. The ABC techniques investigated for which ODOT had past experience were: fiber reinforced polymer (FRP) deck panels, geosynthetic reinforced soil (GRS) abutments, and horizontal skidding/sliding. Additionally, ODOT offered feedback on the spill-through abutments and integral abutments from the "catch-all" list of ABC techniques. Feedback obtained from questions concerning the ABC techniques was then added to the ABC catalog. When asked about the effectiveness of the ABC AHP Decision Tool, ODOT did not have a use for the tool due to the fact that the program bases decision-making around the duration and timeline of the entire project, while the decision process in use by ODOT is based around the critical path of the bridge construction project being considered for ABC.

The MnDOT interview contact was Paul Rowekamp. The ABC techniques investigated for which MnDOT had experience were: precast inverted-T beams, arch span without deck, and barge use. Rowekamp also offered feedback on integral abutments and precast box culverts from the "catch-all" list of ABC techniques. The information obtained relating to these ABC techniques was added to the ABC catalog, and then the effectiveness of the ABC AHP Decision Tool was discussed. MnDOT took part in the development of the tool along with many other state DOT offices; however, MnDOT would most likely not have a use for the tool because the input process was too complicated and time-consuming for use of the tool to be efficient and effective.

Finally, the WSDOT interview contact was Ron Lewis. Ron Lewis was referred as the interview contact by Bijan Khaleghi, who authored two of the literature review reports used for the purpose of this project. The ABC techniques investigated for which WSDOT had experience were: prefabricated full height wall panels, proprietary retaining wall systems, precast box culverts, partial-depth precast deck panels, and steel grid deck systems. After feedback was obtained pertaining to the ABC catalog categories of interest, the information was added to the ABC catalog. Use of the ABC AHP Decision Tool was then discussed. The feedback offered suggested that the tool was not effective for use by the WSDOT office because every project is site specific, and so many of the input factors included in the decision tool were not applicable to WSDOT. WSDOT applies limits to when and where traffic can be closed, and works only around those parameters to determine what needs should be met through the use of ABC techniques.
The process of obtaining appropriate cost information proved to be the biggest challenge of populating the ABC catalog. Even after the catalog was considered as complete as possible, much of the cost information included was relatively compared to conventional costs (i.e., 2-3 times conventional cost, same as the conventional cost, etc.). The information is relative because most of the cost information for each ABC technique was considered to be heavily project dependent. For instance, there can be vastly different costs for precast elements depending on how far they are being transported. The cost information obtained was so relative that it was deemed necessary to contact local manufacturers and contractors in South Dakota to ensure local cost information.

### 2.2.3 User-Friendly Format

Throughout the process of populating the ABC catalog, the vast amount of information included posed the challenge of how to better organize the information for user-friendliness. User-friendliness is an important quality because simplicity and efficiency are beneficial for effectiveness of the ABC catalog. Otherwise, traversing through the catalog becomes a time-consuming chore for whoever is using it. The greatest priorities for SDDOT for this project were simplicity and efficiency. The ABC catalog has many columns and rows, and viewing all the information at once can be cumbersome. Therefore, a user-friendly version of the ABC catalog had to be created.

The catalog information was compiled into a pivot table using Microsoft Excel® to provide a user-friendly interface. Pivot tables allow the catalog user to apply information filters that narrow down the information of interest. The use of a pivot table is similar to the use of a Microsoft Access® database, but without the requirement of having to call for items or categories specifically by name. Some minor issues arose when creating the pivot table with the proper alignment and organization, but the determination was made that the pivot table was the better alternative for the development of a user-friendly ABC catalog. Figure 2.2 portrays an example of the user-friendly pivot table with the dropdown filters applied.

| | |
|---|---|
| Type of Construction | Accelerated Bridge Construction |
| Category | Substructure |
| Subcategory | Abutments |

| ABC Techniques | Benefit | Special Equipment | Special Crew Experience |
|---|---|---|---|
| **Precast Abutments** | **Time-saving, unnecessary detours avoided** | Specialty heavy load crane used for installation | Special permit trucks required |
| **Geosynthetic Reinforced Soil (GRS) Abutments** | **Eliminates settlement between abutment and approach backfill; limited equipment required, takes little technical ability to construct, material easy to warehouse** | N/A | N/A |
| **Integral Abutments** | **Can be built very quickly, are inexpensive, and eliminates joints; there are no physical expansion joints due to the abutment pieces physically moving** | N/A | N/A |
| **Precast Pier Box Cofferdams** | **Time savings due to precasting vs. CIP** | INF | INF |
| **Spill-Through Abutments** | **Reduces soil pressure on cantilever abutments** | INF | INF |

**Figure 2.2** Example of User-Friendly Pivot Table

## 2.3 Cost Information

One of the biggest challenges of this project was obtaining cost information relating to the researched ABC techniques that can be applied to South Dakota local construction. The cost information required for development of the ABC evaluation tool can be broken down into three categories: 1) conventional bridge construction costs, 2) user costs due to traffic interruption applied to the travelling public, and 3) change in cost of construction due to the use of ABC techniques. The current averages for conventional bridge construction costs were obtained from the Bridge Design Office at SDDOT and were used to aid in estimating the cost difference of using ABC techniques on a given bridge construction project. User costs are an important factor to take into account when making the decision to use either ABC techniques or conventional construction because substantially lowered user costs correspond to significant savings for the travelling public. The greatest reduction in costs due to the use of ABC techniques in bridge construction will be seen in the user cost category. The cost estimating for ABC was broken into costs related to three categories: substructure, superstructure, and placement.

### 2.3.1 SDDOT Conventional Construction Costs

Currently, the Bridge Design Office at SDDOT has not implemented many ABC techniques into their bridge construction. However, SDDOT has been routinely using prestressed/precast bridge girders and beams and precast box culverts for several decades. SDDOT Bridge Design Office and the Bid Letting Office maintained an access database containing current conventional bridge construction costs from 2004 to 2013. To incorporate this conventional cost data into the project, average costs per square foot of bridge were determined based on bridge type. The Access database contained cost information on the following bridge types: prestressed girder bridges, steel girder bridges, and continuous concrete bridges. A bridge construction project at SDDOT has three types of cost information: 1) total bridge cost, 2) mobilization costs, and 3) traffic control costs. The total bridge cost involves those costs relating to materials and construction for the bridge elements used. The mobilization costs are those costs incurred from transporting equipment and materials to the job site. Finally, traffic control costs refer to those costs incurred from diverting traffic onto detours away from the affected bridge construction site. The Access database was used to determine these three components of cost information. These costs were then combined and divided by the total area of the bridge construction project to obtain total cost per square foot of the bridge. An assumption made during the process of cost estimation is that mobilization and traffic control costs are the same on each structure of a project. For example, if a total construction project consisted of two (2) new bridge structures and eight (8) new culvert structures with a total mobilization cost of $100,000, then it is assumed that the mobilization cost is divided equally among the ten (10) structures, or $10,000 per bridge. This assumption was made because there was no detailed information on the mobilization and traffic control related costs provided by SDDOT.

Some complications are associated with the conventional cost estimating process. The prestressed girder bridge type involves implementation of ABC techniques and therefore cannot be considered completely conventional construction. The purpose of identifying average conventional costs of bridge construction in South Dakota is to estimate the total cost of a construction project if the approximate added or reduced cost of using ABC techniques on a bridge project is available. If some of the ABC techniques are already incorporated into conventional cost, then any additional cost due to ABC techniques—if not properly accounted for—would be overly conservative, thereby resulting in an output that would be less likely to recommend ABC implementation.

The data used for estimating conventional cost were obtained from thirty-one (31) total bridge construction projects. Seven (7) of these projects consisted of steel girder bridge construction projects, while ten (10) of the projects were continuous concrete bridge construction projects, and fourteen (14) were prestressed girder bridge construction projects. In Table 2.5, the average, minimum, and maximum cost per square foot is displayed based upon the data obtained from these thirty-one (31) bridge construction projects. All project data used for these average costs are attached to this report in Appendix E.

**Table 2.5** Average, Minimum, and Maximum Conventional Construction Costs

| Bridge Type | Average Cost/SF | Minimum Cost/SF | Maximum Cost/SF |
|---|---|---|---|
| Steel Girder | $145.04 | $80.12 | $160.48 |
| Continuous Concrete | $175.18 | $87.97 | $188.56 |
| Prestressed Girder | $132.48 | $66.76 | $195.03 |

### 2.3.2 Daily Road User Costs

Determining the agency user costs for a bridge construction project assigns a monetary value to interruption of the travelling public during construction. The user cost for a given project primarily depends on the following factors: average annual daily traffic, the out-of-distance travel (detour length for the project), accident rates for the project site, crash modification factors (CMF), and a mileage rate assigned by the Federal Highway Administration (FHWA). These basic construction project inputs can be used to determine user cost for a given project. Any of the above listed factors can change significantly from project to project, even if the exact same construction components and techniques are being used. Therefore, user costs are hard to generalize and should be determined for each project individually.
Two basic methods are used for determining the user cost of a project for the purpose of this research study. The first method is a simplified calculation that can be easily done with limited inputs. This method involves the use of an empirical formula to calculate approximate daily user costs associated with a project based on four input parameters: average annual daily traffic (AADT), average daily truck traffic (ADTT), out-of-distance travel (OODT), and the FHWA assigned mileage rate, which is currently set at 37.5 cents per mile as of 2012. This empirical formula for calculating the daily road user cost (DRUC) for a project is displayed in Equation 2.1.

$$DRUC\ (\$) = (AADT + 2 * ADTT)(OODT)(Mileage\ Rate) \qquad \text{Equation 2.1}$$

This empirical formula was adopted from literature obtained from the Iowa DOT, whose evaluation tool was also referenced in this study. The average daily truck traffic was tripled in Equation, according to a recommendation from Iowa DOT. The purpose of this operation is to obtain a conservative estimate in accounting for the amount of commercial truck traffic. The largest portion of the user costs is from commercial trucks.

The second method for calculating daily road user costs is a detailed cost estimation that is only done for projects with higher potential of benefitting from the use of ABC techniques. In a previous research project managed by SDDOT (Qin and Cutler 2013), a SDSU Road User Cost Tool was developed by researchers at SDSU. This tool uses detailed information related to a construction project to calculate user cost due to traffic interruption including traffic, detour, speed, and accident information. An average daily cost can be calculated. Then, project duration can be used to calculate total cost incurred to the public by the project. The inputs to this tool are much more involved, but the results are more accurate. A more detailed description of the theory and use of this detailed user cost estimation tool can be found in the final report of Project SD2011-05, "Road User Costs and Methods." By using both the empirical formula and the SDSU Road User Cost Tool, daily road user costs can be determined with different levels of accuracy and then can be compared to the added cost related to the use of ABC techniques.

### 2.3.3 Change in Cost of Using ABC Techniques

Out of the three types of cost information obtained for use by this project, the change in cost of implementing ABC techniques in South Dakota was the most difficult to estimate due to the lack of experience of ABC in SD. As each project can have a unique nature that affects implementation, it is nearly impossible to assign a universally applicable additional cost of using a specific ABC technique. For example, the transport cost of precast bridge elements to the construction site for the project will vary depending on distance the precast elements must travel before arrival at the job site. In addition, some of the ABC techniques require specialty load cranes for installation of larger precast bridge elements; the transport and usage costs of these specialty cranes can vary, depending on how far the crane must be transported and how long it will be used for the bridge construction project.

Due to complications encountered throughout the process of attempting to approximate change in cost of using the ABC techniques investigated, a simplified solution was proposed. This procedure includes breaking the costs down into three main categories: price of the materials used to construct the ABC techniques, price of installation at the project site, and alternate cost of labor based on the time saving from ABC techniques. These categories are estimated based upon information obtained from manufacturers, contractors, and transporting companies. Precast concrete companies in South Dakota were surveyed about approximate cost of implementing ABC techniques using precast components. Both Gage Brothers and Cretex Concrete Products provided feedback regarding current prices for precast girders and beams, which are routinely used in South Dakota bridge construction and considered an ABC component. The information collected was not complete due to the lack of some ABC techniques in South Dakota to date, such as precast spread footings, precast bent caps, prefabricated columns, integral abutments, precast abutments, and precast approach slabs.

The information obtained from Gage Brothers and Cretex Concrete Products was analyzed to determine average cost per linear foot of all precast beams and girders and converting this value to a cost per cubic foot. This conversion was based on geometry of the girders' and beams' cross sections. For example, if a beam was $150 per linear foot and a cross section of three square foot, the cost per cubic foot would be $50. By using this method, an average cost of $30-40 per cubic foot was found for the purposes of estimating the cost of using precasting concrete. This per cubic foot cost was applied to all precast bridge elements produced in this study. It should be noted that this value is only an approximation instead of the actual cost of producing components for each ABC applications, as actual value differs depending on conditions in each project.

Once the materials costs were approximated on a per cubic foot basis for the precasting construction of the ABC techniques, transporting costs and contracting costs were determined. This information was primarily obtained through a survey of South Dakota local contractors. A meeting was conducted with Mr. Jared Gusso of Sioux Falls Construction to determine approximate change in cost due to implementing ABC techniques into bridge construction projects in South Dakota. Mr. Gusso stressed that the information provided was simply an approximation, as the change in cost of using ABC techniques will be project-specific. During the interview, information obtained included any additional equipment that would be used for the implementation of ABC techniques and reduced labor costs resulting from quicker construction was determined. For instance, if the ABC technique in question is precast bent caps, the technique requires a specialty load crane for installation, which will incur additional transport and operation costs. However, due to the more rapid and efficient installation of the bent cap that results from not having to cast the concrete in place, the contractor for the project would use approximately half the labor needed for the CIP alternative. Each technique was addressed in this manner, and the approximate costs for transport and labor was recorded. Transportation costs for materials and the specialty crane usage and operation will change depending on where the construction project is located in the state of South Dakota. For a construction project located west of the Missouri River, a specialty crane will most probably be rented from Denver, Colo. For a construction project located east of the Missouri River, the crane transport will most probably be from Omaha, Neb. In addition, materials being transported will have different distances to travel depending on where they are being shipped in the state.

Two analysis methods were available for SDDOT to determine overall change in cost of using ABC techniques over conventional bridge construction. The first option involves the Bridge Design Office obtaining a detailed bid from the contractor for the project using ABC techniques, where applicable. This would result in a more accurate estimate of the difference between the conventional construction costs. This option will be used for projects that have advanced to the bidding process after it has been determined that ABC techniques will be beneficial after initial consideration. The second option is suitable for initial planning, which uses an approximate formula related to the level of using ABC techniques. Level of implementation depends on the contractor’s choice to use ABC techniques for the substructure only, the substructure and superstructure, or the substructure, superstructure, and placement techniques. Because ABC techniques relating to placement methods are generally used for superstructure ABC techniques, the combination of only substructure and placement is not considered. This simplified method uses approximate ranges of ABC technique implementation costs, rather than the specific quotes to compare ABC and conventional options. A cost catalog displaying approximate materials, contractor, transport, and equipment costs (for the approximate method) is attached in Appendix F and on the FTP website for this project.

## 2.4 Design of Evaluation Tool

An ABC evaluation tool developed in this study will allow SDDOT to evaluate applicability of ABC techniques for any given project. The purpose of the tool is twofold: 1) to use a simplified procedure to eliminate projects that are definitely not suitable for ABC with a simplistic approximate procedure, and 2) to use a more detailed procedure to provide quantitative evaluation for projects that do show some potential for ABC implementation. The process developed was a two-stage evaluation. The first stage eliminates projects with little to no applicability for ABC implementation. The second and more rigorous stage determines on a more detailed level if ABC implementation should be used for a given construction project that had been determined in the first stage of the evaluation process to have potential for ABC implementation.

### 2.4.1 Existing Tools

The process of designing the ABC evaluation tool for SDDOT involved the study of three existing tools developed by other agencies: 1) the ABC AHP (Analytical Hierarchy Process) Decision Tool published by FHWA (FHWA 2012), 2) the ABC decision-making process used by UDOT (UDOT 2010), and 3) the ABC decision-making process used by Iowa DOT (Iowa DOT 2012). These three evaluation tools were all considered when developing the design of the evaluation tool for SDDOT, and a portion of the design of each was incorporated into the final evaluation tool. Each evaluation tool and its role in influencing the final design of the evaluation tool for SDDOT is discussed.

#### 2.4.1.1 ABC AHP Decision Tool

The ABC AHP Decision Tool (FHWA 2012) was the result of a collaborative effort funded by many agencies, including several state DOT offices across the nation. This tool was to provide a process for those state DOT offices that had not yet implemented ABC techniques into current bridge construction practice. The process was to assess potential bridge construction projects and the applicability of each toward implementing ABC techniques into construction. The AHP process involves three basic steps. The first is to establish relative importance between the inputs being used for the evaluation process. The second step is to rank each input in each category according to whether the input is better served by ABC or conventional construction. The final step involves the Analytical Hierarchy Process (AHP) calculations, which produce an output value used for the purposes of deciding to use either ABC techniques or conventional construction for the project.

For the first step, basic inputs included in the program are shown in Table 2.6, denoted by category and subcategory. If desired, unique hierarchies of inputs can be developed to customize use of the tool to the agency using the tool. This option is considered to be a benefit of using the ABC AHP Decision Tool, because inputs used for the program can be changed based on priorities of the agency using the tool.

**Table 2.6** ABC AHP Decision Tool Inputs (FHWA 2012)

| **Category** | **Subcategory** |
|---|---|
| Direct Costs | Construction |
| | Maintenance of Transport |
| | Design and Construct Detours |
| | Right of Way |
| | Project Design and Development |
| | Maintenance of Essential Services |
| | Construction Engineering |
| | Inspection and Maintenance and Preservation |
| | Toll Revenue |
| Indirect Costs | User Delay |
| | Freight Mobility |
| | Revenue Loss |
| | Livability During Construction |
| | Road Users Exposure |
| | Construction Personnel Exposure |
| Schedule Constraints | Calendar or Utility or RxR or Navigational |
| | Marine and Wildlife |
| | Resource Availability |
| Site Constraints | Bridge Span Configurations |
| | Horizontal/Vertical Obstructions |
| | Environmental |
| | Historical |
| | Archaeological Constraints |
| Customer Service | Public Perception |
| | Public Relations |

Table 2.6 illustrates the vast number of inputs used when operating the ABC AHP Decision Tool. These inputs are used to establish relative importance by the use of pairwise comparison. Pairwise comparison involves the use of a double-sided scale comparing the subjective judgment of the relative importance of the two alternatives. For example, if the user would like to compare User Delay against Freight Mobility in the Indirect Costs category, the user must select an option on the double-sided scale shown in Figure 2.3.

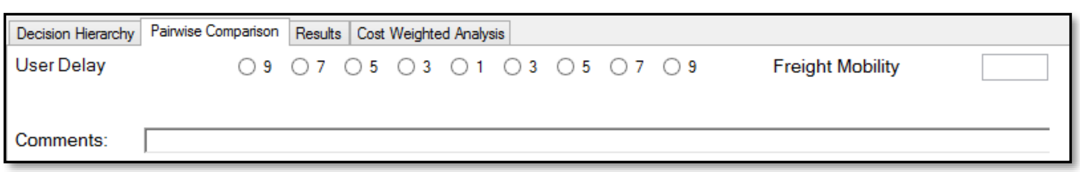


**Figure 2.3** Pairwise Comparison of Inputs (FHWA 2012)

Selection of option "9" on the User Delay side of the scale means that User Delay is far more important than Freight Mobility. Different levels of importance can be assigned to each comparison. If User Delay is only slightly more important than Freight Mobility, the option "3" on the User Delay side would be selected. If the two inputs are considered to be of the same relative importance, the middle option "1" is selected. This process is repeated for each subcategory within each category. Additionally, each main category of inputs is relatively compared against the others to establish additional relative importance.

For the second step, after the pairwise comparisons have been completed, each of the subcategories within each category of inputs is ranked on the same double-sided scale; however, one side of the scale represents ABC and the other end represents Conventional Construction. Figure 2.4 shows an example displaying the subcategory Construction of the category Direct Costs and the request posed to the user to establish if the portion of the project in question is better served through the use of ABC or conventional construction.

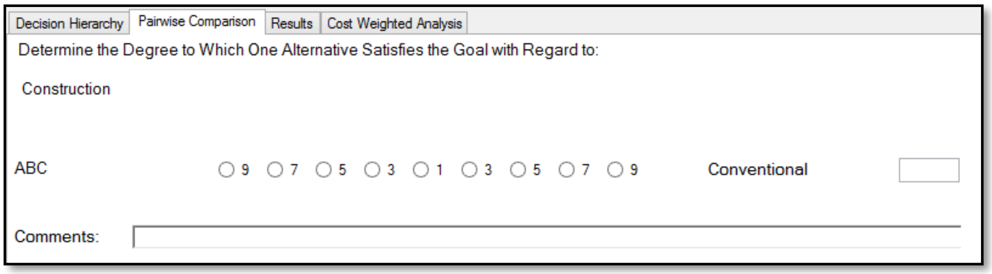


**Figure 2.4** ABC/Conventional Construction Ranking (FHWA 2012)

After this process has been completed for every subcategory in every category, the evaluation process can move to the final step, which uses AHP theory to determine if ABC techniques should be used for the bridge construction project being considered. While this process is comprehensive and requires a vast amount of user input options, the main goal of SDDOT from the beginning of the project was to develop a simple evaluation tool. The input process would simply take too long to feasibly complete for every bridge construction project run through the Bridge Design Office, especially when the user considers that the majority of projects based in South Dakota will not have much applicability for the use of ABC techniques. Additionally, feedback was obtained during the other state DOT office interviewing process about the decision-making tool produced by FHWA (see Appendix C). Many interviewees expressed concerns about efficiency of using the tool due to the complexity of the inputs. The recommendation of many of these contacts was to develop an easier, more simplistic decision-making tool with much less detail and time-consuming inputs.

#### 2.4.1.2 UDOT Decision Tool

The second tool referenced when developing design of the ABC evaluation tool was the decision-making process used by the Utah Department of Transportation (UDOT). Utah was one of the first states in the United States to begin implementing ABC techniques as an alternative to conventional bridge construction. Because UDOT has extensive experience with ABC implementation, the decision-making process in use at UDOT was a beneficial reference for the aiding customization of a decision tool for SDDOT. The UDOT tool involves eight basic inputs as displayed in Figure 2.5. These inputs are entered within given ranges. For example, if the average daily traffic through a given construction project is 17,000 per day, the input for average daily traffic would be a 4 on a scale from 0 to 5.

Enter values for each aspect of the project. Attach applicable supporting data.

| | | | |
|---|---|---|---|
| **Average Daily Traf** Combined on and under Enter 5 for Interstate Highways | 5 | 0 | No traffic impacts |
| | | 1 | Less than 5000 |
| | | 2 | 5000 to 10000 |
| | | 3 | 10000 to 15000 |
| | | 4 | 15000 to 20000 |
| | | 5 | More than 20000 |
| **Delay/Detour Time** | 2 | 0 | No delays |
| | | 1 | Less than 5 minutes |
| | | 2 | 5-10 minutes |
| | | 3 | 10-15 minutes |
| | | 4 | 15-20 minutes |
| | | 5 | More than 20 minutes |
| **Bridge Classificati** | 1 | 1 | Normal Bridge |
| | | 3 | Essential Bridge |
| | | 5 | Critical Bridge |
| **User Costs** | 4 | 0 | No user costs |
| | | 1 | Less than $10,000 |
| | | 2 | $10,000 to $50,000 |
| | | 3 | $50,000 to $75,000 |
| | | 4 | $75,000 to $100,000 |
| | | 5 | More than $100,000 |
| **Economy of Scale** (total number of spans) | 2 | 0 | 1 span |
| | | 1 | 2 to 3 spans |
| | | 2 | 4 to 5 spans |
| | | 3 | More than 5 spans |
| **Use of Typical Det** | 1 | 1 | Complex geometry or unfavorable site conditions |
| | | 3 | Some complexity, but favorable site conditions |
| | | 5 | Simple geometry and favorable site conditions |
| **Safety** | 5 | 1 | Short duration impact with simple MOT scheme |
| | | 2 | Short duration impact with multiple traffic shifts |
| | | 3 | Normal duration impact with multiple traffic shifts |
| | | 4 | Extended duration impact with multiple traffic shifts |
| | | 5 | Extended duration impact with complex MOT scheme |
| **Railroad Impacts** | 0 | 0 | No railroad or minor railroad spur |
| | | 3 | One mainline railroad track |
| | | 5 | Multiple mainline railroad tracks |

**Figure 2.5** Inputs for UDOT Decision Process (UDOT 2010)

Each input is then given a predetermined weighting factor, which can either be kept constant through all the projects or changed for specific projects if the need arises. Then, based on inputs and predetermined weighting factors, an output indicator is calculated for the bridge construction project. A section in the decision tool also allows for construction and user costs of two different alternatives for construction to be completed and used for decision-making with the output indicator. The predetermined weighting factors, output indicator, and cost considerations sections of the decision tool are displayed in Figure 2.6.

Note: Do not adjust weight factors without prior consultation with UDOT Structures Division Project Manager

| ABC RATING SCORE FACTORS AND WEIGHTS | | | | | |
|---|---|---|---|---|---|
| | Score | Weight Factor | Adjusted Score | Maximum Score | Adjusted Score |
| Average Daily Traffic | 5 | 10 | 50 | 5 | 50 |
| Delay/Detour Time | 2 | 10 | 20 | 5 | 50 |
| Bridge Classification | 1 | 5 | 5 | 5 | 25 |
| User Costs | 4 | 10 | 40 | 5 | 50 |
| Economy of Scale | 2 | 3 | 6 | 3 | 9 |
| Use of Typical Details | 1 | 3 | 3 | 5 | 15 |
| Safety | 5 | 10 | 50 | 5 | 50 |
| Railroad Impacts | 0 | 5 | 0 | 5 | 25 |
| | | Total Score | 174 | Max. Score | 274 |

**ABC Rating Score: 64**

The ABC Rating Score is driven by the four most heavily weighted factors: Average Daily Traffic, Delay/Detour Time, User Costs and Safety. For a detailed explanation, review the narrative on page 4 of the ABC Decision Making Process.

**Cost Considerations:**

Calculate the following costs for use in determining the lowest total project cost

| TOTAL PROJECT COST EVALUATION | | |
|---|---|---|
| | Alternative #1 | Alternative #2 |
| Construction Costs | $2,500,000 | $3,000,000 |
| User Costs | $1,000,000 | $250,000 |
| **Total Project Cost** | **$3,500,000** | **$3,250,000** |

**Figure 2.6** UDOT Output and Cost Information (UDOT 2010)

Based on the output indicator, a flowchart is used to determine next steps needed for the project. At this point, the decision is made whether or not to implement ABC techniques into the bridge construction project. This flowchart is shown in Figure 2.7.

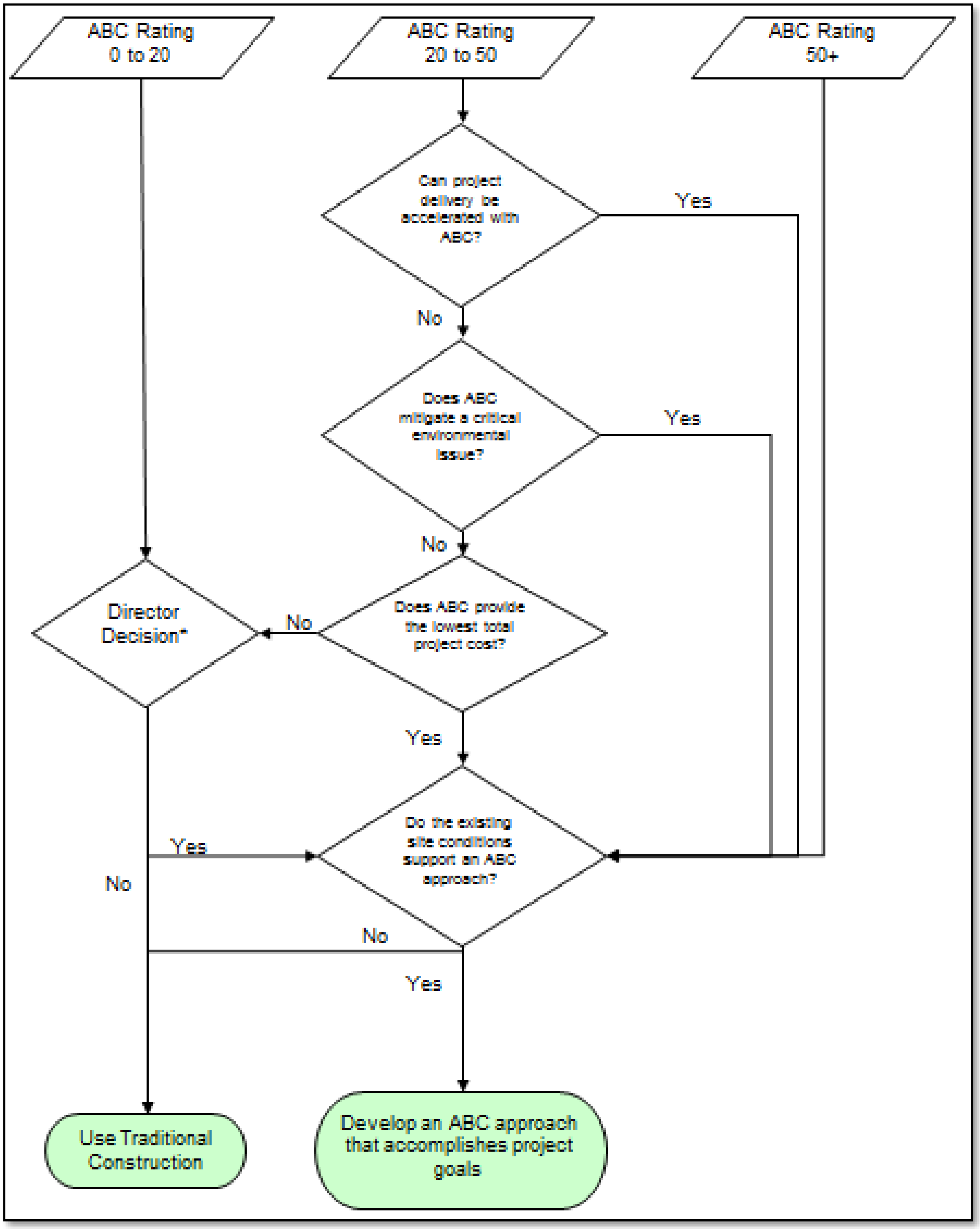


**Figure 2.7** UDOT Flowchart for Decision-Making (UDOT 2010)

The UDOT Decision Tool provides the simplicity that was a priority of SDDOT in the current project. However, for many low-traffic volume bridges in South Dakota, there is little to no incentive to use ABC techniques. The UDOT Decision Tool cannot be used directly since it does not provide a method for eliminating those projects with low potential for ABC technique implementation. By simply eliminating sites that are apparently not applicable for ABC, the evaluation process for SDDOT can become more efficient, because the majority of the bridges in South Dakota will have low potential for the application ABC techniques. Running a lengthy analysis on every project would not be a time-efficient method of performing the evaluation.

#### 2.4.1.3 Iowa DOT Decision Tool

The Iowa DOT possesses a two-stage decision-making process designed to eliminate those projects that have little to no applicability for ABC technique implementation during the first stage. The process then involves sending only those projects that have a substantial chance for feasible ABC technique implementation through a second, more rigorous decision-making stage that will aid in determining the extent of the ABC techniques implementation. A phone interview was completed with Ahmad Abu-Hawash of the Iowa DOT to obtain specific information regarding this two-stage evaluation procedure. An ABC policy document was obtained, which further explained the process Iowa DOT completes when evaluating projects for their applicability for ABC techniques.

The first stage of the decision-making process for the Iowa DOT involves a process similar to the UDOT Decision Tool process. The first stage involves five basic inputs with predetermined weighting factors, which are presented in Figure 2.8.

### Concept Measure Scores

| Concept Measure | Value | Score | Score range | Criteria |
|---|---|---|---|---|
| **Average Annual Daily Traffic** | Combined value of 100% on and 25% under = 18,300 | 4 | 0 | No traffic impacts |
| | | | 1 | Less than 5000 |
| | | | 2 | 5000 to less than 10,000 |
| | | | 3 | 10,000 to less than 15,000 |
| | | | 4 | 15,000 to less than 20,000 |
| | | | 5 | 20,000 or more |
| **Out of Distance Travel** | Value in miles = 9 | 2 | 0 | No detour |
| | | | 1 | Less than 5 |
| | | | 2 | 5 to less than 10 |
| | | | 3 | 10 to less than 15 |
| | | | 4 | 15 to less than 20 |
| | | | 5 | 20 or more |
| **User Costs** | Value in $ = $76,585.50 | 4 | 0 | No user costs |
| | | | 1 | Less than $10,000 |
| | | | 2 | $10,000 to less than $50,000 |
| | | | 3 | $50,000 to less than $75,000 |
| | | | 4 | $75,000 to less than $100,000 |
| | | | 5 | $100,000 or more |
| **Economy of Scale** | Value is total number of spans = 3 | 1 | 0 | 1 span |
| | | | 1 | 2 or 3 spans |
| | | | 2 | 4 or 5 spans |
| | | | 3 | 6 spans or more |

### ABC Rating Score Factors and Weights

| Concept Measure | Score | Weight Factor | Adjusted Score | Maximum Score | Adjusted Score |
|---|---|---|---|---|---|
| Average Annual Daily Traffic | 4 | 10 | 40 | 5 | 50 |
| Out of Distance Travel | 2 | 10 | 20 | 5 | 50 |
| User Costs | 4 | 10 | 40 | 5 | 50 |
| Economy of Scale | 1 | 5 | 5 | 3 | 15 |
| | | Total Score | 105 | Max. Score | 165 |
| | | Calculated ABC Rating Score | 64 | | |
| | | **ABC Rating Score** | **64** | | |

**Figure 2.8** Iowa DOT Stage One Inputs, Weighting Factors, and Output (Iowa DOT 2012)

As can be seen in Figure 2.8, the inputs function similarly to that of the UDOT Decision Tool with similar ranges of input values. Then, predetermined weighting factors are used, assigning an importance to each input relative to one another. Then, the same mathetical operations are completed to obtain the ABC Rating Score. For the Iowa DOT evaluation process, any bridge construction project yielding an ABC Rating Score of less than 50 is recommended for conventional construction techniques only. Any bridge construction project yielding an ABC Rating Score of 50 or higher is sent through a decision-making flowchart, which can yield two output options: 1) proceed with conventional cosntruction or 2) send the prospective bridge construction project through the second stage of the decision-making process.

The second stage of the decision process for the Iowa DOT involves the same ABC AHP Decision Tool inputs previously discussed. The Iowa DOT only completes the rigorous and time-consuming process of using the ABC AHP Decision Tool for those projects that have already exhibited strong potential for the use of ABC techniques in the project construction. However, because the evaluation tool for SDDOT was requested to be simplistic and easy to use, the second stage of the Iowa DOT Decision Tool would not be an ideal method per-SDDOT needs.

### 2.4.2 Customized Tool for SDDOT

Based on SDDOT recommendation, the decision was made to develop a two-stage decision-making process tailored to perform both o functions when evaluating a bridge construction project. However, because of the disadvantages associated with the use of the ABC AHP Decision Tool, a recommendation was made to develop a second stage similar to that of the first stage, but with more detailed inputs. This procedure is beneficial to SDDOT because a small volume of potential bridge construction projects will be sent through the second stage of the evaluation tool, and therefore inputs for the second stage of the process can be more detailed and require more time for completion. Each stage of the evaluation tool will be explained on two levels: the structure of the tool and the evaluation mechanism of the tool.

#### 2.4.2.1 Evaluation Tool Structure

The structure of each stage of the evaluation tool is similar to the structure of the UDOT Decision Tool. Inputs for each stage were developed based on those inputs used by the reference tools considered when developing design of the evaluation tool for SDDOT. After inputs for each stage of the decision-making process were developed, an additional meeting for feedback was conducted with the technical panel for this project at SDDOT. Based on feedback of the panel, the inputs used for each stage of the decision-making process and a brief description for each type of input are listed in Table 2.7.

**Table 2.7** Customized Tool Inputs and Descriptions

| Stage | Input | Description |
|---|---|---|
| **One** | Average Annual Daily Traffic (AADT) | Combined value of 100% on and 25% under the bridge structure |
| | Out of Distance Travel (OODT) | Detour distance in miles |
| | Daily Road User Costs (DRUC) | Empirical formula shown in Equation 2.1 |
| | Economy of Scale (EOS) | Total number of spans in a project |
| **Two** | Direct Costs (DC) | Information obtained in Section 2.3.3 |
| | Indirect Costs (IC) | SDSU Road User Cost Tool |
| | Non-ABC Conventional Costs (NCC) | Information obtained in Section 2.3.1 |
| | Schedule Constraints (SchC) | i.e. emergency repairs, seasonal deadlines, etc. |
| | Site Constraints (SC) | i.e. prefab/precast site, geographic constraints, etc. |

Each stage of the evaluation tool will work similarly to that of the UDOT Decision Tool with predetermined weighting factors (shown in Table 2.8) and an output indicator that will determine the next actions for the bridge construction project analyzed for ABC technique applicability. The weighting factors were assigned arbitarily based on experience of similar tools by other states. As of now, there are no guidelines on how to calibrate these factors for South Dakota due to lack of ABC experiences.

However, these factors may be adjusted based on the actual data generated through future planning practice for ABC in South Dakota.

**Table 2.8** Predetermined Weighting Factors

| **Stage** | **Input** | **Weighting Factor** |
|---|---|---|
| **One** | Average Annual Daily Traffic | 10 |
| | Out of Distance Travel | 10 |
| | Daily Road User Costs | 10 |
| | Economy of Scale | 10 |
| **Two** | Direct Costs | 10 |
| | Indirect Costs | 10 |
| | Non-ABC Conventional Costs | 10 |
| | Schedule Constraints | 10 |
| | Site Constraints | 10 |

For the second stage of the process, inputs will function slightly differently than in the UDOT Decision Tool. The approximate change in cost of using ABC techniques will be approximated according to the three bridge categories: superstructure, substructure, and/or placement. The higher the additional cost of implementing ABC techniques, the less likely the use of ABC techniques will be recommended for the project being considered. The Non-ABC Conventional Costs input is used to approximate what the construction costs would be per square foot of bridge if conventional construction alone were to be used. The higher the approximate conventional costs, the more likely ABC techniques should be used for the project. The schedule cosntraints and site constraints inputs represent any special circumstances surrounding evaluation of the bridge construction project. The most common schedule constraints will likely be emergency repairs and important seasonal deadlines, but also can include busy holiday weekends, local area events that will increase traffic, etc. The most common site constraints would be if a prefabrication and precasting area is not available in a close proximity to the project, or if geography of the project location favors/does not favor access for cranes or clearance for concrete trucks. The layout and orientation of the two stages of the decision-making process are displayed in Figure 2.9 and Figure 2.10.

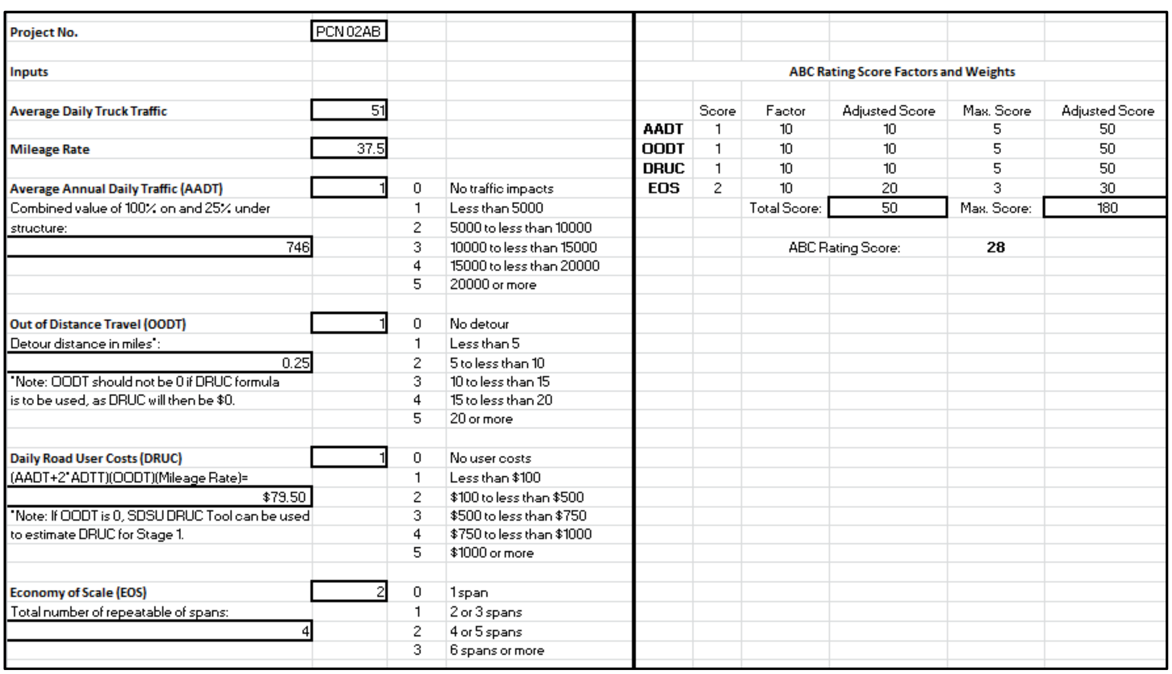

**Figure 02.9** Stage One Rating Procedure Layout

| | | | |
|---|---|---|---|
| **Project No.** | | | |
| **Inputs** | | | |
| **Direct Costs** | 3 | 0 | $100000 or more additional cost |
| Input approximate costs for superstructure, | | 1 | $75000 to less than $100000 additional cost |
| substructure, and/or placement: | | 2 | $50000 to less than $75000 additional cost |
| $32,000 | | 3 | $25000 to less than $50000 additional cost |
| | | 4 | $0 to less than $25000 additional cost |
| | | 5 | Lesser cost than conventional |
| **Indirect Costs** | 2 | 0 | No user costs |
| Transfer info from Daily Road User Cost tool: | | 1 | Less than $100 |
| $120 | | 2 | $100 to less than $500 |
| . | | 3 | $500 to less than $750 |
| | | 4 | $750 to less than $1000 |
| | | 5 | $1000 or more |
| **Non-ABC Conventional Costs** | 3 | 0 | $0 to less than $50/SF of bridge |
| Transfer info from SDDOT cost data per sq. ft. | | 1 | $50 to less than $75/SF of bridge |
| of bridge: | | 2 | $75 to less than $100/SF of bridge |
| $112 | | 3 | $100 to less than $125/SF of bridge |
| | | 4 | $125 to less than $150/SF of bridge |
| | | 5 | $150 or more/SF of bridge |
| **Schedule Constraints** | 1 | 0 | No schedule constraints |
| i.e. emergency repairs, seasonal deadlines, etc. | | 1 | Slight schedule constraints |
| | | 2 | Moderate schedule constraints |
| | | 3 | Substantial schedule constraints |
| **Site Constraints** | 1 | 0 | No site constraints |
| i.e. critical path, geographic constraints, etc. | | 1 | Slight site constraints |
| | | 2 | Moderate site constraints |
| | | 3 | Substantial site constraints |

**ABC Rating Score Factors and Weights**

| | Score | Weight Factor | Adjusted Score | Max. Score | Adjusted Score |
|---|---|---|---|---|---|
| **DC** | 3 | 10 | 30 | 5 | 50 |
| **IC** | 2 | 10 | 20 | 5 | 50 |
| **NCC** | 3 | 10 | 30 | 5 | 50 |
| **SchC** | 1 | 10 | 10 | 3 | 30 |
| **SC** | 1 | 10 | 10 | 3 | 30 |
| | | Total Score: | 100 | Max. Score: | 210 |
| | | ABC Rating Score: | | **48** | |

**Figure 2.10** Stage Two Rating Procedure Layout

The following input ranges were derived from the Iowa and Utah DOT evaluation tools for stage one of the evaluation procedure: AADT, OODT, and EOS. The DRUC input range was derived from the three completed case studies. For the second stage of the evaluation procedure, the Indirect Costs input ranges were carried over from the first stage of the evaluation tool. Schedule and Site Constraints input ranges were developed from feedback obtained during the SDDOT training that took place on December 18, 2013, while the remaining input ranges are arbitrary values chosen as starting points and will need to be further calibrated after the tool has been used for South Dakota specific projects in the future.

### 2.4.2.2 Evaluation Mechanism

After inputs have been selected and are entered into the evaluation tool, a simple calculation is completed to obtain the output indicator. This calculation is based on predetermined weighting factors shown previously in Table 2.8. The maximum score for each input is multiplied by the predetermined weighting factor to obtain a maximum adjusted score. Then, the assigned score for each input is multiplied by each predetermined weighting factor to obtain the project adjusted score. The maximum adjusted scores are summed as are the project adjusted scores;, and the total project adjusted score divided by the maximum adjusted score (presented as a percentage) is the output indicator for the project being analzyed by the evaluation tool. This calculation process is shown in Equation 2.2 through Equation 2.4.

$$Project\ Adjusted\ Score = Input\ Score * Weighting\ Factor \qquad \text{Equation 1.1}$$

$$Maximum\ Adjusted\ Score = Maximum\ Input\ Score * Weighting\ Factor \qquad \text{Equation 1.2}$$

$$Output\ Indicator = \frac{\sum Project\ Adjusted\ Score}{\sum Maximum\ Adjusted\ Score} * 100\% \qquad \text{Equation 1.3}$$

The process of entering input values for both stages of the evaluation tool and receiving output indicators for respective bridge construction projects is quite simple; however, determining what should be done with the output indicator to make a final decision regarding the evaluation is a more complicated process. Decision making flowcharts were used in the ABC evaluation process for both UDOT and Iowa DOT, as it helps to streamline the procedure. The flowchart for the first stage of the evaluation process is simplistic; an output indicator of 49 or less is recommended for conventional construction techniques, while an output indicator of 50 or higher is sent through to the second stage of the evaluation process. This flowchart is shown in Figure 2.11.

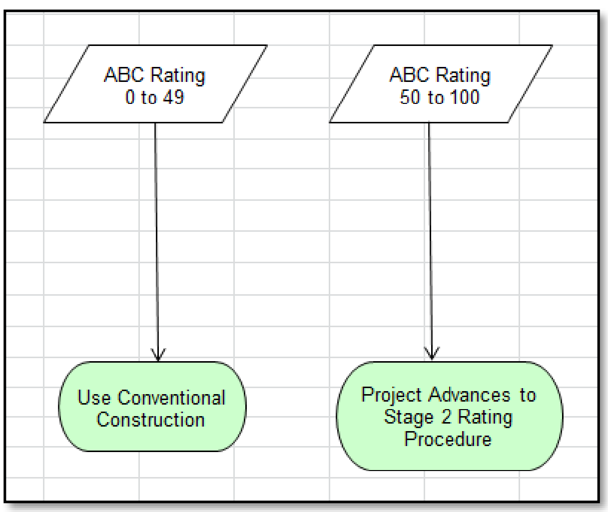


**Figure 2.11** Stage One Decision-Making Flowchart

The second stage of the evaluation process involves a more complicated decision-making flowchart. Although the projects with rating over 50 from stage 1 will enter stage 2, the rating of these projects will have to be re-calculated based on more detailed data input. Recall that the input for the stage 2 evaluation is different than for stage 1, thus the stage 2 rating of the same project may not be the same as its own rating in stage 1. When determining if using ABC techniques in the project design is feasible, flowchart questions are applied to the output indicator value range of 20-49. This is considered to be the range where the benefits and costs of using ABC techniques are approximately equal. When the output indicator is in the range 0-19, conventional construction methods are recommended for the project. Similarly, if the output indicator is in the range 50-100, an ABC approach for the project is recommended. The questions posed in the flowchart for the range of 20-49 are shown in the decision-making flowchart shown in Figure 2.12.

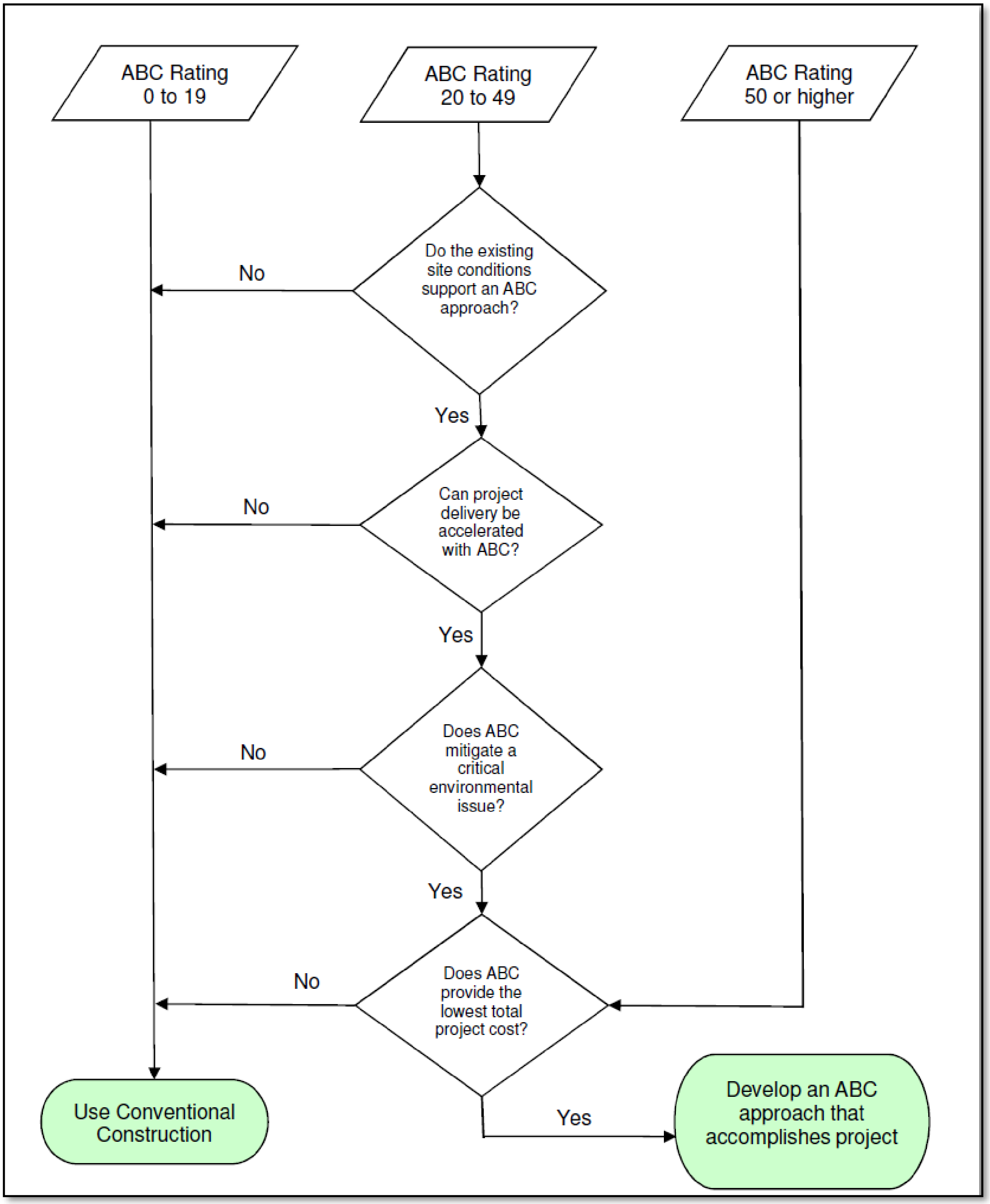


**Figure 2.12** Stage Two Decision-Making Flowchart

While these flowcharts are considered to be helpful guides for the process of decision-making for ABC purposes, they are not considered to be strict rules that must be followed. If special circumstances exist relating to specific needs of a given project, the use of ABC or conventional construction or ABC can and should be used regardless of what is recommended for use by the flowcharts. For example, if the costs of the ABC technique options for a project are far too high for an output indicator to yield a 20 or higher in the second stage of the decision-making process, but the project needs include emergent and rapid repair, ABC techniques should still be implemented into the replacement design of the bridge construction project. Likewise, if the output indicator for a project recommends that an ABC approach be used but the project committee determines that the fit is not right for ABC implementation, conventional construction can be used instead. The flowcharts are meant to be used as guidelines for the decision-making process, but the decision is ultimately up to those in charge of the bridge project design and construction. A user manual was created to instruct the affected employees of SDDOT how to operate and used the evaluation tool to make decisions regarding the use of ABC or conventional construction for a given a project. This user manual is on the FTP website for this project.

## 2.5 Case Studies to Validate Evaluation Procedure

Once the evaluation procedure design and format was completed, case studies were sent from the SDDOT Bridge Design Office to validate functionality of the evaluation procedure. Three case studies representing low, medium, and high potential for the application of ABC techniques were chosen by the Bridge Design Office. This decision was made based on average annual daily traffic (AADT) for different projects, as the potential for the application of ABC techniques will increase with the AADT value for any given project. AADT is considered to be one of the most important determining factors when deciding whether the development of an ABC approach is more feasible than the use of conventional construction practices.

### 2.5.1 Stage One Case Study Validation

Three previously completed projects were selected for the use of validating the evaluation procedure. The three case studies were sent through the first stage of the evaluation procedure to determine which projects would have enough potential for the application of ABC techniques to warrant evaluation using the second stage of the evaluation procedure. Information provided for the three case studies sent from the Bridge Design Office are shown below in Table 2.9.

**Table 2.9** Case Study Information from Bridge Design Office

| Project Number | AADT | ADTT | OODT | Mileage Rate | Number of Spans |
|---|---|---|---|---|---|
| SD34 (PCN 02AB) | 746 on, none below | 6.8% (51) | Less than ¼ mile | 37.5 cents per mile | 3 and 4 spans |
| I90 (PCN 01KK) | 1,015 on, none below | 2.6% (26) | None | 37.5 cents per mile | 4 and 5 spans |
| I29/I229 interchange (PCN 01QS) | 18,012 on, 12,827 below (21219 total) | 18.7% (1,526) | None | 37.5 cents per mile | 2 spans |

Based on information submitted for case study validation, inputs were derived for the first stage of the evaluation procedure. The empirical formula presented in Equation 2.1 was used to approximate the daily road user costs for each of the projects presented in the case studies. For the purposes of this calculation, the assumption was made that a minimum of 0.25 miles of detour would be incurred to any given bridge construction project, even if there is no official detour due to partial traffic flow through a bridge construction project. This assumption is valid because user costs will still be incurred on a bridge construction project even if there is no detour due to reduced work zone speeds and reduced traffic flow. However, if desired, the users of the evaluation tool may use the SDSU Road User Cost Tool in place of the empirical formula for those projects that do not have a detour length. Based on the assumption that the minimum detour distance is 0.25 miles, the approximate daily user costs for each of the three case studies is shown in the sample calculations below.

Project SD34 (PCN 02AB):

$$DRUC = (746 + 2 * 51)\frac{vehicles}{day} * (0.25)\frac{miles}{vehicle} * (0.375)\frac{dollars}{mile} = \$79.50/day$$

Project I90 (PCN 01KK):

$$DRUC = (1{,}015 + 2 * 26)\frac{vehicles}{day} * (0.25)\frac{miles}{vehicle} * (0.375)\frac{dollars}{mile} = \$100.03/day$$

Project I29/I229 interchange (PCN 01QS):

$$DRUC = (21{,}219 + 2 * 1{,}526)\frac{vehicles}{day} * (0.25)\frac{miles}{vehicle} * (0.375)\frac{dollars}{mile} = \$2{,}275.40/day$$

From calculations shown previously and ranges of inputs displayed on the ABC Rating Procedure (see FTP project website), output indicators were obtained for each case study and the corresponding decision according to the decision-making flowchart presented previously in Figure 2.11. Results are shown in

**Table**Table 2.10.

**Table 2.10** Case Study Output Indicators and Decisions

| Project Number | AADT | OODT | DRUC | EOS | Output Indicator | Decision |
|---|---|---|---|---|---|---|
| SD34 (PCN 02AB) | 1 | 1 | 1 | 2 | 28 | Conventional Construction |
| I90 (PCN 01KK) | 1 | 1 | 2 | 2 | 33 | Conventional Construction |
| I29/I229 interchange (PCN 01QS) | 5 | 1 | 5 | 1 | 67 | Advance to Stage 2 |

Based on the information presented in Table 2.10, the two projects representing a low and medium potential for the applicability of ABC techniques were recommended for the use of conventional construction practices, while the project representing a high potential for the application of ABC techniques was recommended for advancement to the second stage of the evaluation procedure.

### 2.5.2 Stage Two Case Study Validation

Only the project with the highest AADT and DRUC was recommended for advancement to the second stage of the evaluation procedure. The project information required for this second stage evaluation was obtained from the Bridge Design Office in April 2014. This information is presented in Table 2.11.

**Table 2.11** Stage Two Evaluation Project Information for I-29/I-229 Project

| AADT | ADTT | OODT | Normal & Work Zone Speeds | Traffic Detour Percentage | Conventional Costs | Additional Cost of Using ABC |
|---|---|---|---|---|---|---|
| 18,012 on, 12,827 below (21219 total) | 18.7% (1,526) | 0.25 mi each | 65 mph & 45 mph | 75% (I-29) 100% (I-229) | $113.25/SF | ~$420,000 |

The additional cost of using ABC was requested from the Technical Panel for this project. Figure 2.13 shows the table of information provided by the Technical Panel for use in estimating the additional cost of using ABC for this stage two case study.

COSTS WITH OVERLAY

| Pre-cast ABC cost ($) | Columns & caps | deck panels | |
|---|---|---|---|
| fabrication | 122950 | 679967 | |
| shipping | 16500 | 69500 | |
| Excise & sales (15%) | 18443 | 101995 | |
| labor* | 1200 | 41700 | |
| grouting# | 600 | 20000 | |
| epoxy chip seal | | 239750 | |
| total | 159693 | 1152912 | 1312605 |

| Cast-in-place ($) | Columns & caps | deck | |
|---|---|---|---|
| cu. Yds | 136.6 | 755.6 | |
| cost/yd | 1000 | 1000 | |
| total | 136600 | 755600 | 892200 |
| difference = | 420405 | | |

epoxy chip seal = 3425 sq. yds. x $70 /sq. yd

**Figure 2.13** Additional Cost of Using ABC for I-29/I-229 Project

Other information obtained from the Bridge Design Office included existing schedule and site constraints, and the total project duration. From this information, inputs for the second stage of the evaluation procedure were developed and run through the program. The above information was used in conjunction with the SDSU Daily Road User Cost Tool to determine user costs incurred per day for this bridge construction project. The final number obtained for this input was approximately $12,000 per day for the duration of the project. This figure is the combined DRUC value obtained from analyzing each highway segment involved in the project. See Figure 2.14 for the breakdown of the DRUC Tool inputs and outputs.

**QUICK REPORT ROAD USER COST: PROJECT C**

Project Name I-29/I-229 Interchange    County Minnehaha
Project Number PCN 01QS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ZONE CONDITI | Phases: | | | | | | | | |
| | ADT | 18012 | | 12827 | | | | | |
| | Percent Trucks | 18.7 | % | 11.9 | % | | % | | |
| | Operating Speed | 65 | mph | 65 | mph | | mph | | |
| | Project Length | 1 | miles | 1.5 | miles | | miles | | |
| | Accident Rate | 1.11 | | 1.11 | | | | | |
| | WZ Speed | 45 | mph | 45 | mph | | mph | | |
| | Detour | 75 | % | 100 | % | | % | | |
| | CMF | 1 | | 1 | | | | | |
| | Project Duration | 210 | days | 210 | days | | days | | |
| | Detour Segment | Speed | Length | Speed | Length | Speed | Length | | |
| | 1 | 45 | 0.25 | 45 | 0.25 | | | | |
| OUTPUT | VOT | ($2,502.11) | | ($4,250.96) | | | | | |
| | *Auto* | *($2,055.17)* | | *($3,769.56)* | | | | | |
| | *Truck* | *($446.94)* | | *($481.41)* | | | | | |
| | VOC | ($1,960.97) | | ($3,084.91) | | | | | |
| | *Auto* | *($957.99)* | | *($1,941.89)* | | | | | |
| | *Truck* | *($1,002.97)* | | *($1,143.02)* | | | | | |
| | AC | ($110.96) | | ($131.70) | | | | | |
| | Daily RUC | ($4,574.04) | | ($7,467.57) | | ($12,041.61) | | | |
| | Project Total | ($960,548.15) | | ($1,568,190.66) | | | | | |

**Figure 2.14** DRUC Inputs and Outputs for I-29/I-229 Project

Because the value for DRUC differs so greatly from the estimate used for the first stage of the evaluation tool (~$2,275/day), it is recommended that the Bridge Design Office obtain a more accurate estimate for the mileage rate to be used in South Dakota for the empirical formula used for stage one of the evaluation procedure. If this solution is not favorable, the SDSU Daily Road User Costs Tool may be used for both stages of the evaluation procedure for determining daily user costs incurred for a given project. For more details on how to calculate user costs using the inputs presented above and the SDSU Daily Road User Cost Tool, see the final report for Project SD2011-05. The resulting inputs obtained for this project and the corresponding action to be taken are shown in Table 2.12.

**Table 2.12** Stage Two Inputs, Output Indicator, and Corresponding Action

| Inputs | | | | | Output Indicator | Corresponding Action |
|---|---|---|---|---|---|---|
| **Direct Costs** | **Indirect Costs** | **Non-ABC Conventional Costs** | **Schedule Constraints** | **Site Constraints** | | |
| 0 | 5 | 3 | 1 | 1 | 48 | Use flowchart decision-making questions |

As can be seen from Table 2.12, the recommended action for the Bridge Design Office would be to assemble a panel of appropriate parties to address each question in the decision-making flowchart for the second stage of the evaluation procedure. This would determine whether or not it would be in the best interests for SDDOT and the project needs to proceed with either a conventional construction or ABC approach.

This information was presented to the affected SDDOT employees on December 18, 2013, and feedback was obtained at that time to make final alternations and adjustments to the ABC Rating Procedure and ABC Rating Procedure User Manual. All final deliverables have been uploaded to the FTP website for this project.

# 3. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This project involved three objectives to achieve the goal of developing a decision-making process concerning the use of ABC techniques. The first objective was to develop an ABC technique catalog denoting techniques previously used in the United States. The second objective was to estimate the associated costs and benefits encountered through the use of the researched ABC techniques. The third objective was to develop a cost/benefit analysis tool to evaluate potential projects for applicability of the use of ABC techniques. This chapter will summarize what was done and present conclusions and recommendations regarding the three objectives of this project.

## 3.1 Summary

The first objective involved development of a catalog of ABC techniques to inform the user of what has been used in the past and how each technique was implemented into the construction of a bridge project. This catalog is to inform the user of what has been done in the past and relate each technique to the benefits, special requirements, or problems pertaining to each technique. To accomplish this objective, an in-depth literature review was completed that familiarized the reader with the current ABC techniques t used across the United States to-date. Sources investigated throughout the course of the literature review provided a list of ABC techniques currently used in practice across the United States. The information found throughout the course of this literature review was used to create ABC technique profiles. The ABC technique profiles are designed to inform the reader of applications of each ABC technique and provide the information source. In some cases, an example project and visual aid are given.

Additionally, several interviews were completed to structure and populate the ABC catalog. Interviews with the SDDOT were completed to determine priorities of importance to the Bridge Design and Local Government Assistance Offices to include in the ABC catalog. These interview results were also used to finalize the list of ABC techniques obtained from the literature review. Then, several interviews were conducted with employees of other state DOT offices who had previous experience with ABC techniques researched in the literature review. Information obtained from these interviews was used to populate various cells of the ABC catalog.

The second objective of this project was to estimate the costs and benefits associated with the use of ABC techniques. These costs needed to be South Dakota-specific estimates for information to be useful to SDDOT. To obtain this cost information, three sources were used. The first source was SDDOT, which provided conventional cost information regarding bridge construction projects that have been completed in the past. The second source was South Dakota manufacturers and contractors, which provided information pertaining to the implementation and construction costs of using ABC techniques in the state. The third source was the SDSU Road User Cost Tool, which was obtained from Project SD2011-05, “Review of Road User Costs and Methods,” and through the use of the empirical equation displayed in Equation 5-1. The empirical formula was used for the first stage of the evaluation tool procedure, while the Road User Cost Tool was used for the second, more rigorous stage of the evaluation tool procedure. The third and final objective of this project was to develop a cost/benefit analysis procedure tool for the purposes of evaluating applicability of ABC techniques for a given bridge construction project at SDDOT. This objective involved the development of several inputs based on reference tools used for the creation of the evaluation tool for SDDOT. These three reference tools were: 1) the Accelerated Bridge Construction (ABC) Analytical Hierarchy Process (AHP) Decision Tool, 2) the UDOT ABC Decision Tool, and 3) The Iowa DOT ABC Decision Tool. These three references were used to develop a two-stage evaluation process for determining if ABC techniques should be used for the purposes of given bridge construction projects in South Dakota. An output indicator is obtained from the inputs with their given predetermined weighting factors for the first stage of the decision-making procedure. This indicator is used with decision-making flowcharts generated from reference tools to determine if a given project will move on to the second stage of the decision-making procedure. If the project does proceed to the second stage of the decision-making procedure, new inputs are generated for the project to obtain a second output indicator, which is then used with decision-making flowcharts to determine if ABC techniques should be used over a conventional construction approach.

## 3.2 Conclusions and Recommendations

### 3.2.1 ABC Catalog Intended Use

First, the ABC catalog is to be used as a reference tool for determining which ABC techniques should be used on a given bridge construction project after the decision has been made that ABC techniques are applicable for the project (i.e., after the project has exited the second stage of the decision-making procedure with the recommendation of implementing ABC techniques into the project design).

### 3.2.2 Cost Information Intended Use

Second, costs used for generation of the second stage inputs should not be considered as project specific cost estimates of ABC techniques. Due to the lack of use of ABC techniques in South Dakota and because costs for given ABC techniques can vary greatly from project to project, exact costs were not able to be obtained for the use of ABC techniques. Therefore, a general estimation of the total cost of implementing substructure, superstructure, and placement of ABC techniques were generated. These estimations should not be considered accurate estimations of the actual cost of implementing ABC techniques into a given bridge construction project. If a more accurate cost of implementing ABC techniques into a project is desired, a South Dakota contractor would be contacted in order to obtain a bid price for the project based upon the ABC techniques desired.

### 3.2.3 Evaluation Tool Limited Data

Finally, although the evaluation tool developed in this study laid out framework for a simplified assessment for ABC applicability in South Dakota, the available data related to actual ABC costs in South Dakota is limited. It is recommended that, through future use of the tool in realistic SDDOT projects, additional data be collected and used to calibrate weighting factors used in the evaluation tool. It will be beneficial to run realistic project scenarios through the evaluation tool to see if the indicator reflects realistic decision making conditions. Ideally, the weighting factors should be adjusted using several clearly defined benchmark projects, so the calculated indicator will be representative of actual measured benefits from these projects. As such data is currently unavailable in South Dakota, results from the proposed process remain partially subjective and must be used with caution.

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# APPENDIX A: ABC TECHNIQUE PROFILES

ABC Technique Profiles

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Published October 24, 2012

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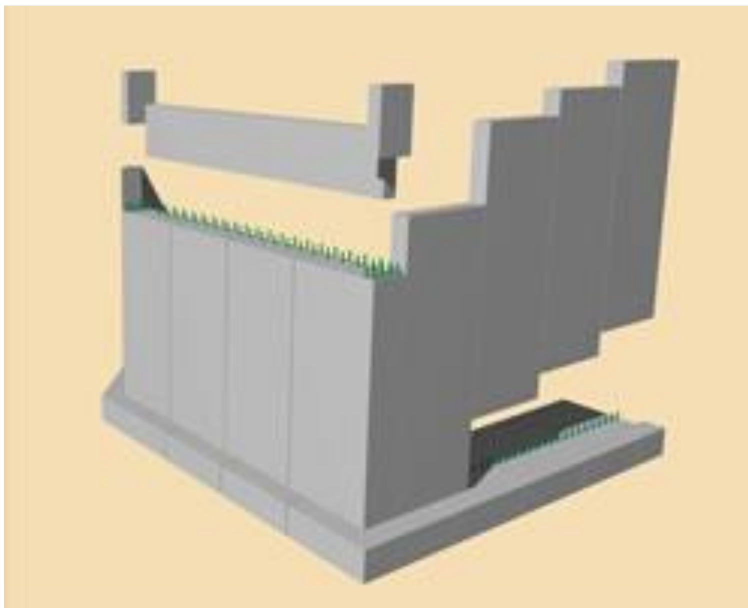
## PRECAST ABUTMENTS

**Description:** Abutments support the ends of a bridge's superstructure. In general, precast abutments are abutments that are poured and cured off site and moved into place after curing is complete.

**Source:** "ABC Applications in CA—A Lesson Learned"

**Example Project:** I-40 Bridges Replacement in CA (20-mile stretch along I-40 about 80 miles east of Barstow, CA)



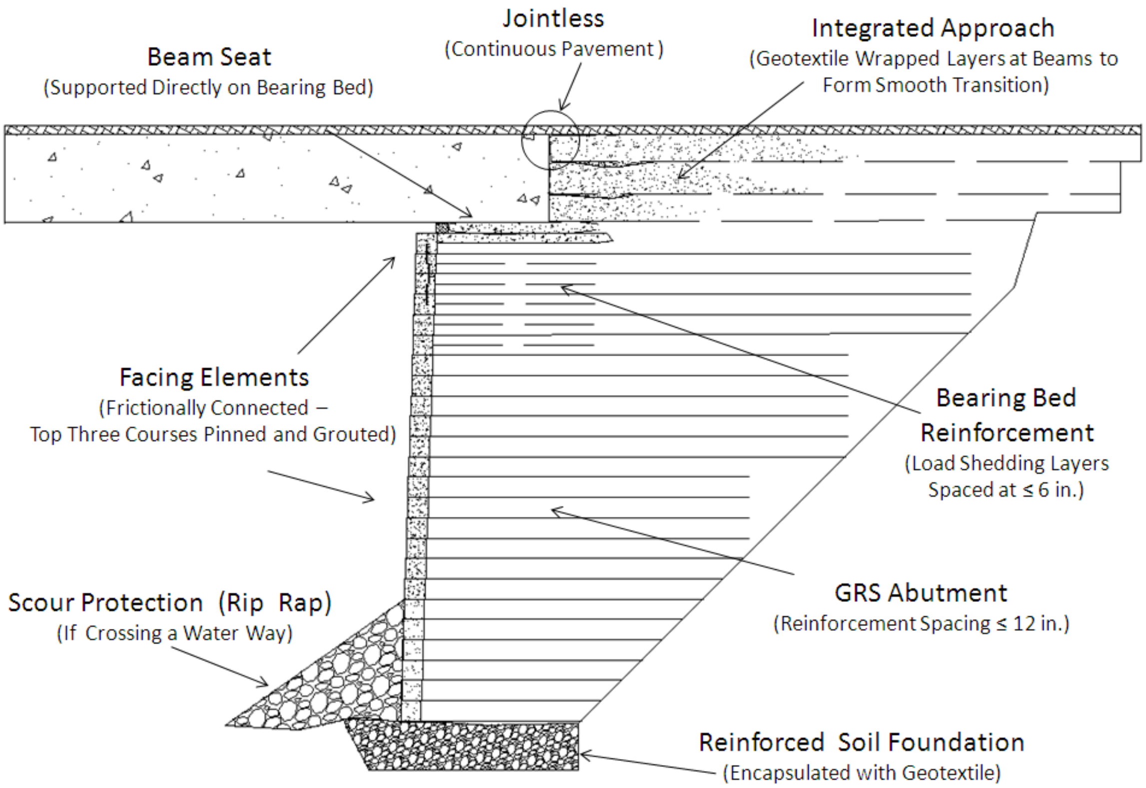
*Typical Precast Abutment*
*http://www.fhwa.dot.gov/everydaycounts/technology/bridges/pbeswebinartraining/s3_m7.cfm*
*Accessed 23 Oct 2012*

## GEOSYNTHETIC REINFORCED SOIL ABUTMENTS

**Description:** This is a method that involves combining the foundation, abutment, and approach embankment into one composite material. The composite mass extends beyond the ends of the bridge superstructure and into the embankment. This integration of the abutment with the superstructure and approach allows the system to move and settle as one unit, thereby eliminating the problem with differential settlement between the abutment seat and the approach backfill.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** Founders/Meadows Parkway Bridge, crossing I-25 approx. 20 miles south of Denver, CO



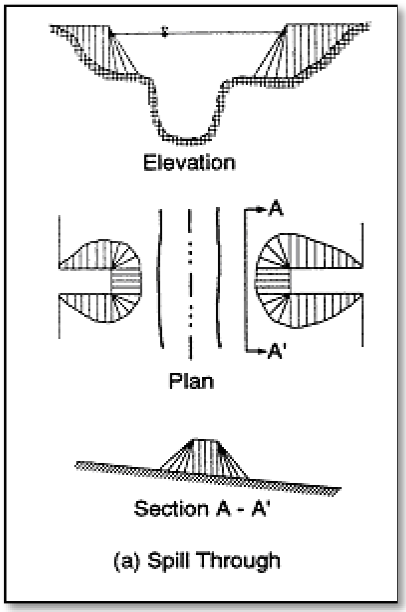

*Typical Section of a GRS/IBS Bridge Abutment*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## SPILL-THROUGH ABUTMENTS

**Description:** The intent of spill-through abutments is to reduce the amount of soil pressure on the cantilever abutment by installing large voids in the stem. Spill-through abutments are similar to piers, except the majority of the structure is below grade.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** Road 971, Milepost 4.50, Tombigbee National Forest, Mississippi




*Spill-Through Abutment Design*
*http://www.fhwa.dot.gov/engineering/hydraulics/pubs/idfieldpoa.cfm*
*Accessed 23 Oct 2012*

## PRECAST PIER BOX COFFERDAMS

**Description:** This ABC technique is used for placement of bridge support columns in channels of water. The pile cap footing is commonly placed just below the surface of the water. By prefabricating pier boxes, they can be floated downstream from wherever they were cast and set into place to block off water flow for the installation of the pile caps.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** Providence River Bridge

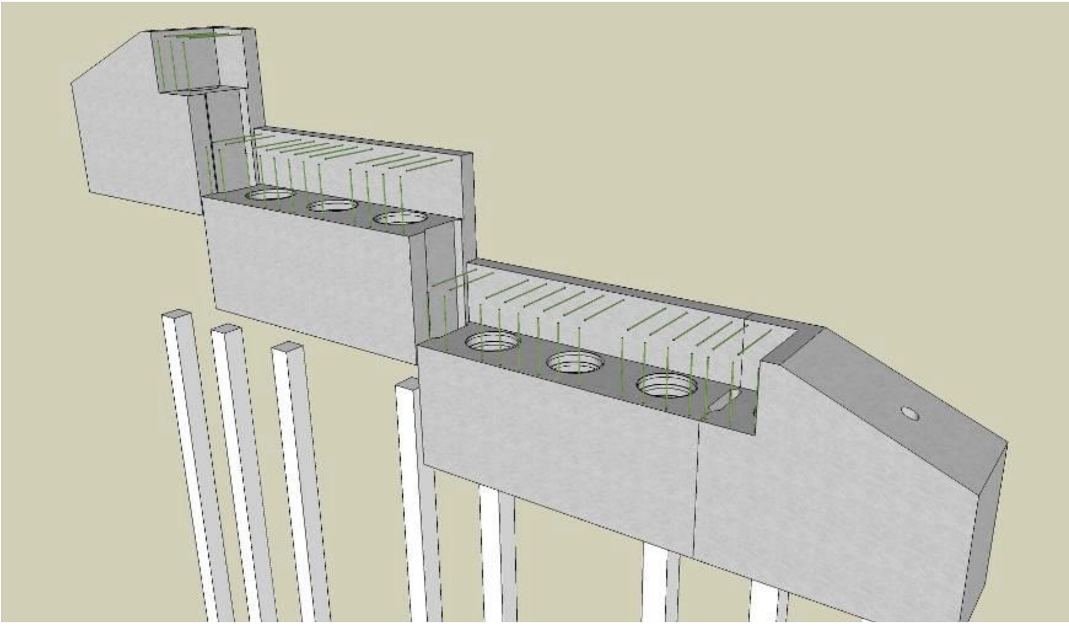
*Example of a Precast Pier Box Cofferdam*
*http://www.fhwa.dot.gov/bridge/prefab/if09010/04.cfm*
*Accessed 23 Oct 2012*

## INTEGRAL ABUTMENTS

**Description:** Abutments in which the abutment structure is made integral with the superstructure elements. Integral abutments do not have deck joints, which is one of the most common deterioration areas on a bridge. Integral abutments transfer the embankment soil forces into the bridge superstructure. Integral abutments are normally supported on a single row of piles that are designed to move with the bridge during thermal cycles and rotate with the beam end under live load. The result of this approach is that the abutment does not need a spread footing or multiple rows of piles to resist the overturning soil forces.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** NYDOT



*Prefabricated Integral Abutment*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## PRECAST BENT CAPS

**Description:** A bent cap is the top horizontal portion of a bent that supports the superstructure of a bridge. Precast bent caps simply provide a way of precasting portions of each bent without prefabricating the entire bent away from the bridge site. Instead, the portions are brought to the job site and assembled in place.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** Lake Ray Hubbard Bridge, Dallas, TX

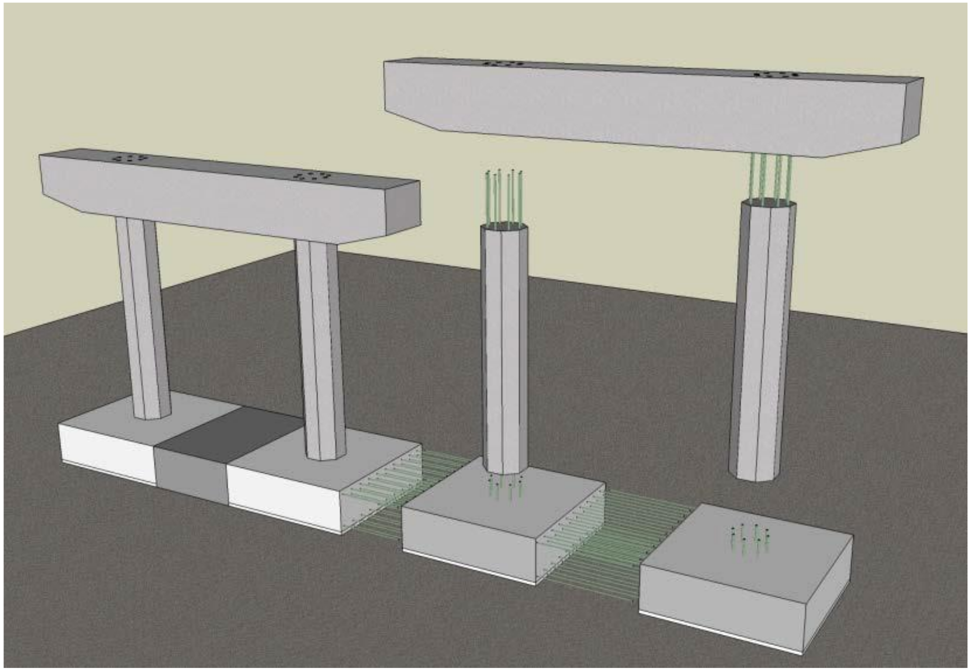

*Precast Bent Cap*
*http://www.fhwa.dot.gov/publications/publicroads/03nov/02.cfm*
*Accessed 23 Oct 2012*

## PRECAST SPREAD FOOTINGS

**Description:** Precast spread footings are footings that are precast off-site, transported to the construction site and placed on a prepared subgrade and then grouted into place. These spread footings will then be connected to piers or columns and fill is placed over the footings and compacted.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** 4500 South Bridge, Salt Lake City, UT

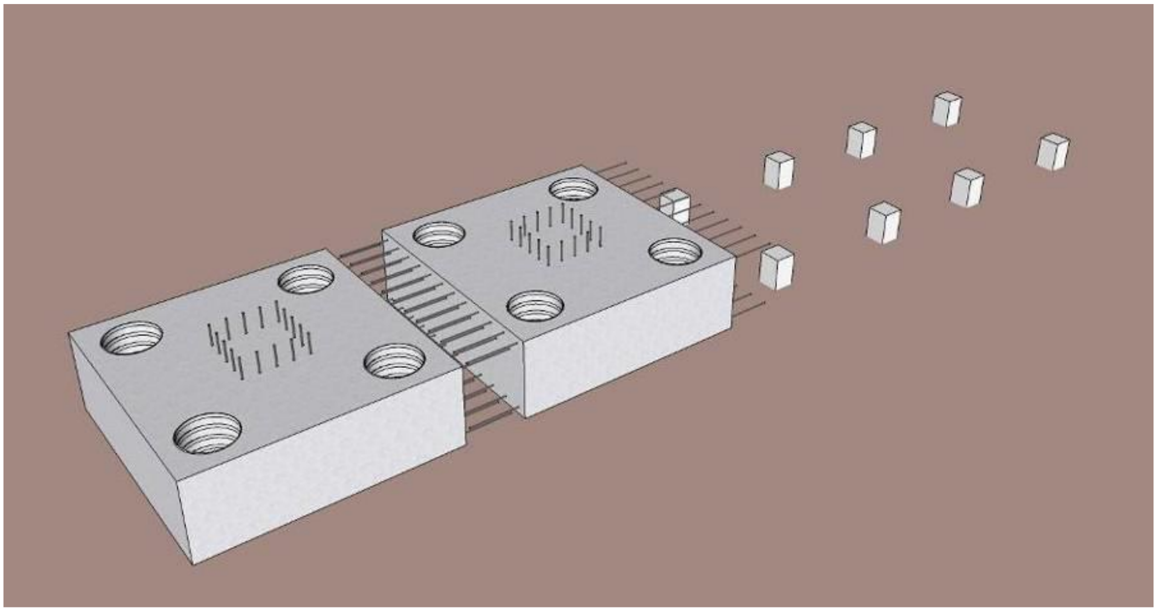


*Spread Footings Beneath Columns and Column Caps*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## PRECAST PILE CAP FOOTINGS

**Description:** These are precast footings that include corrugated steel pipe voids. When the piles are connected to the precast pile cap footings, they are poured partially within these voids to increase shear resistance at the footing and pier.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"



*Precast Pile Cap Footing*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## PREFABRICATED FULL HEIGHT WALL PANELS

**Description:** These elements are used in front, behind, or around foundation elements of the bridge to stabilize and provide support the foundation. This is especially beneficial in areas with high seismic or hurricane activity.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

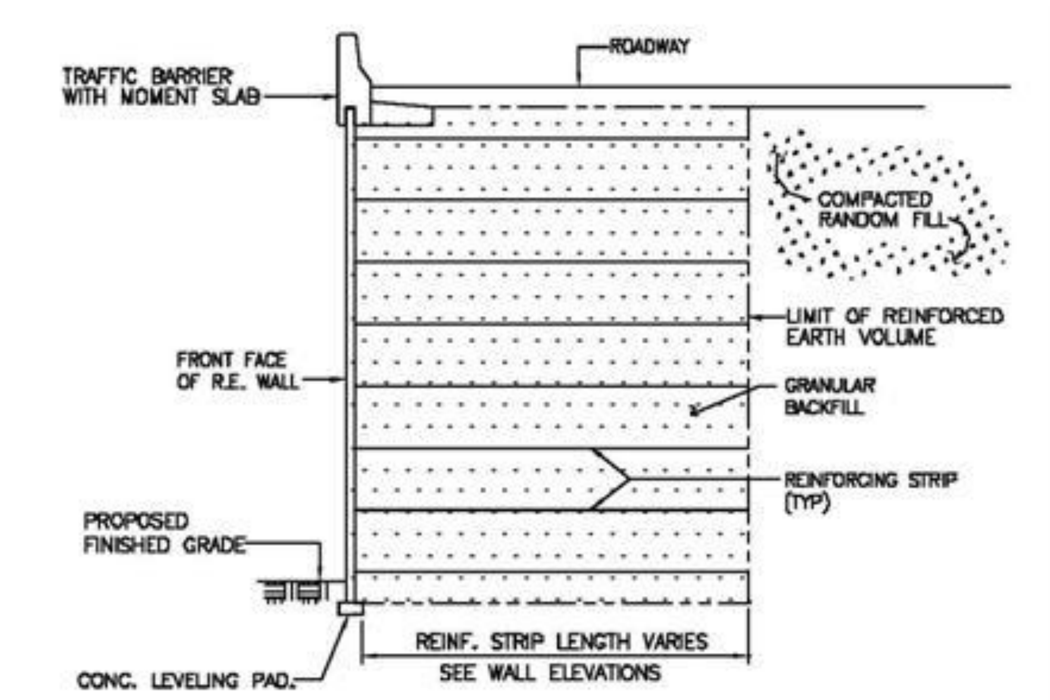
*Prefabricated Full Height Wall Panels*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## PROPRIETARY RETAINING WALL SYSTEMS

**Description:** A proprietary retaining wall is a wall system in which the wall system itself or some portion of the wall system is typically patented. They are normally purchased from providers and simply installed on site after purchase and delivery.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** TXDOT



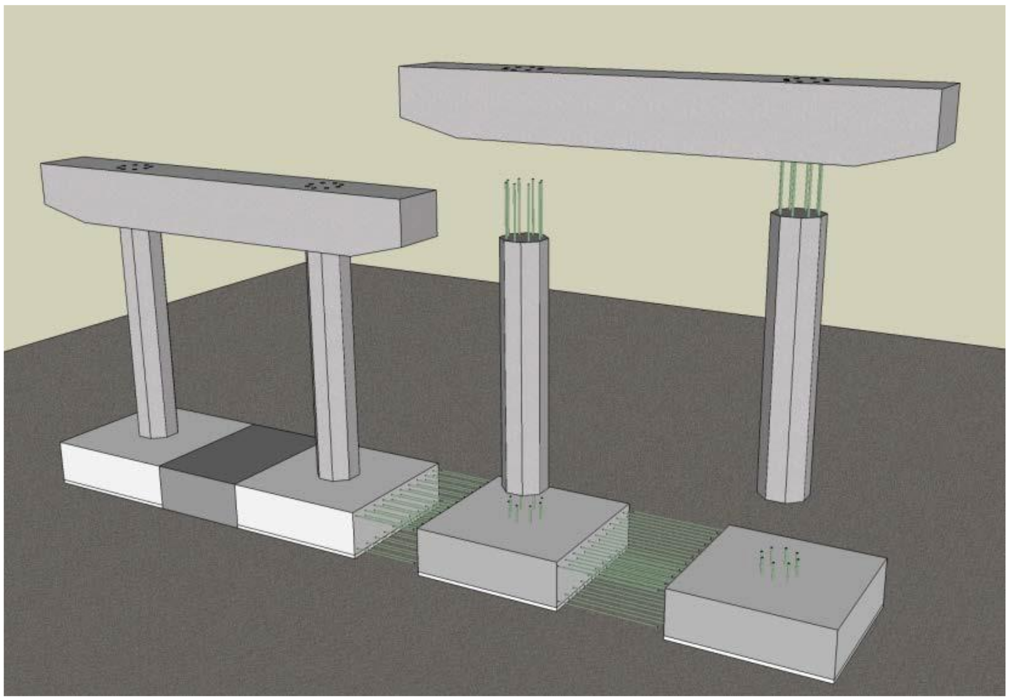

*Proprietary Retaining Wall Layout*
*http://www.fhwa.dot.gov/bridge/prefab/if09010/03a.cfm*
*Accessed 23 Oct 2012*

## PREFABRICATED COLUMNS

**Description:** This element is self-explanatory. The columns of a bridge are simply precast off-site and transported to the job site for installation and construction.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** Multiple



*Precast Columns Between Spread Footings and Column Caps*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## PRECAST BOX CULVERTS

**Description:** Precast concrete box culverts have different uses. They can be used as a portion of the substructure of a bridge—for smaller scale bridge projects—or they can be used for drainage purposes beneath a structure. The use of precast concrete box culverts allows for precast elements to be transported, rather than allowing for fresh concrete to be transported, which can be a more complicated process.

**Source:** SDDOT

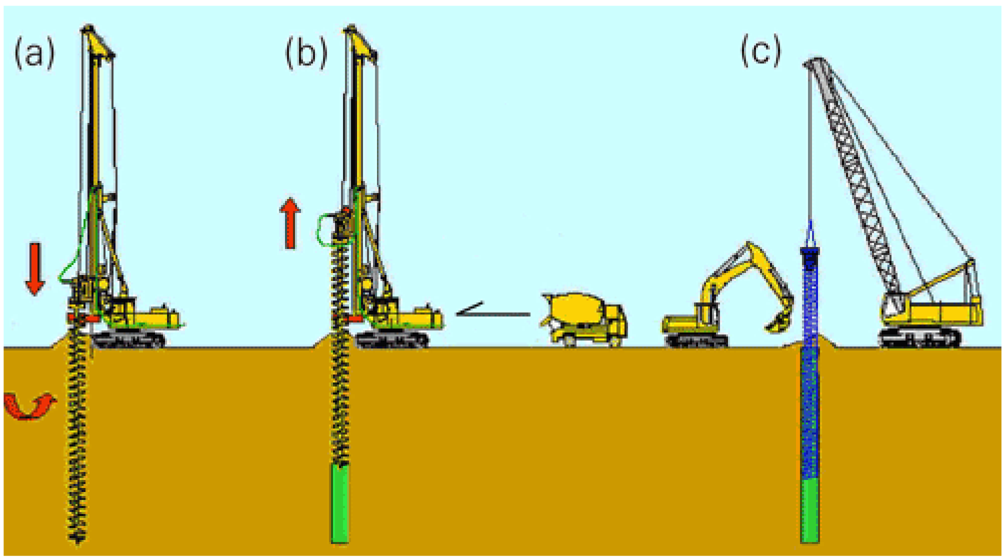
**Example Project:** FDOT

*Precast Box Culvert Assembly*
*http://www.mcprecast.com/products.asp*
*Accessed 16 Nov 2012*

## CONTINUOUS FLIGHT AUGER (CFA) PILES

**Description:** The figure shown below depicts the process of installing CFA piles, which are regular piles installed in a more efficient manner. In process "a" below, a soil auger is drilled into the ground in a continuous stroke. Once the proper depth is achieved, the auger is withdrawn from the soil in the hole, while continuously injecting concrete through the hollow stem of the auger. This process is labeled "b" in the figure. Once the auger has been withdrawn from the hole, a reinforcing cage is inserted into the wet concrete to complete the installation. This process is labeled "c" in the figure. This greatly reduces the time required for foundation installation.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"




*CFA Pile Installation*
"ABC—Experience in Design, Fabrication, and Erection of PBES"

## FULL-DEPTH PRECAST DECK PANELS

**Description:** Full-depth precast deck panels are panels of a bridge that are precast at the full depth at which they will be after construction on the bridge is complete. Connected full-depth precast deck panels can also be connected to be moved from the precasting site to the job site in fewer trips or as few as one trip.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** UDOT

*Full-Depth Precast Deck Panels*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## PARTIAL-DEPTH PRECAST DECK PANELS

**Description:** The difference between this ABC technique and the full-depth precast deck panels is that the partial-depth precast deck panels are only precast to serve as the form for the rest of the deck to be poured. It eliminates the need for removable concrete forms, and the bottom layer of the deck can then be the strongest portion of the deck to help prevent future failure.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

*Partial-Depth Precast Deck Panels*
*http://www.fhwa.dot.gov/bridge/abc/prefab_def.cfm*
*Accessed 23 Oct 2012*

## FIBERGLASS REINFORCED POLYMER (FRP) DECK PANELS

**Description:** These panels are much like the partial- and full-depth precast deck panels previously discussed. However, they are constructed from fiberglass reinforced polymer rather than concrete. The polymer is reinforced with fiber or some other material of equal strength to reinforce the panels in one or more directions along the span of the bridge.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** Project 100 in Ohio

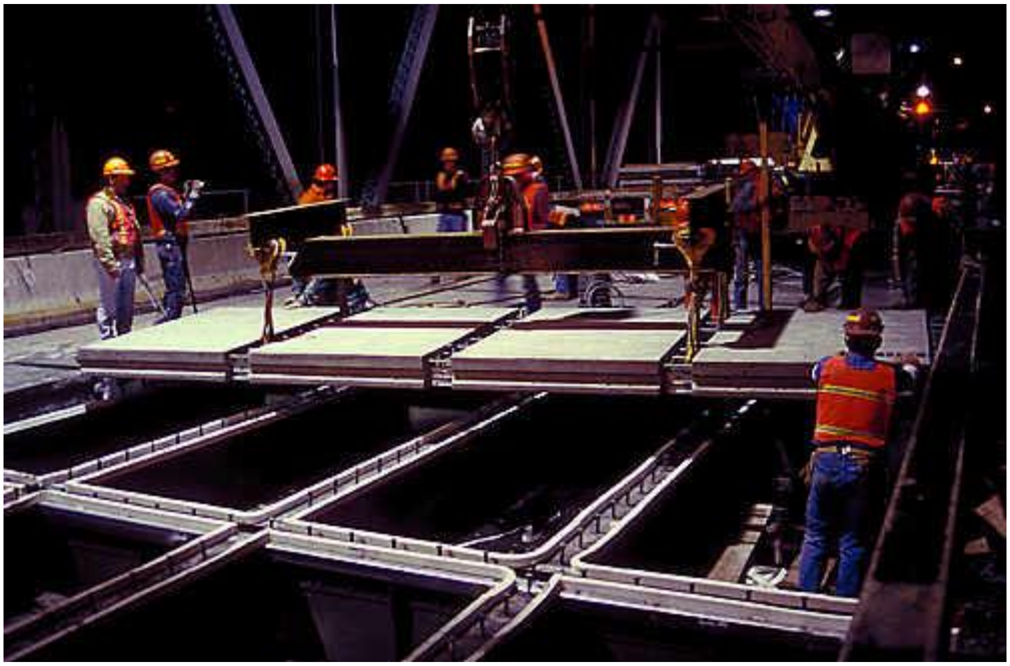
*Full-Depth FRP Panels*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## STEEL GRID DECK SYSTEMS

**Description:** A steel grid is simply a platform for the concrete deck to lay on in an interlocking pattern that reinforces the strength of the bridge in both horizontal directions. These grids can be constructed and installed one at a time or all at once, depending on the project's needs and considerations.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** 17th St. Causeway Bridge in Ft. Lauderdale, FL



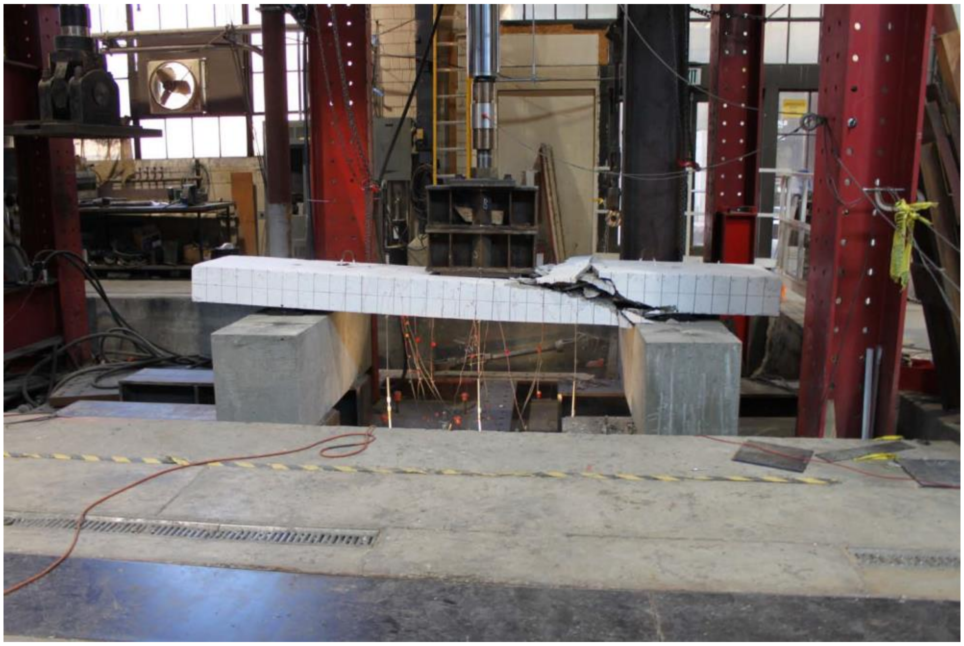
*Steel Grid System with Full-Depth Precast Concrete Deck Installation*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## LIGHTWEIGHT PRECAST DECK PANELS

**Description:** This technique is similar to precast deck panels, with the only difference being the added advantage of using lightweight concrete. This improves the transportability of the panels, which is a good way to reduce construction time for a given project.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** UDOT



*Testing of Lightweight Precast Deck Panels at UDOT*
*http://www.civil.utah.edu/pdf/research_areas/structures_3_09.pdf*
*Accessed 23 Oct 2012*

## PRECAST APPROACH SLABS

**Description:** Precast approach slabs are structural slabs that span between the bridge abutments and the approach fill. They are used to span across the potential settlement of the approach roadway fills directly behind the abutments.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** UDOT


*Precast Approach Slab Installation*
*http://www.flickr.com/photos/25664139@N06/5899098381/*
*Accessed 16 Nov 2012*

## PRECAST I-GIRDER

**Description:** This technique is no different than standard I-girders used in bridge construction. The girders are simply precast off-site and transported to the job site before installation.

**Source:** "ABC Applications in CA—A Lesson Learned"

**Example Project:** I-5 Southbound Truck Route Crossing Repair, Los Angeles County

*Placement of a Precast I-Girder at the Job Site*
*"ABC Applications in CA—A Lesson Learned"*

## PRECAST BULB-T GIRDERS

**Description:** This technique is no different than standard bulb-T girders used in bridge construction. The girders are simply precast off-site and transported to the job site before installation.

**Source:** "ABC Applications in CA—A Lesson Learned"

**Example Project:** I-40 Bridges Replacement in CA (20-mile stretch along I-40 about 80 miles east of Barstow, CA)

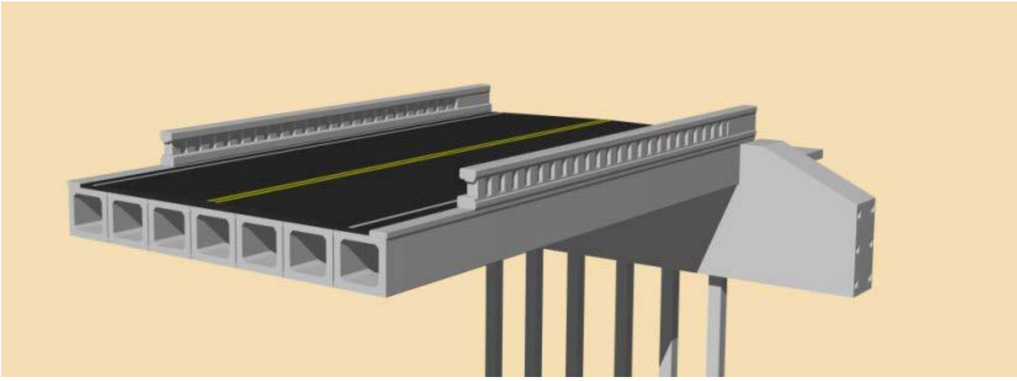
*Precast Bulb-T Girders*
*http://www.fhwa.dot.gov/everydaycounts/technology/bridges/pbeswebinartraining/s3_m7.cfm*
*Accessed 23 Oct 2012*

## PRECAST BOX GIRDERS

**Description:** This technique is no different than standard box girders used in bridge construction. The girders are simply precast off-site and transported to the job site before installation.

**Source:** "ABC Applications in CA—A Lesson Learned"

**Example Project:** Russian River Bridge, Geyserville, CA



*Precast Box Girder Design*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## STEEL TUB GIRDER

**Description:** Steel tub girder use is becoming more commonplace in modern infrastructure design. They offer advantages over other superstructure types in terms of span range, stiffness and durability—particularly in curved bridges. In addition, steel tub girders have distinct aesthetic advantages due to their clean, simple appearance.

**Source:** "Induced Stresses from Lifting and Moving Highway Bridges with Self-Propelled Modular Transporters"

**Example Project:** Brightman Street Bridge Replacement Project, Fall River, Somerset, MA

*Steel Tub Girder Placement*
*http://www.highsteel.com/project_gallery/bridges/Brightman-Street-Bridge.cfm*
*Accessed 23 Oct 2012*

## PRECAST INVERTED T-BEAMS

**Description:** A precast inverted t-beam is a type of prestressed concrete beam used to support the decks of bridges. One design application for this geometric concept is shown in the first photo below. It was developed in Nebraska, and research has shown the use of these reduces the overall weight of short span bridges. A different application of the same geometric concept is shown in the second picture. This is a concept used at MNDOT as a way to butt flatter inverted T-beams together.

**Source:** http://rebar.ecn.purdue.edu/ect/links/technologies/civil/itbeam.aspx

**Example Project:** MNDOT, NDOR

*Precast Inverted T-Beam*
*http://rebar.ecn.purdue.edu/ect/links/technologies/civil/itbeam.aspx*
*Accessed 23 Oct 2012*

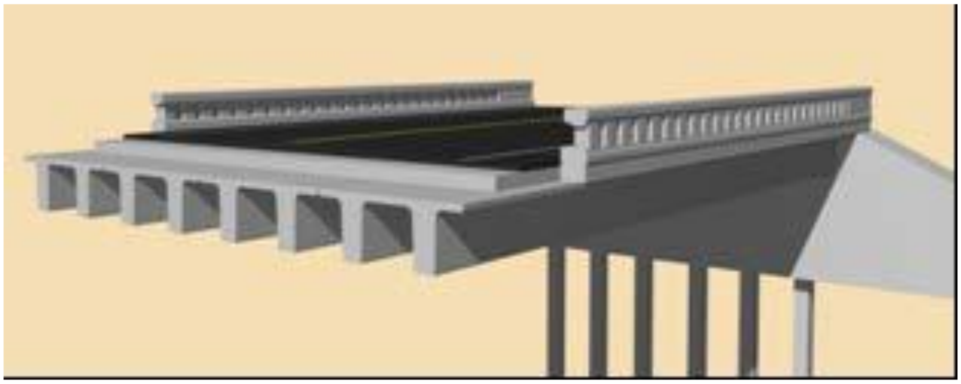
*Inverted T Bridge System*
*http://www.fhwa.dot.gov/bridge/prefab/slab.cfm*
*Accessed 15 Nov 2012*

## PRECAST DOUBLE-T BEAMS

**Description:** Precast double-T beams are used in bridges much like cast-in-place double-T beams are used. The benefits of precasting are that it allows for prefabrication, reduces or eliminates the cost of transporting fresh concrete, and allows for better quality control during the construction phase of a project.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** TXDOT



*Adjacent Double-T Beams*
"ABC—Experience in Design, Fabrication, and Erection of PBES"

## PRETOPPED U-BEAM DESIGN

**Description:** Pretopped U-beams use a portion of the existing Texas U-beam form system. Each beam is fabricated as a closed U-beam and hauled to the contractor's yard, where a 4-in. topping is placed before beam erection. A cast-in-place closure pour joins the deck girder sections after erection.

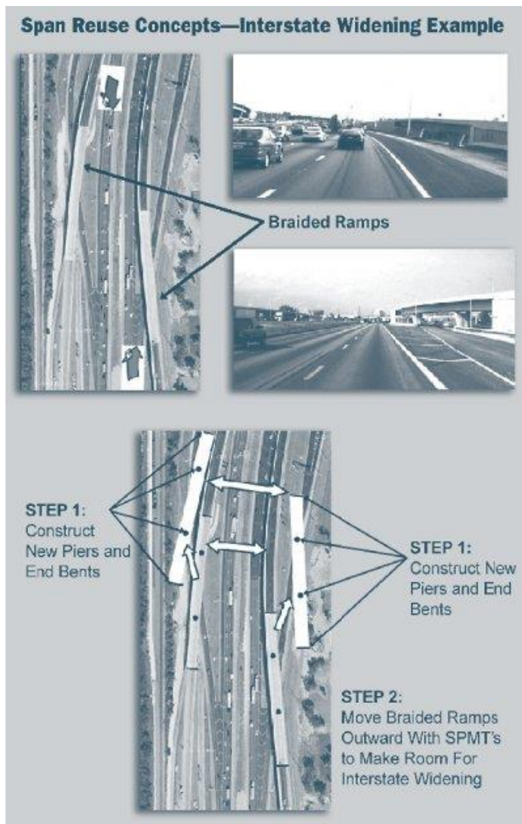
**Source:** "Texas's Totally Prefabricated Bridge Superstructures"

**Example Project:** TXDOT

## SPAN REUSE

**Description:** Frequently bridges are replaced based on increased highway capacity requirements well before they have reached their useful service life. The ability to lift and drive an entire single- or multiple-span bridge into position with SPMTs expands the potential use of bridges to more than one location. Consideration could be given in the design of bridge spans to facilitate their relocation in the future to address traffic needs more quickly and at lower cost.

**Source:** "Manual of Use of Self-Propelled Modular Transporters to Remove and Replace Bridges"




*Span Reuse Process*
*http://www.fhwa.dot.gov/bridge/pubs/07022/chap04.cfm*
*Accessed 23 Oct 2012*

## ARCH SPAN WITH/WITHOUT DECK

**Description:** This is an example of a full-width beam element. Part of the superstructure is prefabricated and constructed off site. Then, SPMTs, barges, or other placement devices are used to move it into place. This technique also serves as a testament to ABC being implemented to different degrees. Spans can also be moved with the bridge deck already constructed to it.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** Hastings, MN Tied Arch Bridge on Hwy 61

*Hastings Arch Bridge with Deck Move (Barge Use)*
*http://www.hastingsstargazette.com/event/photogallery/id/57/*
*Accessed 23 Oct 2012*

## TRUSS SPAN WITH/WITHOUT DECK

**Description:** This is an example of a full-width beam element. Part of the superstructure is prefabricated and constructed off site. Then, SPMTs, barges, or other placement devices are used to move it into place. This technique also serves as a testament to ABC being implemented to different degrees. Spans can also be moved with the bridge deck already constructed to it.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** Providence River Bridge, Rhode Island

*Replacement of Truss Span without Deck (Barge Use)*
*http://www.fhwa.dot.gov/bridge/abc/docs/aashto.pdf*
*Accessed 23 Oct 2012*

## SELF-PROPELLED MODULAR TRANSPORTERS (SPMTS)

**Description:** Self-propelled modular transporters are a tool used to transport bridge decks or portions of bridge decks from the prefabrication site to the project site. This is especially useful when working on projects located away from any rivers or bodies of water where barges could be used for transport. This technique is one of the main ideas behind accelerated bridge construction.

**Source:** "Manual of Use of Self-Propelled Modular Transporters to Remove and Replace Bridges"

**Example Project:** 4500 South Bridge, Salt Lake City, UT


*Self-Propelled Modular Transporter Carrying a Bridge Deck*
*http://www.ecvv.com/product/2996068.html*
*Accessed 23 Oct 2012*

## LONGITUDINAL LAUNCHING

**Description:** Longitudinal launching involves erection of the bridge superstructure in a launching pit located behind one or both of the abutments. A lightweight launching nose is often used to minimize deflection of the cantilevered end of the superstructure during launching and to account for defection of the end of the bridge as it reaches each support. In some cases, intermediate towers are used to minimize deflections on longer spans.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** UDOT

*Longitudinal Launching of a Utah Bridge*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## HORIZONTAL SKIDDING OR SLIDING

**Description:** This method requires the new bridge be built in parallel to the proposed finished location. The structure is normally built on a temporary support frame that is equipped with rails. The bridge can be moved transversely using cables or hydraulic systems. Minor vertical adjustment can also be incorporated into these systems.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Project:** ODOT

*Lateral Bridge Slide in Oregon*
*"ABC—Experience in Design, Fabrication, and Erection of PBES"*

## BARGE USE

**Description:** When a bridge project site is nearby a river or other body of water, a convenient way to transport constructed portions of bridges from the prefabrication site to the project site is through the use of barges. The prefabricated portions are simply lifted onto barges and the barges are directed downstream to the project site where the portions of the bridge (or in some cases, the entire bridge) are lifted into place from the barge.

**Source:** "ABC—Experience in Design, Fabrication, and Erection of PBES"

**Example Site:** Hastings, MN Tied Arch Bridge on Hwy 61

*Hastings, MN Tied Arch Bridge on Barge Before Being Lifted into Place*
*http://www.hastingsstargazette.com/event/photogallery/id/57/*
*Accessed 23 Oct 2012*

# APPENDIX B: SDDOT INTERVIEW QUESTIONS AND ANSWERS

1. What are the current conventional bridge construction and practices typically employed for bridge projects of SDDOT?

2. Typically, what is considered to be the normal time duration required for conventional bridge construction and practices listed in question 1?

3. What is the typical duration of traffic interruption involved with conventional bridge construction projects using conventional practices listed in question 1? Can some of the techniques allow partial traffic flow during construction?

4. Based on the categories of ABC techniques listed, what are the current ABC techniques or practices employed at SDDOT?

   Is there any category you think is missing in this table?

5. Based on the categories of ABC techniques listed, what are the ABC techniques or practices that are currently being considered for implementation at SDDOT?

6. What are the current performance issues (short or long term) most commonly encountered in using conventional bridge construction techniques and practices at SDDOT?

7. What are the available resources at the disposal of SDDOT for connecting SDSU and this project with SD contractors for a survey on their experience on different construction techniques and plausibly employable ABC techniques?

8. What is the typical general decision-making process(es) used by SDDOT for making bridge construction technique selection decisions? What are the priorities of SDDOT? Please take a look at ABC Manual, p. 140 for some flowchart examples in current ABC manual and comment on if you like the format or not.

9. From the decision-making processes discussed in question 8, what portion of these decisions and selections are left to the contractor and what portion is left to SDDOT?

10. Does SDDOT have any experience with ABC placement equipment such as barge use, self-propelled modular transporters, or lateral/horizontal skidding?

# APPENDIX C: OTHER STATE DOT INTERVIEWS

We have found through research and literary review that your organization has experience with one or more of the following accelerated bridge construction techniques in one or more of your past projects.

List of ABC techniques with which each other state DOT office has experience

Due to your current experience with these ABC techniques, I would like to inquire about the details related to each of the techniques listed above.

1. What are the benefits, if any, to using the above mentioned ABC techniques over the conventional construction alternative? Please be specific and list multiple benefits if they exist.

2. Is there any special equipment required to construct, install, or implement any of the above techniques?

3. Is there any special crew experience necessary to construct, install, or implement any of the above techniques?

4. Is there any special site requirement necessary to construct, install, or implement any of the above techniques?

5. What is the typical duration associated with the construction, installation or implementation of each of the above techniques?

6. What is the overall cost of using this ABC technique versus the cost of the alternative conventional construction method?

7. Are there any potential problems associated with any of the above techniques?

8. Are there any additional comments you would like to offer regarding any of the above techniques?

9. Have you encountered or performed any of the following additional ABC techniques?

   List here the "catch-all" ABC techniques that cannot be assigned to specific other state DOT offices

10. If so, can you offer supplemental information on the details of these additional ABC techniques? Please give answers addressing the same concerns as the questions previously answered.

11. In order to obtain the information you were unable to provide, do you think it would be beneficial to offer a list of contact information for regularly used contractors and consultants in your state that may have the specific information we require about any of the ABC techniques listed above?

12. Have you ever heard of and/or utilized the ABC AHP Decision Tool produced by the FHWA?

# APPENDIX D: ABC CATALOG

Substructure Techniques:

| Type of Construction | Category | Subcategory | ABC Techniques | ABC Tech. Profile | Benefit | Special Equipment | Special Crew Experience |
|---|---|---|---|---|---|---|---|
| Accelerated Bridge Construction | Substructure | Abutments | Precast Abutments | Profiles PDFs\Precast Abutments.pdf | Time-saving, unnecessary detours avoided | Specialty heavy load crane used for installation | Special permit trucks required |
| Accelerated Bridge Construction | Substructure | Abutments | Geosynthetic Reinforced Soil (GRS) Abutments | Profiles PDFs\GRS Abutments.pdf | Eliminates settlement between abutment and approach backfill; limited equipment required, takes little technical ability to construct, material easy to warehouse | N/A | N/A |
| Accelerated Bridge Construction | Substructure | Abutments | Spill-Through Abutments | Profiles PDFs\Spill-Through Abutments.pdf | Reduces soil pressure on cantilever abutments | INF | INF |
| Accelerated Bridge Construction | Substructure | Abutments | Precast Pier Box Cofferdams | Profiles PDFs\Precast Pier Box Cofferdams.pdf | Time savings due to precasting vs. CIP | INF | INF |
| Accelerated Bridge Construction | Substructure | Abutments | Integral Abutments | Profiles PDFs\Integral Abutments.pdf | Can be built very quickly, are inexpensive, and eliminates joints; there are no physical expansion joints due to the abutment pieces physically moving | N/A | N/A |
| Accelerated Bridge Construction | Substructure | Caps | Precast Bent Caps | Profiles PDFs\Precast Bent Caps.pdf | Time-saving, safer for workers by keeping them out of the air; beneficial for repeatable construction (many of the same element) | Specialty heavy load crane used for installation | Field welders required |
| Accelerated Bridge Construction | Substructure | Footings | Precast Spread Footings | Profiles PDFs\Precast Spread Footings.pdf | Time-savings due to not having to wait for concrete to cure before column placement | N/A | N/A |
| Accelerated Bridge Construction | Substructure | Footings | Precast Pile Cap Footings | Profiles PDFs\Precast Pile Cap Footings.pdf | Increased shear resistance at footing of pier; ease of construction over water channels | Corrugated steel pipe voids are used | N/A |
| Accelerated Bridge Construction | Substructure | Miscellaneous Elements | Prefabricated Full Height Wall Panels | Profiles PDFs\Prefabricated Full Height Wall Panels.pdf | Beneficial for reinforcement of structures in areas of high seismic or hurricane activity; placement of wall panels on complicated terrain with a crane from a distance improves worker safety; time-savings of precasting vs CIP | Generally would need larger cranes (360 ton range) | N/A |
| Accelerated Bridge Construction | Substructure | Miscellaneous Elements | Proprietary Retaining Wall Systems | Profiles PDFs\Proprietary Retaining Wall Systems.pdf | Purchased and installed, no construction or assembly required; better quality concrete by precasting vs. CIP; time savings due to precasting | N/A | N/A |
| Accelerated Bridge Construction | Substructure | Miscellaneous Elements | Prefabricated Columns | Profiles PDFs\Prefabricated Columns.pdf | Time-saving of precasting vs. CIP | INF | INF |
| Accelerated Bridge Construction | Substructure | Miscellaneous Elements | Precast Box Culverts | Profiles PDFs\Precast Box Culverts.pdf | Time-saving due to precasting vs. CIP; less cost of transporting fresh concrete to remote job sites; on sites with soils subject to settlement, the precast elements will bear the weight of the settlement better and not crack as easily as a CIP box culvert would | Requires a fabricator with forms to build them; initial start-up costs for formwork for fabrication yard required | N/A |
| Accelerated Bridge Construction | Substructure | Miscellaneous Elements | CFA Piles | Profiles PDFs\CFA Piles.pdf | Time-saving on foundation installation | INF | INF |

Substructure Techniques (cont'd):

| Special Site Requirement | Connections Details | Typical Duration | Potential Problems | Existing Experience | Other Comments |
|---|---|---|---|---|---|
| Room to store the elements until use | N/A | Time savings of 1 week to 10 days compared to conventional | Transport of large elements can be difficult over short bridges or windy roads | Caltrans, Barstow, CA | These elements are typically incorporated with precast wingwalls, which complicates the project when there is a skew. |
| Only used for short span bridges <140 ft | N/A | 1 week compared to 4-5 weeks conventional | If you have scour potential, this technique should not be used; durability of the block is a concern that you need to be aware of | Founders/Meadows Parkway Bridge, Denver, CO | |
| INF | N/A | INF | INF | Tombigbee National Forest, MS | |
| INF | N/A | INF | INF | Providence River Bridge, Providence, RI | |
| Maximum span of 300 ft | Creating a joint system in the road adds 40 ft of length to the bridge; there have been difficulties creating a joint system that will work well | INF | Approach slab will experience some movement due to the joint within the slab | NYDOT | |
| N/A | Special grouting is used for connection purposes; field welding is used for the connections within the bent cap | A threefold increase in speed of construction of the bent cap elements | Transporting is high cost compared to conventional bent caps; systems need to be flexible with error tolerances | Lake Ray Hubbard Bridge, Dallas, TX | Not used very often anymore in Texas (no mention of why) |
| Access clearance for lifting elements | N/A | Time savings of approx. 1-2 days compared to conventional | Due to size, transporting can be difficult or impossible; CIP is easier to level than precast elements | 4500 South Bridge, Salt Lake City, UT | Not used very often, typically there is sufficient access to cast spread footings in place |
| N/A | N/A | INF | INF | INF | |
| N/A | N/A | Dependent on wall size | Access can be an issue on some job sites | INF | Prefabrication is helpful for aethetical purposes and an effective way to achieve architectural detail |
| N/A | The more pieces present, the more connections that will require special attention | 1:5 ABC:conventional | If you use a proprietary system on a federal project, you need authorization to complete the project | TXDOT | Geotechnical office is highly involved in the selection of the proprietary walls and makes recommendations based on the foundation material at the project site |
| INF | N/A | INF | INF | Multiple | Rectangular columns are easier to fabricate and are recommended for ABC practices. |
| N/A | Joints created at intervals within the culvert using grouting to prevent water leakage | 2 days for precast vs. at least 2 weeks for CIP | Water leakage through the joints creating settlement is a concern, but has not been much of an issue | Multiple | |
| INF | N/A | INF | INF | INF | |

Superstructure Techniques:

| Type of Construction | Category | Subcategory | ABC Techniques | ABC Tech. Profile | Benefit | Special Equipment | Special Crew Experience |
|---|---|---|---|---|---|---|---|
| Accelerated Bridge Construction | Superstructure | Decks and Panels | Full-Depth Precast Deck Panels | Profiles PDFs\Full-Depth Precast Deck Panels.pdf | Can be connected off-site and transported as one element; time savings by not having to cure concrete | Large panels could require specialty heavy load cranes | N/A |
| Accelerated Bridge Construction | Superstructure | Decks and Panels | Partial-Depth Precast Deck Panels | Profiles PDFs\Partial-Depth Precast Deck Panels.pdf | Eliminates the need for removable concrete forms, prevents future failure by making bottom of deck the strongest portion | N/A | Crew needs experience in leveling and sealing the panels |
| Accelerated Bridge Construction | Superstructure | Decks and Panels | FRP Deck Panels | Profiles PDFs\FRP Deck Panels.pdf | High tensile strength, lightweight, high fatigue resistance, corrosion resistance because the composites don't deterioriate; they gain capacity by lessening the dead load applied to the structure | Premanufactured in a plant, but no special equipment used on site | N/A |
| Accelerated Bridge Construction | Superstructure | Decks and Panels | Steel Grid Deck Systems | Profiles PDFs\Steel Tub Girder.pdf | Can be prefabricated for rapid installation; more lightweight than concrete systems; can increase the load capacity of older bridges requiring deck replacements | Dependent on method of attachment | Welders might be necessary for connections |
| Accelerated Bridge Construction | Superstructure | Decks and Panels | Lightweight Precast Deck Panels | Profiles PDFs\Lightweight Precast Deck Panels.pdf | Improves transportability of panels, thereby reducing construction time; reducing the weight can bring a bridge up to current code | N/A | N/A |
| Accelerated Bridge Construction | Superstructure | Decks and Panels | Precast Approach Slabs | Profiles PDFs\Precast Approach Slabs.pdf | Time-savings due to not having to wait for concrete to cure like with CIP | N/A | N/A |
| Accelerated Bridge Construction | Superstructure | Girders/Beams | Precast I-Girder | Profiles PDFs\Precast I-Girder.pdf | No falsework required, time-savings due to faster construction | N/A | N/A |
| Accelerated Bridge Construction | Superstructure | Girders/Beams | Precast Bulb-T Girders | Profiles PDFs\Precast Bulb-T Girder.pdf | No falsework required, time-savings due to faster construction | N/A | N/A |
| Accelerated Bridge Construction | Superstructure | Girders/Beams | Precast Box Girders | Profiles PDFs\Precast Box Girder.pdf | No falsework required, time-savings due to faster construction | N/A | N/A |
| Accelerated Bridge Construction | Superstructure | Girders/Beams | Steel Tub Girder | Profiles PDFs\Steel Tub Girder.pdf | Particularly in curved bridges, offers advantages in terms of span range, stiffness, and durability | N/A | N/A |
| Accelerated Bridge Construction | Superstructure | Girders/Beams | Precast Inverted T-Beams | Profiles PDFs\Precast Inverted T-Beams.pdf | Reduces the overall weight of short span bridges; must faster construction due to elimination of falsework | Special equipment and expenses for the fabricator for the first time producing | N/A |
| Accelerated Bridge Construction | Superstructure | Girders/Beams | Precast Double-T Beams | Profiles PDFs\Precast Double T-Beams.pdf | Time savings due to precasting vs. CIP | INF | INF |
| Accelerated Bridge Construction | Superstructure | Girders/Beams | Pretopped U-Beam Design | Profiles PDFs\Pretopped U-Beam Design.pdf | Limits construction and closures to just a few hours; can be used with longer spans (80-130ft) | Specialty heavy load crane used for lifting | N/A |
| Accelerated Bridge Construction | Superstructure | Spans | Span Reuse | Profiles PDFs\Span Reuse.pdf | Cost-saving due to being able to recycle material | INF | INF |
| Accelerated Bridge Construction | Superstructure | Spans | Arch Span with/without Deck | Profiles PDFs\Arch Span with-without Deck.pdf | All built off-site, then can be brought in and floated into place in a very narrow window of time, very little interference with barge traffic major water channels | Requires advanced placement equipments (e.g. SPMTs) to move; special jacks on the piers to lift the arch span into place | N/A |
| Accelerated Bridge Construction | Superstructure | Spans | Truss Span with/without Deck | Profiles PDFs\Truss Span with-without Deck.pdf | All built off-site, then can be brought in and floated into place in a very narrow window of time, very little interference with barge traffic major water channels | Requires advanced placement equipments (e.g. SPMTs) to move; special jacks on the piers to lift the arch span into place | N/A |

Superstructure Techniques (cont'd):

| Special Site Requirement | Connections Details | Typical Duration | Potential Problems | Existing Experience | Other Comments |
|---|---|---|---|---|---|
| Crane placement and clearance tolerances; room to store panels prior to placement | Connections can occur offsite, or can occur after placement of panels | 2-3 weeks for deck panels vs. 4 weeks minimum for CIP | Decks without asphalt overlays create a somewhat bumpy ride due to the panels; leveling and tolerances are also considerable issues | UDOT | Longitudinally post-tensioning the deck panels provides long-term durability |
| N/A | N/A | Faster than full-depth precast deck panels | Negative results with reflective cracking due to panel bedding during construction; you can't see what's going on underneath the deck (i.e. cracks, leaks) | ODOT, WSDOT | The use of these is limited due to the complications encountered in previous projects, along with complaints from bridge inspectors on the job sites |
| N/A | Connected with high quality epoxy, crew must be able to mix and use correctly due to time constraints on placement for the epoxy to still be usable | 60 ft length, 34 ft width bridge installed in 1 day (5-6 weeks conventionally) | Lightweight panels can be a problem because uplift can occur if there are not enough connection points. The overlays used on the panels can be a challenge. | Project 100 in Ohio | According to ODOT: They're not cost-effective; they're a niche market where you would need a very lightweight deck. |
| Only used on moveable bridges (15-20 in WA) | N/A | Might take longer than with a CIP deck due to grid deck manufacturing, transporting, attachment, etc. | Fatigue issues, traffic hazard if there is water or slick roads, vehicles with studded tried (10-15% in CA) wear the steel grid deck down | 17th St. Causeway Bridge in Ft. Lauderdale, FL | Very expensive, so generally used when preserving live load of the system is important (due to lightweight nature of the deck) |
| N/A | N/A | INF | N/A | UDOT | |
| N/A | N/A | Only difference between precast and CIP is cure time | Shear transfer across joints can lead to independent deflections | UDOT | |
| N/A | N/A | Weeks to months of time savings | Joints have weak lateral capacity (important for seismic regions) | I-5 Southbound Truck Route Crossing Repair, Los Angeles County | |
| N/A | N/A | Weeks to months of time savings | Joints have weak lateral capacity (important for seismic regions) | Caltrans, Barstow, CA | |
| N/A | N/A | Weeks to months of time savings | Joints have weak lateral capacity (important for seismic regions) | Russian River Bridge, Geyserville, CA | |
| N/A | N/A | Little to no time savings | INF | Brightman Street Bridge Replacement Project, Fall River, Somerset, MA | According to contractors in SD, this method is only used when the project calls for it, and therefore does not have many benefits for use vs. other precast or conventional methods |
| Maximum span of 45ft | N/A | Approx. 4 weeks from closure to opening (CIP could be 10-11 weeks) | Significant problems with deck cracking on the surface of the shape; differential shrinkage between precast shape and placed shape | MNDOT, NDOT | MnDOT is trying several things to resolve the deck cracking, but they are encountering several obstacles; in terms of constructability and time-savings it's been very beneficial |
| Shorter span lengths (50-60ft) | N/A | INF | If overlay is not CIP, durability is an issue and recommended for non-major highways | TXDOT | |
| Requires a build site away from project for building bridge on similar bearings | N/A | INF | INF | TXDOT | |
| INF | N/A | INF | INF | INF | |
| Staging and prefabricating area required, distance dependent on distance between lock and dams | N/A | INF | Monitoring tolerances within the arch span during movement and placement can be a difficult process | Hastings, MN Tied Arch Bridge on Hwy 61 | |
| Staging and prefabricating area required, distance dependent on distance between lock and dams | N/A | INF | Monitoring tolerances within the truss span during movement and placement can be a difficult process | Providence River Bridge, Rhode Island | |

## Placement Techniques

| Type of Construction | Category | Subcategory | ABC Techniques | ABC Tech. Profile | Benefit | Special Equipment | Special Crew Experience |
|---|---|---|---|---|---|---|---|
| Accelerated Bridge Construction | Placement | | SPMTs | Profiles PDFs\SPMTs.pdf | Significantly reduces traffic disruption, improves work zone safety, and improves quality and constructibility, and increases constractor and owner options | Stress trackers for moving the bridge | Highly specialized work; therefore the heavy lift contractor will generally bring his/her own people |
| Accelerated Bridge Construction | Placement | | Longitudinal Launching | Profiles PDFs\Longitudinal Launching.pdf | No interruption of major channels beneath structure, including deep canyons, waterways, and especially highly traveled roads | N/A | N/A |
| Accelerated Bridge Construction | Placement | | Horizontal Skidding or Sliding | Profiles PDFs\Horizontal Skidding or Sliding.pdf | Time-savings even greater than with SPMTs, with less risk involved; impact to traffic is extremely low; generally safer due to off-site construction for the travelling public and the construction crew | Jacking systems and manifolds required | Specialized crew must be brought in to operate |
| Accelerated Bridge Construction | Placement | | Barge Use | Profiles PDFs\Barge Use.pdf | Can move large pieces on a river or waterway, whereas on land or over a major railroad, SPMTs would be required; however, SPMTs can be used with barges | N/A | N/A |

| Special Site Requirement | Connections Details | Typical Duration | Potential Problems | Existing Experience | Other Comments |
|---|---|---|---|---|---|
| Minimum width requirements; off-site area required for bridge precasting, as well as a clear path from precasting site to project site | N/A | A day to a weekend vs. CIP (6 week min.) | Monitoring stresses within the bridge during picking up, moving, and placing the bridge | 4500 South Bridge, Salt Lake City, UT | Very precise surveys are important for the use of these |
| Need room to build bridge behind where it is being launched | N/A | A day to a weekend vs. CIP (6 week min.) | Tolerances and stresses need to be monitored closely during bridge movements | UDOT | |
| Bridge must be built parallel to final location; the use of a crross street is quite important for bridge prefabrication | N/A | Bridge can be replaced in as little as 12 hrs, typically 2-3 days vs. 2-3 months conventionally | Jacks must move in unison, otherwise twisting can occur; sliding surfaces must be smooth, as imperfections can cause frictional stresses; tolerances need to be monitored | ODOT | |
| Room for navigation of river traffic | N/A | INF | Monitoring of water level on all four edges of the barge; maintaining a level platform as much as possible if being used in conjunction with SPMTs | Hastings, MN Tied Arch Bridge on Hwy 61 | Though SPMTs are normally not required for barge use, SPMTs were used on the project in Hastings, MN to move the bridge onto the barge. |

# APPENDIX E: SDDOT CONVENTIONAL COSTS TABLES

| | Project Number | Total 'ON' Bridge Cost | Mobilization | Traffic Control | Area | Total Cost/SF |
|---|---|---|---|---|---|---|
| Steel Girder Bridges | NH 0235(1)0 | $1,323,138.00 | $183,333.33 | $64,025.38 | 19602 | $80.12 |
| | IM-BRF 90-1(185)30 | $3,155,362.00 | $376,135.00 | $268,254.00 | 45474 | $83.56 |
| | NH-BRF 0012(103)30 | $1,702,942.00 | $325,000.00 | $33,457.50 | 16464 | $125.21 |
| | IM 29-2(52)72 | $1,813,860.00 | $730,000.00 | $37,735.00 | 17746 | $145.47 |
| | IM 90-2(134) | $1,884,335.00 | $637,280.00 | $333,996.83 | 17794 | $160.48 |
| | BRF 0012(92)248 | $1,258,500.00 | $90,000.00 | $19,349.30 | 12385 | $110.44 |
| | IM 29-3(76)78 | $3,483,607.00 | $323,835.76 | $30,643.96 | 43886 | $87.46 |
| | | | | | **Mean** | $113.25 |
| | | | | | **Std. Dev.** | $31.79 |
| | | | | | **Mean + Std. Dev.** | **$145.04** |

| | Project Number | Total 'ON' Bridge Cost | Mobilization | Traffic Control | Area | Total Cost/SF |
|---|---|---|---|---|---|---|
| Continuous Concrete Bridges | NH-PH 0085(30)45 | $349,559.00 | $166,666.67 | $26,387.67 | 6168 | $87.97 |
| | P 0010(38)362 | $680,894.00 | $113,300.00 | $14,524.60 | 6059 | $133.47 |
| | BRF 0903(44)167 | $1,123,264.00 | $253,490.72 | $65,782.06 | 12408 | $116.26 |
| | BRF 3134(01)276 | $913,187.00 | $180,000.00 | $5,226.00 | 7687 | $142.89 |
| | P-BRF 0018(126)387 | $744,120.00 | $95,000.00 | $14,748.24 | 6283 | $135.90 |
| | NH-PH 0018(139)87 | $501,429.00 | $105,000.00 | $46,423.00 | 3555 | $183.64 |
| | EM 0018(152)69 | $636,655.00 | $40,000.00 | $6,702.86 | 6728 | $101.57 |
| | P 0034(152)69 | $722,630.00 | $136,620.06 | $16,728.29 | 9377 | $93.42 |
| | EM0385(15)0 | $746,777.00 | $200,000.00 | $16,194.29 | 5200 | $185.19 |
| | NH0018(160)424 | $1,216,297.00 | $157,800.00 | $17,700.00 | 7381 | $188.56 |
| | | | | | **Mean** | $136.89 |
| | | | | | **Std. Dev.** | $38.29 |
| | | | | | **Mean + Std. Dev.** | **$175.18** |

| | Project Number | Total 'ON' Bridge Cost | Mobilization | Traffic Control | Area | Total Cost/SF |
|---|---|---|---|---|---|---|
| Prestressed Girder Bridges | NH 0235(1)0 | $637,076.00 | $366,666.66 | $128,050.76 | 11986 | $94.43 |
| | P-PH 0011(5)81 | $1,583,459.00 | $104,000.00 | $4,742.40 | 25346 | $66.76 |
| | BRF-P 3052(3)319 | $186,880.00 | $61,666.67 | $6,396.70 | 3326 | $76.65 |
| | BRF 0212(64)36 | $421,626.00 | $68,700.23 | $14,556.58 | 7124 | $70.87 |
| | BRF 0073(20)202 | $371,134.00 | $62,000.00 | $8,801.00 | 4466 | $98.96 |
| | NH 0083(23)191 | $283,554.00 | $47,562.50 | $9,008.34 | 4214 | $80.71 |
| | BRF 3130(6)196 | $492,577.00 | $110,000.00 | $8,052.76 | 6279 | $97.25 |
| | IM 90-6(37)281 | $935,307.00 | $123,352.00 | $29,736.00 | 14764 | $73.72 |
| | BRF 90-2(92)64 | $1,039,927.00 | $30,000.00 | $69,000.00 | 15233 | $74.77 |
| | IM 90-5(39)239 | $1,093,907.00 | $99,400.00 | $19,036.34 | 11286 | $107.42 |
| | NH 0212(107)318 | $424,375.00 | $85,000.00 | $10,155.00 | 5547 | $93.66 |
| | EM 0902(39)61 | $2,686,235.00 | $465,250.00 | $124,524.75 | 38494 | $85.10 |
| | IM 0909(69)390 | $721,433.00 | $71,140.00 | $15,666.29 | 9472 | $85.33 |
| | BRF 3071(5)3 | $917,151.00 | $190,000.00 | $24,742.00 | 11561 | $97.91 |
| | IM-PH 0901(61)49 | $1,469,425.00 | $383,333.33 | $100,704.00 | 17590 | $111.06 |
| | IM 0909(77)390 | $893,429.00 | $81,622.78 | $9,529.11 | 9472 | $103.95 |
| | EM 0018(98)44 | $2,188,425.00 | $95,567.79 | $12,860.91 | 24283 | $94.59 |
| | EM-P 4411(01) | $1,900,925.00 | $407,877.00 | $13,003.75 | 20069 | $115.69 |
| | IM-EM 0909(68)396 | $1,831,151.00 | $383,650.00 | $26,235.00 | 24163 | $92.75 |
| | NH-PH 0018(139)87 | $353,563.00 | $105,000.00 | $46,423.00 | 3248 | $155.48 |
| | P 0065(04)214 | $1,553,250.00 | $438,000.00 | $24,093.00 | 13820 | $145.83 |
| | P1282(06) | $3,251,778.00 | $650,000.00 | $142,893.80 | 29750 | $135.96 |
| | P0028(31)281 | $1,493,010.00 | $297,932.50 | $13,761.80 | 16899 | $106.79 |
| | NH-PS0012(145)387 | $1,072,152.00 | $676,500.00 | $22,839.50 | 9083 | $195.03 |
| | | | | | **Mean** | $102.53 |
| | | | | | **Std. Dev.** | $29.95 |
| | | | | | **Mean + Std. Dev.** | **$132.48** |

# APPENDIX F: ABC COST CATALOG

| Category | ABC Technique | Approximate Materials Cost | | Time | Equipment |
|---|---|---|---|---|---|
| | | Materials | Contractor | | |
| Substructure | Precast Abutments | ~ $30-40/CF for precasting | ~ $10,000 saved | 1 week | Crane transport and operation |
| | Geosynthetic Reinforced Soil (GRS) Abutments | INF | ~ $20,000 saved | ~ 2 weeks | Less equipment used than with conventional |
| | Spill-Through Abutments | INF | INF | INF | INF |
| | Precast Pier Box Cofferdams | ~ $30-40/CF for precasting | Transport costs: $20,000-$25,000 plus $200-$250/hr | INF | INF |
| | Integral Abutments | ~ $30-40/CF for precasting | Transport costs: $20,000-$25,000 plus $200-$250/hr | INF | INF |
| | Precast Bent Caps | ~ $30-40/CF for precasting | 1/2 of original labor costs | Threefold increase in speed | Crane transport and operation |
| | Precast Spread Footings | ~ $30-40/CF for precasting | ~ $2,000 saved | 1-2 days | N/A |
| | Precast Pile Cap Footings | ~ $30-40/CF for precasting | INF | INF | N/A |
| | Prefabricated Full Height Wall Panels | INF | Transport costs: $20,000-$25,000 plus $200-$250/hr | Depedent on wall size | Crane transport and operation |
| | Proprietary Retaining Wall Systems | INF | 1/3 of original labor costs | Fivefold increase in speed | N/A |
| | Prefabricated Columns | ~ $30-40/CF for precasting | Transport costs: $20,000-$25,000 plus $200-$250/hr | Similar to conventional | N/A |
| | Precast Box Culverts | ~ $30-40/CF for precasting | ~ $10,000-15,000 saved | ~ 1-1.5 weeks | N/A |
| | CFA Piles | INF | INF | INF | INF |
| Superstructure | Full-Depth Precast Deck Panels | INF | ~ $10,000-15,000 saved, but transport costs | ~ 1-1.5 weeks | Placement equipment, possibly crane transport due to size of panels |
| | Partial-Depth Precast Deck Panels | INF | ~ $15,000-20,000 saved | ~ 1.5-2 weeks | N/A |
| | FRP Deck Panels | INF | ~ $20,000-30,000 saved | ~ 2-3 weeks | N/A |
| | Steel Grid Deck Systems | INF | Slightly more labor | Slightly longer than conventional | INF |
| | Lightweight Precast Deck Panels | INF | ~ $10,000-15,000 saved | ~ 1-1.5 weeks | N/A |
| | Precast Approach Slabs | ~ $30-40/CF for precasting | Transport costs: $20,000-$25,000 plus $200-$250/hr | Faster by cure time for CIP | N/A |
| | Precast I-Girder | $125-210/LF, depending on cross section | ~ $20,000-30,000 saved | ~ 2-3 weeks | N/A |
| | Precast Bulb-T Girders | ~ $30-40/CF for precasting | ~ $20,000-30,000 saved | ~ 2-3 weeks | N/A |
| | Precast Box Girders | $380-420/LF | ~ $20,000-30,000 saved | ~ 2-3 weeks | N/A |
| | Steel Tub Girder | | INF | Similar to conventional | N/A |
| | Precast Inverted T-Beams | ~ $30-40/CF for precasting | ~ $30,000-50,000 saved | ~ 3-5 weeks | N/A |
| | Precast Double-T Beams | $105-125/LF | ~ $30,000 saved | ~ 3 weeks | N/A |
| | Pretopped U-Beam Design | U-beam portion is $25/SF | INF | INF | Crane transport and operation |
| | Span Reuse | INF | INF | INF | Specialty placement equipment |
| | Arch Span with/without Deck | INF | INF | INF | Specialty placement equipment |
| | Truss Span with/without Deck | INF | INF | INF | Specialty placement equipment |
| Placement | SPMTs | N/A | ~ $40,000-60,000 saved | ~ 4-6 weeks | ~$1 million for first use, ~$500k for every use after |
| | Longitudinal Launching | N/A | ~ $40,000-60,000 saved | ~ 4-6 weeks | Similar to SPMTs, but highly project dependent |
| | Horizontal Skidding or Sliding | N/A | ~ $60,000-80,000 saved | ~ 6-8 weeks | Much less expensive than SPMTs |
| | Barge Use | N/A | INF | INF | Barge |

| Category | Change in Cost Due to ABC | Description of Additional Cost |
|---|---|---|
| Substructure | $12,500 (additional) - $55,000 (additional) | ($20000-$25000) (crane) + ($2500-$10000) (operating costs) - ($10000-$20000) (avg time savings) + ($10000-$30000) (avg precasting cost) |
| Superstructure | $17,500 (saved) - $55,000 (additional) | ($20000-$25000) (crane) + ($2500-$10000) (operating costs) - ($10000-$50000) (avg time savings) + ($10000-$30000) (avg precasting cost) |
| Superstructure and Placement | $82,500 (additional) - $435,000 additional | ($20000-$25000) (crane) + ($2500-$10000) (operating costs) - ($50000-$130000) (avg time savings) + ($10000-$30000) (avg precasting cost) + ($100000-$500000) (excess placement costs) |