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Implementation Guidance for Accelerated Bridge Construction in South Dakota

**Project SD2012-03
Final Report**

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<p>16. Abstract</p> <p>A study was conducted to investigate the 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. Less interruption to traffic also lowers agency costs associated with traffic control and road user costs from delays and detours. 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.</p> <p>A comprehensive literature review was conducted in order to develop a catalog of ABC techniques, as well as 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, SDDOT needs to determine whether ABC techniques will provide a more efficient use of construction funds than conventional bridge construction methods. Therefore, this research was geared toward developing both the knowledge base and the tool to evaluate if implementation of ABC techniques is beneficial to a particular project scenario based on South Dakota local cost and experience data.</p> <p>Many other state DOT offices currently have evaluation tools for ABC and some were used as references when designing the tool for SDDOT. Various types of program inputs, as well as output information were used in conjunction with decision-making flow charts to formulate the process that recommends whether or not to use ABC on a given bridge construction project. Examples for using the developed tool were also included in this study to illustrate the use of the evaluation tool for ABC decision making in South Dakota.</p>					
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TABLE OF ACRONYMS

Acronym	Meaning
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

1 EXECUTIVE SUMMARY

Through its implementation in recent years in the U.S., ABC (primarily through the use of prefabricated elements) has been proven to improve work zone safety and reduce interruption to end users. The concept itself has been gaining momentum to become 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 U.S. including multiple projects in Utah (Ardani et al. 2010, Park 2011), Washington (Khaleghi 2005, Khaleghi 2010, and Marsh et al. 2005), California (Chung et al. 2008), etc. All these demonstrative projects on critical bridge sites had been very successful in minimizing traffic interruption to a level that is not possible with traditional construction methods (e.g. removal and replacement of a major bridge in a week (Ardani et al. 2010)). A number of 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 very typical highway bridge systems, as it was demonstrated in an Iowa DOT project (bridge over Keg Creek near Council Bluffs, Iowa) as part of the second Strategic Highway Research Program (SHRP 2). In order to achieve the 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 up the cost of the project when compared to traditional construction. On the other hand, reduced construction time will benefit both the end users and the workers with reduced interruption and safety hazard. The benefit of ABC tends to be significant and worth considering when the potential traffic volume affected by the project is high.

It is hypothesized in this study that given the project condition and current viable ABC techniques, there exists a set of influential factors that will control whether ABC is beneficial, such as site condition, material availability, traffic volume, etc. Among these factors, the controlling factor will likely be related to the traffic volume, type of the road corridors, the availability of immediate detour options, and material availability. For most areas in South Dakota, it is very 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 there have been guidelines used by other DOT's to assess the necessity of ABC (e.g. ABC rating system used by Utah DOT). But it cannot be directly applied to South Dakota because the cost of implementing different ABC techniques differs based on the 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.

The following sections will summarize the contents of this final report and the recommendations offered for the purposes of implementing the project into current practice at SDDOT.

1.1 PROBLEM DESCRIPTION

In Chapter 2 of this report, the problem description is presented. The previous minimal use of accelerated bridge construction in South Dakota is discussed as well as the “Every Day Counts” initiative put into place by the Federal Highway Administration (FHWA).

1.2 OBJECTIVES

In Chapter 3 of this report, the three main objectives of the report are explained. These three 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 the 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 if the use of ABC techniques in place of conventional construction is feasible.

1.3 TASK DESCRIPTIONS

In Chapter 4 of this report, the fourteen (14) tasks associated with this project are presented and briefly described. Included in these task descriptions are several presentations and memos that had to be completed throughout the duration of the project to present project progress to the technical panel as well as to obtain feedback from the panel for further modifications that were to be made to the project. For full descriptions of all of the tasks completed for the purposes of this project, see Chapter 4 of this report.

1.4 FINDINGS AND CONCLUSIONS

In Chapter 5 of this report, the full findings and conclusions for the project are presented. Each section within this chapter explains the different research methodologies used in order to obtain the information required to meet the needs of the project. This chapter also presents information regarding the sources used to obtain the necessary information as well as to design and populate with data the final deliverables required for the project. This chapter contains the following sections which present information about different portions of the project: 5.1) Literature Review, 5.2) ABC Catalog, 5.2) Cost Information, 5.3) Design of Evaluation Tool, and 5.4) Case Studies to Validate Evaluation Procedure.

1.5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This project involved three objectives that achieve the goal of developing a decision-making process concerning the use of ABC techniques. The first of these objectives was to develop an ABC technique catalog denoting those techniques that have been 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 that would evaluate potential projects for the applicability of the use of ABC techniques. This chapter will summarize what was done as well as present both conclusions and recommendations regarding the three objectives of this project.

1.5.1 SUMMARY

The first objective involved the 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. The purpose of this catalog is to inform the user of what has been done in the past as well as relate each technique to the benefits, special requirements, or problems pertaining to each technique. In order to accomplish this objective, an in-depth literature review was completed that familiarized the reader with the current ABC techniques that have been used to date across the United States. The sources investigated throughout the course of the literature review provided a list of ABC techniques that have currently been 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 the applications of each ABC technique as well as providing the source from which the information came, and, in some cases, an example project and visual aid are given as well.

Additionally, several interviews were completed in order to structure and populate the ABC catalog. Interviews with the SDDOT were completed in order to determine priorities of importance to the Bridge Design and Local Government Assistance Offices to include within the ABC catalog. These interview results were also used to finalize the list of ABC techniques that was obtained from the literature review. Then, several interviews were conducted with employees of other state DOT offices that had previous experience with the use of the ABC techniques that were researched in the literature review. The information obtained from these interviews was used to populate the 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 in order for the information to be useful to SDDOT. In order to obtain this cost information, three sources were utilized. The first source was SDDOT itself, 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 within 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 utilized 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 the applicability of ABC techniques for a given bridge construction project at SDDOT. This objective involved the development of several inputs based upon reference tools that were 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 utilized in order 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 along with decision-making flowcharts generated from the reference tools in order 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 that is used in conjunction with decision-making flowcharts to determine if ABC techniques should be used over a conventional construction approach.

1.5.2 CONCLUSIONS AND RECOMMENDATIONS

1.5.2.1 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).

1.5.2.2 Cost Information Intended Use

Second, the costs used for the generation of the second stage inputs should not be considered as project specific cost estimates of ABC techniques. Due to both the lack of use of ABC techniques within South Dakota and the fact that the 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 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.

1.5.2.3 Evaluation Tool Limited Data

Finally, although the evaluation tool developed in this study laid out the framework for a simplified assessment for ABC applicability in South Dakota, the available data related to actual ABC costs in SD is very limited. It is recommended that, through future use of the tool in realistic SDDOT projects, additional data be collected and used to calibrate the 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 that the calculated indicator will be representative for the actual measured benefits from these projects. As such data is currently unavailable in South Dakota, the results from the proposed process remain partially subjective and need to be used with caution.

2 PROBLEM 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 as well as 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 South Dakota Department of Transportation’s 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 has not been a 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 South Dakota Department of Transportation 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 both technical and economic guidance to identify ABC techniques that are applicable to South Dakota and to quantify potential costs and benefits of using them.

3 OBJECTIVES

The study covered in this report was undertaken to address the following three main objectives.

1. 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 of the information included in the catalog was obtained from practices of other state DOT and review of existing literature. More information can be found on the creation and organization of the ABC catalog in Chapter 6 of this report.

2. 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 utilizing 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. This cost information is discussed further in Chapter 7 of this report.

3. Develop an ABC cost-benefit analysis model and procedure to determine the 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 the 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 will be beneficial, and what the options are 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 along with decision-making flowcharts to determine whether or not ABC will be used for the construction project. This evaluation procedure will be discussed further in Chapter 8 of this report.

4 TASK DESCRIPTION

In the following chapter, each task of this project is briefly described and, when applicable, an associated reference to later chapters or sections is given where more information regarding each task can be found.

Task 1: *Meet with the project's technical panel to review the project scope and work plan.*

A kick-off meeting took place in September of 2012 to introduce the scope and work plan for the project to the technical panel. The meeting also provided an opportunity to obtain suggestions and comments from the technical panel to be incorporated in the later implementation of the project. The kick-off presentation was completed by Dr. Nadim Wehbe and Dr. Shiling Pei.

Task 2: *Interview representatives of the SDDOT Office of Bridge Design to identify ABC techniques already being used and potential criteria for deciding when new ABC techniques should be employed.*

The researchers worked with the SDDOT Office of Bridge Design and Local Government Assistance Office to approve a list of ABC techniques that was developed throughout the course of the literature review. Each interviewee was then individually questioned based upon the completeness of the list of ABC techniques to his or her knowledge. In addition, the skeleton of the developing ABC Catalog was evaluated by each interviewee and feedback was obtained regarding the completeness of the skeleton in regard to organization and categories of interest pertaining to the list of ABC techniques with potential applicability within South Dakota. Other topics investigated included any ABC techniques that are currently used in practice at SDDOT, the current conventional bridge construction practices used at SDDOT, and reputable contractors that may be contacted for further information. For more information regarding these interviews, see Section 6.1. To view the interview questions and answers that were obtained, see Appendix B.

Task 3: *Review results of current research project SD2010-02, Evaluation of Cost Effectiveness, Performance, and Selection Criteria of Concrete Structures, for data on prefabricated structure performance in South Dakota.*

After the results of project SD2010-02, "Evaluation of Cost Effectiveness, Performance, and Selection Criteria of Concrete Structures" were approved in the spring of 2013, the final report was evaluated and determined not to be of significant contribution for the purposes of this project due to the project focusing mainly on short-span concrete bridges, which is not representative of the remaining bridge types in use at SDDOT. However, this project was not negatively impacted by the lack of information that was usable from project SD2010-02.

Task 4: *Through review of literature, develop a catalog describing ABC techniques potentially applicable to South Dakota.*

A comprehensive literature review was conducted for this project. Several DOT reports, journal articles, and manuals were reviewed in order to compile a list of previously used ABC techniques (see Chapter 5). From this review and the compiled list of previously used ABC techniques, profiles were developed briefly describing each technique as well as providing a source from which the information came and, when available, an example project and visual aid for the technique. These ABC technique profiles can be viewed in Appendix A. Based upon the information obtained from the literature review, several categories of interest pertaining to ABC techniques were compiled for review during the SDDOT interviews. These

categories of interest that make up the columns of the ABC catalog can be viewed in Table 5-2, and the organization of the ABC techniques within the ABC catalog can be viewed in Table 5-1. After the structure of the ABC catalog was designed and approved during the SDDOT interviews (see Section 6.1), the catalog was populated with information obtained from the literature review as well as interviews completed with other state DOT offices that have had experience with implementing ABC techniques in the past (see Section 6.2). See Appendix C for the interviews completed with the other state DOT offices. The ABC catalog is intended to be used as an aid for making project specific decisions regarding which ABC techniques should be implemented after the decision has been made to develop an ABC approach for the given project. The full ABC Catalog can be viewed on the FTP website for this project or in Appendix D. The development and population of the ABC Catalog will be discussed further in Chapter 6 of this report.

Task 5: *Prepare a technical memorandum, to be reviewed by the technical panel, summarizing results of Tasks 2 through 4.*

The technical memo was completed and sent to the technical panel on February 8, 2013.

Task 6: *Estimate agency costs and benefits of employing cataloged ABC techniques in South Dakota by contacting contractors, fabricators, and suppliers.*

The agency costs and benefits of employing ABC techniques within South Dakota refers to the approximate change in cost of utilizing ABC techniques as compared to conventional construction practices. This cost information was obtained from the following South Dakota local manufacturers and contractors: Sioux Falls Construction, Gage Brothers, and Cretex Concrete Products. Because the pricing of ABC techniques for given bridge construction projects would be very project-dependent, general ranges of the change in cost of utilizing ABC techniques were determined for the major categories of ABC techniques: substructure, superstructure, and placement. The recommendation was made to obtain project-specific bid pricing if more accurate estimates were desired for the purposes of using the evaluation procedure. The ABC Cost Catalog can be viewed in Appendix F. The second type of cost estimates obtained were the conventional construction average costs per square foot of bridge that have been used within the last ten years at SDDOT. This information is intended to be used in the evaluation tool to aid in determining the applicability of utilizing ABC techniques for specific bridge construction projects. The SDDOT Conventional Cost Tables can be viewed in Appendix E. The method used for obtaining these two types of cost information is discussed further in Chapter 7 of this report.

Task 7: *Estimate user costs and benefits of employing cataloged ABC techniques based upon findings of research project SD2011-05, Review of Road User Costs and Methods.*

To determine the approximate user costs and benefits for given bridge construction projects in South Dakota, two basic methods were used. The first is an empirical formula that was developed by the Iowa Department of Transportation. This state department was used as a reference when developing the customized ABC evaluation procedure for SDDOT. The empirical formula uses basic project inputs in order to broadly estimate the daily user costs that would be incurred for a given bridge construction project. The empirical formula is presented in Equation 7-1. The second method is the SDSU Road User Cost Tool developed in project SD2011-05, “Review of Road User Costs and Methods.” This tool is utilized to obtain a more accurate estimate of the daily user costs incurred for a given bridge construction project using more detailed inputs. This tool is further discussed in Section 7.2 of this report.

Task 8: *Prepare a technical memorandum, to be reviewed by the technical panel summarizing results of Tasks 6 and 7.*

The technical memo was completed and sent to the technical panel on April 15, 2013, prior to a panel meeting that took place on April 29, 2013.

Task 9: *Develop a procedure for evaluating the technical applicability, costs, and benefits of using specific ABC techniques on individual South Dakota bridge construction and rehabilitation projects.*

For the development of the customized ABC evaluation procedure for SDDOT, three reference tools were used: the Accelerated Bridge Construction (ABC) Analytical Hierarchy Process (AHP) Decision Tool, the Utah Department of Transportation (UDOT) Decision Tool, and the Iowa Dept. of Transportation Decision Tool. Elements of each of the reference tools were used in order to develop the final design for the customized evaluation procedure for SDDOT. The result is a two-stage evaluation procedure geared toward the most efficient and simplistic use possible, which was an explicit desire of the SDDOT technical panel. The first stage is responsible for eliminating those projects that have little to no potential for the application of ABC techniques, while the second stage represents a more detailed, rigorous evaluation reserved for only those projects that have progressed through the first stage and exhibited a medium to high potential for the application of ABC techniques. The design of the evaluation procedure is discussed further in Chapter 8 of this report, and the full two-stage evaluation procedure is available on the FTP website for this project.

Task 10: *Demonstrate and validate the evaluation procedure in case studies of bridge projects recommended by the SDDOT Office of Bridge Design.*

Three case studies were sent from the SDDOT Bridge Design Office for the purposes of validating the evaluation procedure in November 2013. Due to the project-specific decision-making that is required to determine the inputs for the second stage of the evaluation procedure, the three case studies were only sent through the first stage of the evaluation procedure. This process was successful in validating the first stage and its ability to eliminate those projects that would have a minimal potential for the application of ABC techniques. The validation of the case studies sent from the Bridge Design Office is discussed further in Chapter 9 of this report.

Task 11: *Prepare a technical memorandum, to be reviewed by the technical panel summarizing the evaluation procedure and the case studies.*

The technical memo was completed and sent to the technical panel on December 2, 2013, prior to a panel meeting that took place on December 5, 2013.

Task 12: *Provide training for use of the evaluation procedure to affected DOT employees.*

The training was completed on December 18, 2013 in Pierre, where the affected DOT employees met to review the evaluation procedure and offer any final comments or changes that should be made prior to the SDDOT Research Review Board presentation. All feedback obtained was utilized in order to make the necessary final alterations to the project deliverables prior to uploading them to the FTP website for this project. The ABC Rating Procedure User Manual was also presented and discussed at this training meeting, and this document can be viewed in Appendix G as well as on the FTP website for this project.

Task 13: *Prepare a final report summarizing the research methodology, findings, conclusions, and recommendations.*

This task is met through this report.

Task 14: *Make an executive presentation to the SDDOT Research Review Board at the conclusion of the project.*

An executive presentation was given on February 26, 2014.

5 FINDINGS AND CONCLUSIONS

5.1 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 are 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.

5.1.1 LITERATURE REVIEW REPORTS

The purpose of the extensive literature review performed for this project was to summarize the current ABC techniques that have been implemented across the United States to date. Several reports were studied in order to obtain this information, and the findings from these reports will be summarized within this section. Several state DOT offices have also published reports on the ABC implementation projects they have completed in the past, together 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, including an analysis of the ABC and PBES implementations that are currently used in practice as well as 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 the construction details of implementing ABC techniques as well as the long term durability assessments that have been completed to evaluate the extended effectiveness of using precast elements instead of cast-in-place components. The ABC technique components that have been 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 within each state. The report entitled “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 a weekend in order 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 entitled “Accelerated Bridge Construction Applications in California—A Lesson Learned” (Chung et al. 2008) focused on seven projects conducted by Caltrans implementing ABC techniques. Four of these projects required emergency replacement construction, and therefore the needs of the project were well-suited for the implementation of ABC techniques. Additionally, the report discusses

three more projects that were planned to utilize ABC techniques from the time the project was initiated. The 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 that the process can be more efficient and streamlined in the future. The 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 in order to populate the ABC catalog with specific information regarding the ABC techniques that were used on the projects included within the report.

The Texas Department of Transportation (TxDOT) published a report entitled “Texas’s Totally Prefabricated Bridge Superstructures” (Freeby 2005) that denotes those projects in which TxDOT fully prefabricated the superstructure of the bridge and used an advanced ABC technique for the use of placing the superstructure on the supports and substructure of the bridge. The report focuses on the 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 the benefits of the use of ABC techniques, the report also discusses the implementation of both steel tub girder designs and pretopped U-beam design.

The Washington State Department of Transportation (WSDOT) has published a report (Khaleghi 2010) annotating the to-date use of ABC techniques in bridge construction in Washington State as well as outlining a plan for the future use of ABC techniques in Washington. This report portrays the use of precast bent caps in bridge projects as well as the specific connections details that were implemented throughout the course of construction. The report also discusses the utilization 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 the girders to piers are covered within the report. The WSDOT’s plan for the future use of ABC techniques in bridge construction is based upon several factors that would affect decision-making for the projects that have potential for the use of ABC techniques. These factors were considered when determining the inputs for the evaluation tool for this project.

The WSDOT additionally published a report entitled “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 the specialized connections used to ensure that the structure joints can withstand the 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 that are discussed within the report. These performance details aided in populating the ABC catalog, discussed further in Chapter 3.

In addition to the reports reviewed from other state DOT projects that have successfully implemented ABC techniques, several of the literature review reports covered alternate aspects of the process of accelerated bridge construction. One of the additional reports published by the FHWA entitled “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, which is discussed further in Chapter 2.

Though the specific connections details for a given ABC technique will change depending on the details of the bridge project, this manual specifies general techniques that are used for several of the 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 that the general guidelines provided within the manual should be adapted to meet the unique needs of ABC techniques used within the bridge construction project design.

Two of the 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 need to be met when utilizing SPMTs as an ABC technique on a bridge construction project and offers general instructions and suggestions for the successful use of the technique in order to maximize construction efficiency and safety. The report involving induced stresses discusses the tolerances that need to be met when using SPMTs, more specifically how the stresses within 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 the 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). Each of these reports was reviewed in order to obtain any additional information related to the ABC techniques that were researched in order to develop both the ABC technique profiles (see Section 2.3) and the ABC catalog (see Chapter 3).

Each of the reports discussed was utilized and thoroughly reviewed in order to develop a knowledge base about the ABC techniques that have currently been employed throughout the United States. In addition, these reports inform the reader of several alternate aspects relating to the use of ABC techniques in order 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.

5.1.2 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 that are of interest to SDDOT relating to each ABC technique. The catalog is organized in form of a table 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 of this information was found in the reports published by other state DOT offices regarding the ABC techniques that have been implemented within each state, and other information was found in the manuals specifying connections details and general ABC technique details, all of which were discussed previously in Section 5.1.1. All the possible categories of interest were compiled using the literature review to help construct the structure of the catalog.

In order to further organize the catalog structure, the ABC techniques that were researched were broken down into the following categories: substructure, superstructure, and placement. These three 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 very useful in developing the structure of the catalog. The information within the manual was organized in a similar manner, breaking bridge construction components into superstructure, substructure, and placement groups (ABC Manual 2011). All of the ABC techniques researched were then organized into categories and subcategories shown in Table 5-1.

Table 5-1. 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 that were finalized during the SDDOT interviews (see Section 5.2.1) are displayed in Table 5-2. The benefits column was deemed necessary because it informs the user of the 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 need to 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 the any current implementation challenges that have been 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 previously and any additional comments that were made about the ABC technique not relating to the other categories.

Table 5-2. 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 that is 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 utilized 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

5.1.3 ABC TECHNIQUE PROFILES

The ABC catalog is presented in a table format that only has limited information related to the ABC techniques in order to provide a brief description of each ABC technique in addition to the 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 in order 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 the 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 5-1.

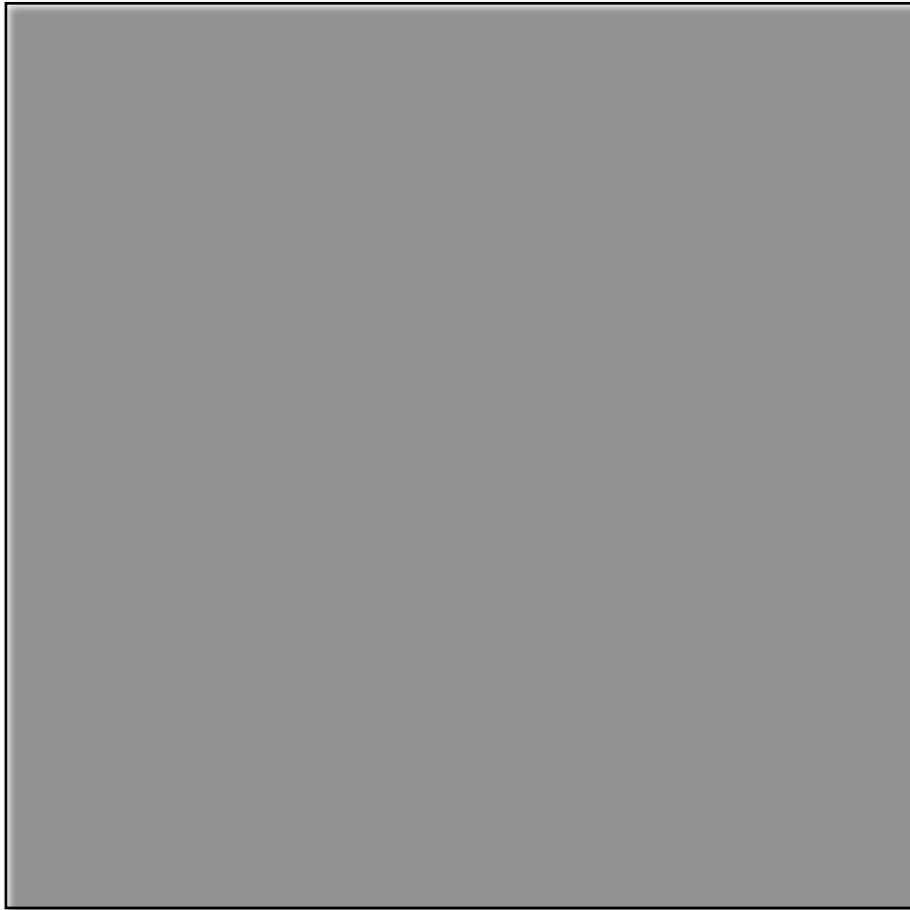


Figure 5-1. Example ABC Technique Profile

Creating these ABC technique profiles during the process of the literature review was essential to become familiar with the 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.

5.2 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 both the ABC technique profiles and the 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 of the information sought was not available. Furthermore, the use and benefit of a certain ABC technique is highly project dependent, thus it is difficult to develop related entry for such

technique in a generalized catalog. However, the resulted catalog still provides a very 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.

5.2.1 **SDDOT INTERVIEWS**

After the ABC techniques were organized into the appropriate categories and subcategories within the ABC catalog (see Section 5.2), the feedback of the technical panel and the relevant employees of SDDOT was inquired through interviews as this department is the end user of the resulted procedure/tool. In November of 2012, five members of SDDOT were interviewed to gather the applicability and current practice of ABC in SD, two of which were from the Bridge Design Office (BDO) and three of which were from the Local Government Assistance Office (LGAO) (see Table 5-3). The 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 introduced in Section 5.1.2 was shown to DOT personnel to see if all ABC categories and information categories are 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 5-3. 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 solely 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 that was 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. All of this 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 the current implementation of the ABC techniques for bridge construction in South Dakota is minimal. Some prestressed girders and beams are used for the construction of the superstructure of interstate and state highway bridges, and precast box culverts have been used since the 1980's, 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 the 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 inquired about how construction and engineering affect the decision-making process. All of this information was used to determine which sources should be used to obtain information further along in the project.

The most important query that was posed in these interviews concerned the information categories of interest to SDDOT relating to the ABC techniques. The answers received to this query 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 (see Section 5.1.2) to present to each interviewee. Then, each contact was asked to evaluate the list of the categories to determine which ones were relevant, which ones were not, and any additional categories that should be included when evaluating the 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 5-2). Each of these columns gives pertinent information pertaining to the ABC techniques listed in the rows of the catalog.

5.2.2 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 these ABC techniques. Table 5-4 shows the other state DOT offices that contributed information to this project and the respective contact(s) from each DOT office.

Table 5-4. 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, each contact at each DOT office was provided with a list of questions that were to be addressed during the interview, and this aided the contacts in familiarizing themselves with the information prior to the interview to save time on both sides of the call. The questions list for each interviewee is listed in Appendix C.

The questions that were 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 each ABC technique being 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 method of interviewing 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 as well as on the FTP website for this project.

The Utah interview contacts were Josh Sletten and Carmen Swanswick. The ABC techniques investigated with 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 the 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 being interviewed in order 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 the 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 Mellon. The interview was set up similarly to the format of the UDOT interview. The ABC techniques that were investigated with 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 feedback was offered concerning the ABC AHP Decision Tool produced by FHWA. Caltrans too 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 very subjective and different outputs may result from the input of different users.

The TxDOT interview contact was Michael Hyzak. The ABC techniques with which TxDOT had experience that were investigated 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 5-2) was investigated concerning both those techniques with which TxDOT has experience as well as the “catch-all” list of ABC techniques previously discussed. Then, the available feedback obtained was inputted into 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 with which ODOT had past experience were: fiber reinforced polymer (FRP) deck panels, geosynthetic reinforced soil (GRS)

abutments, and horizontal skidding/sliding. Additionally, ODOT was able to offer feedback on the spill-through abutments and integral abutments from the “catch-all” list of ABC techniques. All of the feedback obtained from the questions concerning the ABC techniques was then inputted into 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 with which MnDOT had experience that were investigated were: precast inverted-T beams, arch span without deck, and barge use. Rowekamp also was able to offer 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 inputted into 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 the 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 with 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 inputted into the ABC catalog. The 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 due to the fact that every project is site specific, and so many of the input factors included in the decision tool were not applicable to WSDOT. It is typical within WSDOT to apply limits to when and where traffic can be closed, and work around those parameters alone to determine what needs should be met through the use of ABC techniques.

The process of obtaining the 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 due to the fact that 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 within South Dakota to ensure local cost information. This information and the process used to obtain it are discussed further in Section 5.3 of this report.

5.2.3 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 to have because simplicity and efficiency are beneficial for the effectiveness of the ABC catalog. Otherwise, traversing through the catalog becomes a time-consuming chore for whoever is utilizing the catalog. The greatest priority for SDDOT for this project was 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® in order 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 5-2 portrays an example of the user-friendly pivot table with the dropdown filters applied.

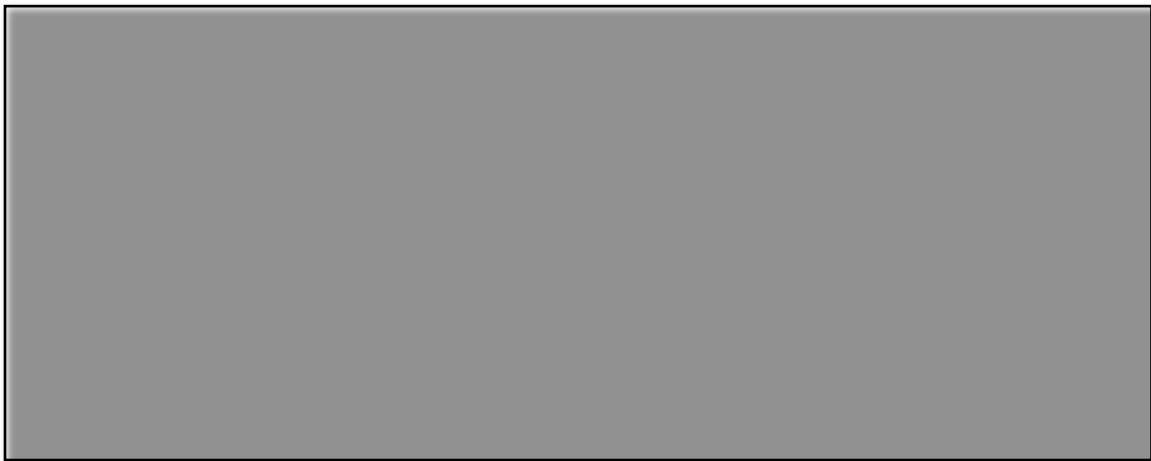


Figure 5-2. Example of User-Friendly Pivot Table

5.3 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 the 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.

5.3.1 SDDOT CONVENTIONAL CONSTRUCTION COSTS

Currently, the Bridge Design Office at SDDOT has not implemented very many ABC techniques into their bridge construction. However, SDDOT has been routinely using prestressed/precast bridge girders and beams as well as precast box culverts for several decades. SDDOT Bridge Design Office and the Bid

Letting Office maintained an access database containing the current conventional bridge construction costs from 2004 to 2013. In order to incorporate this conventional cost data into this 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 the 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 the implementation of ABC techniques and therefore cannot be considered completely conventional construction. The purpose of identifying the average conventional costs of bridge construction in South Dakota is to be able 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. This complication will be discussed further in Section 5.3.3.

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 5-5, 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 of the project data used for these average costs are attached to this report in Appendix E.

Table 5-5. 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

5.3.2 DAILY ROAD USER COSTS

Determining the agency user costs for a bridge construction project assigns a monetary value to the interruption to 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 aid in determining the 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 utilized. 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 the 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 (5-1).

$$DRUC (\$) = (AADT + 2 * ADTT)(OODT)(Mileage Rate) \quad (5-1)$$

This empirical formula was adopted from the literature obtained from Iowa DOT, whose evaluation tool was also referenced in this study. Details of the Iowa evaluation tool will be discussed further in Section 5.4.1.3. The average daily truck traffic was tripled in Equation 5-1 according to the 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 the 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. This process of determining which projects should be considered as with higher potential will be discussed further in Section 5.4.2. 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 utilizes 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, and then the project duration can be used to calculate the 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 utilizing 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.

5.3.3 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 the distance the precast elements need to travel before arrival at the job site. In addition, some of the ABC techniques require specialty load cranes for the installation of larger precast bridge

elements; the transport and usage costs of these specialty cranes can also vary depending on how far the crane needs to be transported and how long it will be used for the bridge construction project.

Due to the complications encountered throughout the process of attempting to approximate the change in cost of using the ABC techniques being investigated, a simplified solution was proposed. This procedure includes breaking the costs down into three main categories: the price of the materials used construct the ABC techniques, the price of installation at the project site, and the alternate cost of labor based upon the time saving from ABC techniques. These three categories are estimated based upon information obtained from manufacturers, contractors, and transporting companies. Precast concrete companies in South Dakota were surveyed about the approximate cost of implementing ABC techniques using precast components. Both Gage Brothers and Cretex Concrete Products provided feedback regarding the 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 the 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 upon the geometry of the girders' and beams' cross sections. For example, if a beam has a cost of \$150 per linear foot and a cross section of 3 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 that are produced in this study; however, it should be noted that this value is only an approximation instead of the actual cost of producing components for each ABC applications, as the actual value differs depending on conditions within 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 next. This information was primarily obtained through survey of SD local contractors. A meeting was conducted with Mr. Jared Gusso of Sioux Falls Construction in order to determine the 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 utilizing 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; in addition, the 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 both the materials and the specialty crane usage and operation will change depending on where the construction project is located within the state of South Dakota. For a construction project located west of the Missouri River in South Dakota, a specialty crane will most probably be rented from Denver, CO. For a construction project located east of the Missouri River, the crane transport will most probably be from

Omaha, NE. In addition, the materials being transported will have different distances to travel depending on where they are being shipped within the state.

Two analysis methods were available for SDDOT to determine the 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 utilizes an approximate formula related to the level of utilizing ABC techniques. The 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 utilized 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 the approximate materials, contractor, transport, and equipment costs (for the approximate method) is attached in Appendix F as well as on the FTP website for this project.

5.4 DESIGN OF EVALUATION TOOL

An ABC evaluation tool developed in this study will allow SDDOT to evaluate the 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 those 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.

5.4.1 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 will be discussed.

5.4.1.1 ABC AHP Decision Tool

The ABC AHP Decision Tool (FHWA 2012) was the result from a collaborative effort funded by many agencies, including several state DOT offices across the nation. The purpose of 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 purpose of this 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 within 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, the basic inputs included in the program are shown in Table 5-6 denoted by category and subcategory. If desired, unique hierarchies of inputs can be developed in order to customize the use of the tool to the agency utilizing the tool. This option is considered to be a benefit of using the ABC AHP Decision Tool, because the inputs used for the program can be changed based upon the priorities of the agency utilizing the tool.

Table 5-6. 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 5-6 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 within the Indirect Costs category, the user must select an option on the double-sided scale shown in Figure 5-3.

Decision Hierarchy	Pairwise Comparison	Results	Cost Weighted Analysis
User Delay	<input type="radio"/> 9 <input type="radio"/> 7 <input type="radio"/> 5 <input type="radio"/> 3 <input type="radio"/> 1 <input type="radio"/> 3 <input type="radio"/> 5 <input type="radio"/> 7 <input type="radio"/> 9	Freight Mobility	<input type="text"/>
Comments: <input type="text"/>			

Figure 5-3. Pairwise Comparison of Inputs (FHWA 2012)

The selection of the option “9” on the User Delay side of the scale means that User Delay is far more important than Freight Mobility. There are different levels of importance that 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 of the subcategories 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 all of 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 5-4 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.

Decision Hierarchy	Pairwise Comparison	Results	Cost Weighted Analysis
Determine the Degree to Which One Alternative Satisfies the Goal with Regard to:			
Construction			
ABC	<input type="radio"/> 9 <input type="radio"/> 7 <input type="radio"/> 5 <input type="radio"/> 3 <input type="radio"/> 1 <input type="radio"/> 3 <input type="radio"/> 5 <input type="radio"/> 7 <input type="radio"/> 9	Conventional	<input type="text"/>
Comments: <input type="text"/>			

Figure 5-4. ABC/Conventional Construction Ranking (FHWA 2012)

After this process has been completed for every subcategory within 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 very 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 of the contacts that were interviewed expressed concerns about the 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.

5.4.1.2 UDOT Decision Tool

The second tool referenced when developing the design of the ABC evaluation tool was the decision-making process utilized 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 in the customization of a decision tool for SDDOT. The UDOT tool involves eight basic inputs as displayed in Figure 5-5. 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.



Figure 5-5. Inputs for UDOT Decision Process (UDOT 2010)

Each of the inputs 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 the inputs and the predetermined weighting factors, an output indicator is calculated for the bridge construction project. A section in the decision tool also allows for the construction and user costs of two different alternatives for construction to be completed and used for decision-making along with the output indicator. The predetermined weighting factors, output indicator, and cost considerations sections of the decision tool are displayed in Figure 5-6.

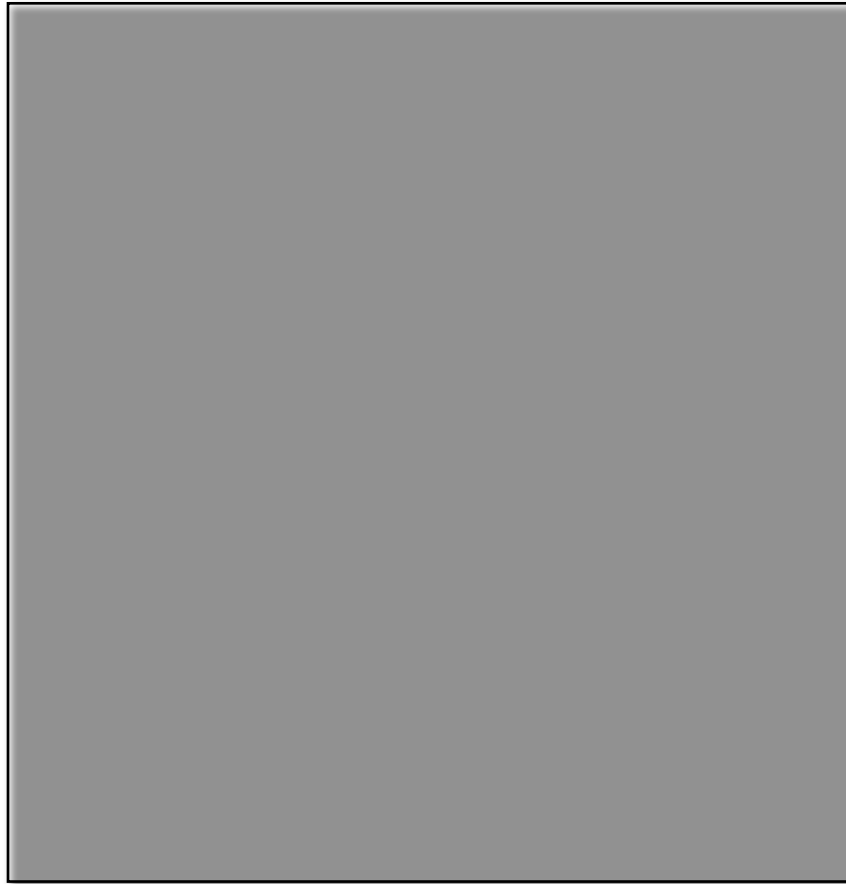


Figure 5-6. UDOT Output and Cost Information (UDOT 2010)

Based on the output indicator, a flowchart is used to determine what the next steps are that need to be taken 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 5-7.

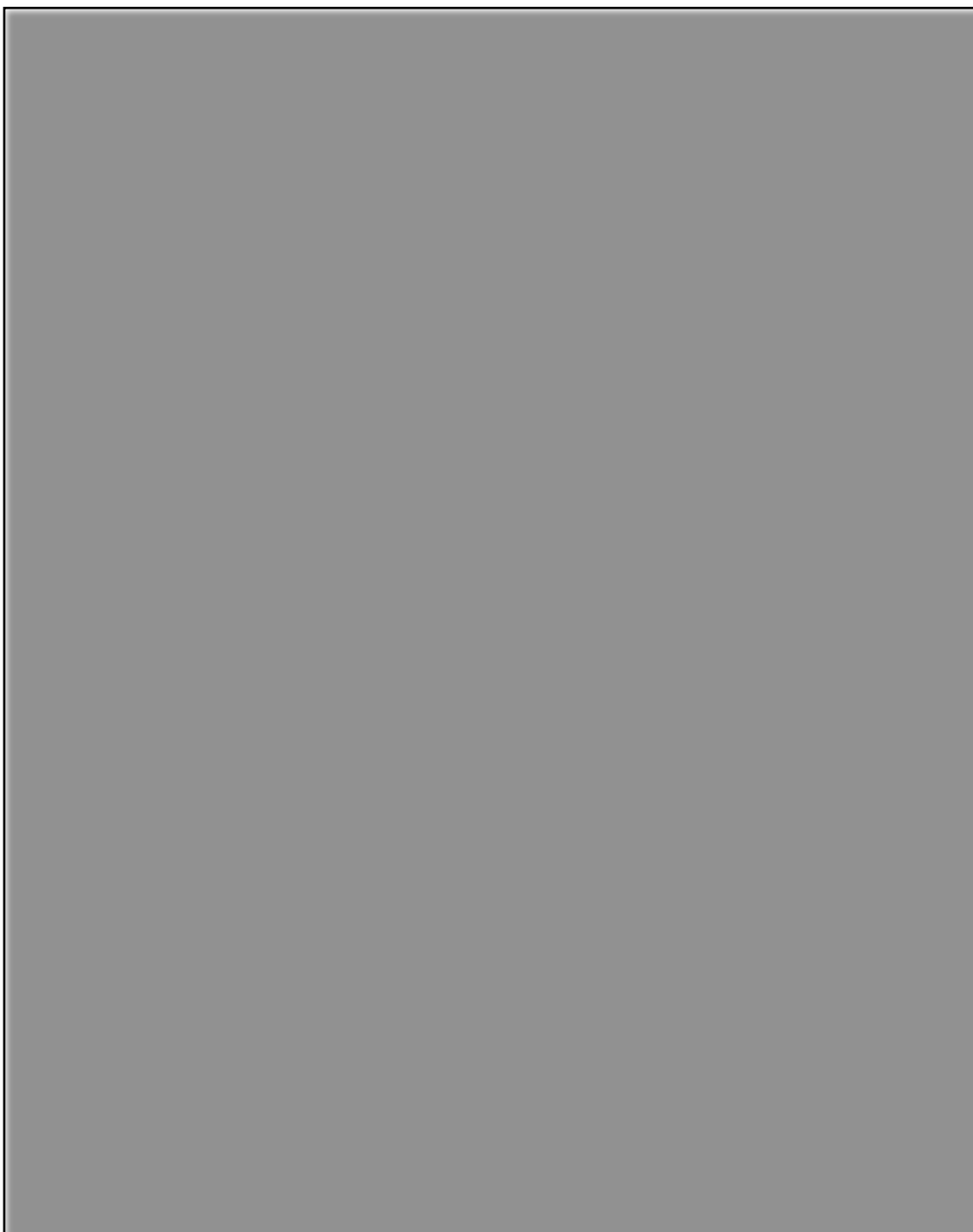


Figure 5-7. UDOT Flowchart for Decision-Making (UDOT 2010)

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 very 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 SD will have a 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.

5.4.1.3 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 in order to obtain the 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 very similar to the UDOT Decision Tool process. The first stage involves five basic inputs with predetermined weighting factors that are presented in Figure 5-8.

Concept Measure Scores	
Concept Measure	Score
Average Annual Daily Traffic Combined value of 100% on and 25% under = <input type="text" value="18,300"/>	<input type="text" value="4"/> <ul style="list-style-type: none"> 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 = <input type="text" value="9"/>	<input type="text" value="2"/> <ul style="list-style-type: none"> 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 \$ = <input type="text" value="\$76,585.50"/>	<input type="text" value="4"/> <ul style="list-style-type: none"> 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 = <input type="text" value="3"/>	<input type="text" value="1"/> <ul style="list-style-type: none"> 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
Average Annual Daily Traffic	4	10	40	50
Out of Distance Travel	2	10	20	50
User Costs	4	10	40	50
Economy of Scale	1	5	5	15
		Total Score	105	Max. Score
		Calculated ABC Rating Score	64	
		ABC Rating Score	64	

Figure 5-8. Iowa DOT Stage One Inputs, Weighting Factors, and Output (Iowa DOT 2012)

As can be seen in Figure 5-8, 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 mathematical 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 construction 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 that were discussed in Section 5.4.1.1. 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 within 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.

5.4.2 CUSTOMIZED TOOL FOR SDDOT

Based on SDDOT recommendation, the decision was made to develop a two-stage decision-making process tailored to perform both of these functions when evaluating a bridge construction project. However, because of the disadvantages associated with the use of the ABC AHP Decision Tool, the 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 the inputs for the second stage of the process can be more detailed and can 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.

5.4.2.1 Evaluation Tool Structure

The structure of each stage of the evaluation tool is quite similar to the structure of the UDOT Decision Tool. The inputs for each stage were developed based on those inputs used by the reference tools that were considered when developing the design of the evaluation tool for SDDOT. After the inputs for each stage of the decision-making process were developed, an additional meeting was conducted with the technical panel for this project at SDDOT to get feedback. Based on the feedback of the technical 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 5-7.

Table 5-7. 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 5-1
	Economy of Scale (EOS)	Total number of spans in a project
Two	Direct Costs (DC)	Information obtained in Section 5.3.3
	Indirect Costs (IC)	SDSU Road User Cost Tool
	Non-ABC Conventional Costs (NCC)	Information obtained in Section 5.3.1
	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 5-8) and an output indicator that will determine the next

actions to be taken with the bridge construction project being analyzed for ABC technique applicability. The weighting factors were assigned arbitrarily 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 5-8. 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, however, the inputs will function slightly differently than in the UDOT Decision Tool. The approximate change in cost of using ABC techniques will be approximated as discussed in Chapter 5.3.3 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 in order 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 utilized for the project. The schedule constraints and site constraints inputs represent any special circumstances surrounding the bridge construction project being evaluated. The most common schedule constraints will most likely be emergency repairs and important seasonal deadlines, but can also 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 the 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 Figures 5-9 and 5-10.

Project No.		PCN02AB							
Inputs				ABC Rating Score Factors and Weights					
Average Daily Truck Traffic		51							
Mileage Rate		37.5							
Average Annual Daily Traffic (AADT)		1		0		No traffic impacts			
Combined value of 100% on and 25% under structure:		746		1		Less than 5000			
				2		5000 to less than 10000			
				3		10000 to less than 15000			
				4		15000 to less than 20000			
				5		20000 or more			
Out of Distance Travel (OODT)		1		0		No detour			
Detour distance in miles:		0.25		1		Less than 5			
				2		5 to less than 10			
*Note: OODT should not be 0 if DRUC formula is to be used, as DRUC will then be \$0.				3		10 to less than 15			
				4		15 to less than 20			
				5		20 or more			
Daily Road User Costs (DRUC)		1		0		No user costs			
(AADT+2*ADTT)(OODT)(Mileage Rate)=		\$79.50		1		Less than \$100			
				2		\$100 to less than \$500			
*Note: If OODT is 0, SDSU DRUC Tool can be used to estimate DRUC for Stage 1.				3		\$500 to less than \$750			
				4		\$750 to less than \$1000			
				5		\$1000 or more			
Economy of Scale (EOS)		2		0		1 span			
Total number of repeatable of spans:		4		1		2 or 3 spans			
				2		4 or 5 spans			
				3		6 spans or more			
				Score		Factor		Adjusted Score	
				AADT		1		10	
				OODT		1		10	
				DRUC		1		10	
				EOS		2		10	
				Total Score:		50		Max. Score: 180	
				ABC Rating Score:		28			

Figure 5-9. Stage One Rating Procedure Layout

Project No.									
Inputs				ABC Rating Score Factors and Weights					
Direct Costs		3		0		\$100000 or more additional cost			
Input approximate costs for superstructure, substructure, and/or placement:		\$32,000		1		\$75000 to less than \$100000 additional cost			
				2		\$50000 to less than \$75000 additional cost			
				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:		\$120		1		Less than \$100			
				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. of bridge:		\$112		1		\$50 to less than \$75/SF of bridge			
				2		\$75 to less than \$100/SF of bridge			
				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			
				Score		Weight Factor		Adjusted Score	
				DC		3		10	
				IC		2		10	
				NCC		3		10	
				SchC		1		10	
				SC		1		10	
				Total Score:		100		Max. Score: 210	
				ABC Rating Score:		48			

Figure 5-10. Stage Two Rating Procedure Layout

For stage one of the evaluation procedure, the following input ranges were derived from the Iowa and Utah DOT evaluation tools: AADT, OODT, and EOS. The DRUC input range was derived from the three case studies that were completed (see Section 5.5.1). For the second stage of the evaluation procedure, the Indirect Costs input ranges were carried over from the first stage of the evaluation tool, the Schedule and Site Constraints input ranges were developed from the feedback obtained during the SDDOT training that took place on December 18, 2013, while the remaining input ranges are arbitrary values that were 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. For more information regarding the calibration of these input ranges, see Section 6.1.2.

5.4.2.2 Evaluation Mechanism

After the inputs have been selected and are entered into the evaluation tool, a simple calculation is completed in order to obtain the output indicator. This calculation is based upon the predetermined weighting factors shown previously in Table 5-8. 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 well as 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 analyzed by the evaluation tool. This calculation process is shown in Equations 5-2, 5-3, and 5-4.

$$\text{Project Adjusted Score} = \text{Input Score} * \text{Weighting Factor} \quad (5-2)$$

$$\text{Maximum Adjusted Score} = \text{Maximum Input Score} * \text{Weighting Factor} \quad (5-3)$$

$$\text{Output Indicator} = \frac{\sum \text{Project Adjusted Score}}{\sum \text{Maximum Adjusted Score}} * 100\% \quad (5-4)$$

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 in order 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 very 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 5-11.

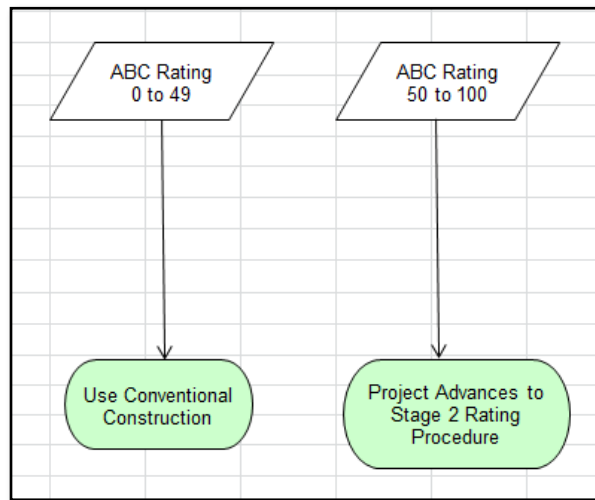


Figure 5-11. Stage One Decision-Making Flowchart

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 (see Section 5.4.2.1), thus the stage 2 rating of the same project may not be

the same as its own rating in stage 1. When determining if utilizing ABC techniques within 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 utilizing 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 5-12.

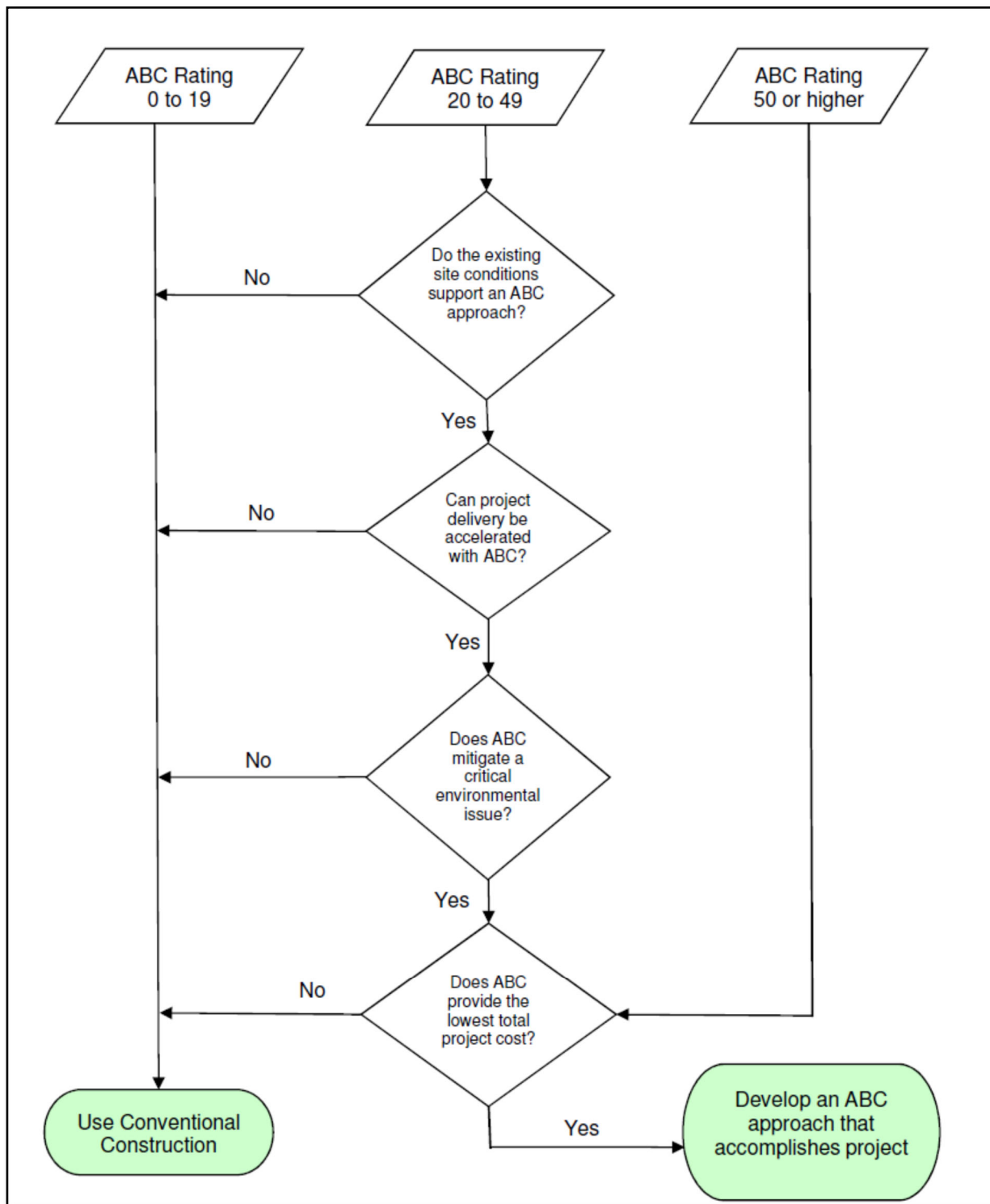


Figure 5-12. Stage Two Decision-Making Flowchart

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 the 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 utilized 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 for the purposes of instructing the affected employees of SDDOT how to operate and utilize the evaluation tool in order 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.

5.5 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 in order to validate the functionality of the evaluation procedure. Three case studies representing low, medium, and high potential for the application of ABC techniques were decided upon by the Bridge Design Office. This decision was made based upon the 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.

5.5.1 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 in order 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. The information provided for the three case studies sent from the Bridge Design Office are shown below in Table 5-9.

Table 5-9. 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 upon the information submitted for case study validation, inputs were derived for the first stage of the evaluation procedure. The empirical formula presented in Equation 5-1 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 upon 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):

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

Project I90 (PCN 01KK):

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

Project I29/I229 interchange (PCN 01QS)

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

From the calculations shown previously and the ranges of inputs displayed 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 5-11. The results are shown in Table 5-10 below.

Table 5-10. 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 upon the information presented in Table 5-10, 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.

5.5.2 STAGE TWO CASE STUDY VALIDATION

As discussed in Section 5.5.1, 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 5-11 below.

Table 5-11. Stage Two Evaluation Project Information for I-29/I-229 Project

AADT	ADTT	ODDT	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 5-13 shows the table of information that was 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			Cast-in-place (\$)	Columns & caps	deck
fabrication	122950	679967			cu. Yds	136.6	755.6
shipping	16500	69500			cost/yd	1000	1000
Excise & sales (15%)	18443	101995			total	136600	755600
labor*	1200	41700					892200
grouting#	600	20000					
epoxy chip seal		239750			difference =	420405	
total	159693	1152912	1312605				
epoxy chip seal = 3425 sq. yds. x \$70 /sq. yd							

Figure 5-13. Additional Cost of Using ABC for I-29/I-229 Project

Other information obtained from the Bridge Design Office included any existing schedule and site constraints and the total project duration. From this information, the 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 in order to determine that 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 5-14 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							
K Z O N E C O N D I T I O U T P U T	<u>Phases:</u>						
	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	<u>Speed</u>	<u>Length</u>	<u>Speed</u>	<u>Length</u>	<u>Speed</u>	<u>Length</u>
	1	45	0.25	45	0.25		
	VOT	(\$2,502.11)		(\$4,250.96)			
O U T P U T	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 5-14. 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 the daily user costs incurred for a given project. For more details on how to calculate the 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 below in Table 5-12.

Table 5-12. 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 5-12, the recommended action for the Bridge Design Office to take would be to assemble a panel of appropriate parties in order to address each question in the decision-making flowchart for the second stage of the evaluation procedure in order to determine whether or 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.

6 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This project involved three objectives that achieve the goal of developing a decision-making process concerning the use of ABC techniques. The first of these objectives was to develop an ABC technique catalog denoting those techniques that have been 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 that would evaluate potential projects for the applicability of the use of ABC techniques. This chapter will summarize what was done as well as present both conclusions and recommendations regarding the three objectives of this project.

6.1.1 SUMMARY

The first objective involved the 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. The purpose of this catalog is to inform the user of what has been done in the past as well as relate each technique to the benefits, special requirements, or problems pertaining to each technique. In order to accomplish this objective, an in-depth literature review was completed that familiarized the reader with the current ABC techniques that have been used to date across the United States. The sources investigated throughout the course of the literature review provided a list of ABC techniques that have currently been 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 the applications of each ABC technique as well as providing the source from which the information came, and, in some cases, an example project and visual aid are given as well.

Additionally, several interviews were completed in order to structure and populate the ABC catalog. Interviews with the SDDOT were completed in order to determine priorities of importance to the Bridge Design and Local Government Assistance Offices to include within the ABC catalog. These interview results were also used to finalize the list of ABC techniques that was obtained from the literature review. Then, several interviews were conducted with employees of other state DOT offices that had previous experience with the use of the ABC techniques that were researched in the literature review. The information obtained from these interviews was used to populate the 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 in order for the information to be useful to SDDOT. In order to obtain this cost information, three sources were utilized. The first source was SDDOT itself, 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 within 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 utilized 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 the applicability of ABC techniques for a given bridge construction project at SDDOT. This objective involved the development of several inputs based upon reference tools that were 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 utilized in order 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 along with decision-making flowcharts generated from the reference tools in order 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 that is used in conjunction with decision-making flowcharts to determine if ABC techniques should be used over a conventional construction approach.

6.1.2 CONCLUSIONS AND RECOMMENDATIONS

6.1.2.1 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).

6.1.2.2 Cost Information Intended Use

Second, the costs used for the generation of the second stage inputs should not be considered as project specific cost estimates of ABC techniques. Due to both the lack of use of ABC techniques within South Dakota and the fact that the 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 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.

6.1.2.3 Evaluation Tool Limited Data

Finally, although the evaluation tool developed in this study laid out the framework for a simplified assessment for ABC applicability in South Dakota, the available data related to actual ABC costs in SD is very limited. It is recommended that, through future use of the tool in realistic SDDOT projects, additional data be collected and used to calibrate the 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 that the calculated indicator will be representative for the actual measured benefits from these projects. As such data is currently unavailable in South Dakota, the results from the proposed process remain partially subjective and need to be used with caution.

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APPENDIX A: ABC TECHNIQUE PROFILES

ABC Technique Profiles

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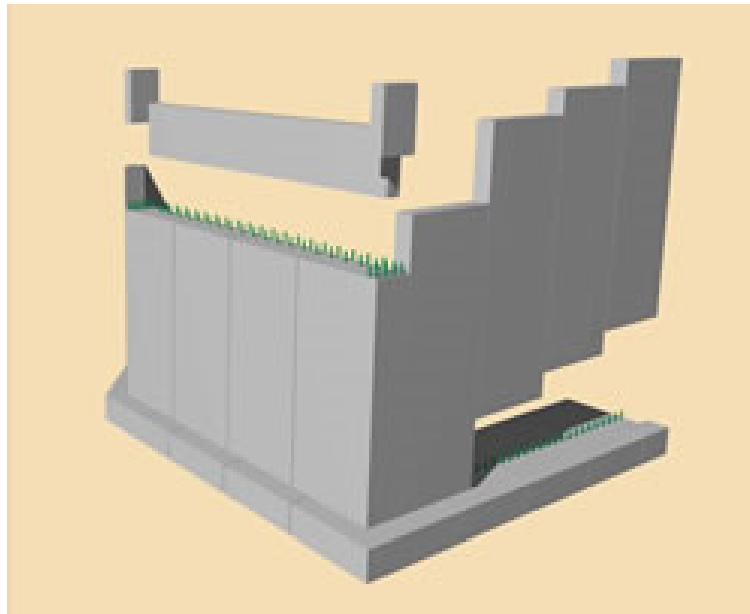
South Dakota State University
Dept. of Civil and Environmental Engineering

Precast Abutments

Description: Abutments support the ends of a bridge's superstructure. Precast abutments in general 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

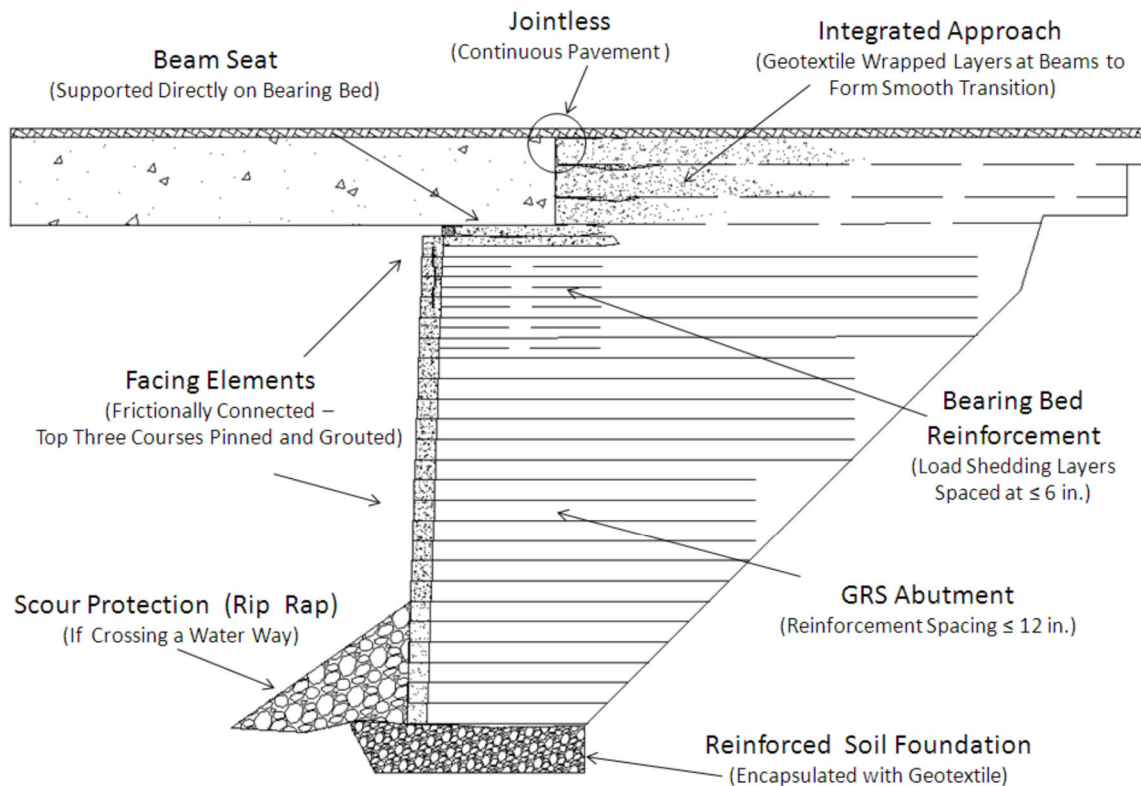
Accessed 23 Oct 2012

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



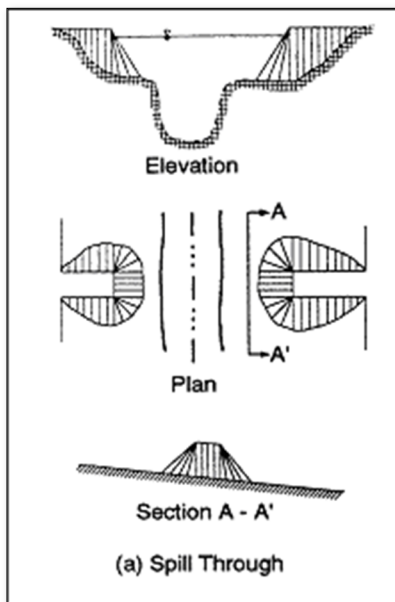
Typical Section of a GRS/IBS Bridge Abutment
“ABC—Experience in Design, Fabrication, and Erection of PBES”

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:

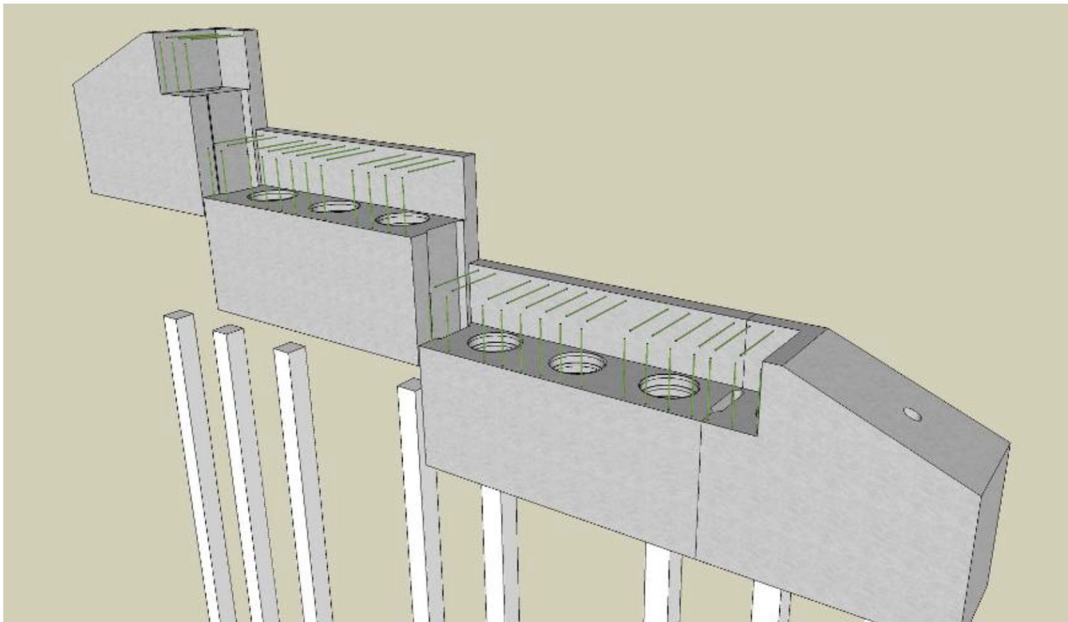
Abutments in which the abutment structure is made integral with the superstructure elements. Integral abutments do not have deck joints, which is one of the most common deterioration areas on a bridge. Integral abutments transfer the embankment soil forces into the bridge superstructure. Integral abutments 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>

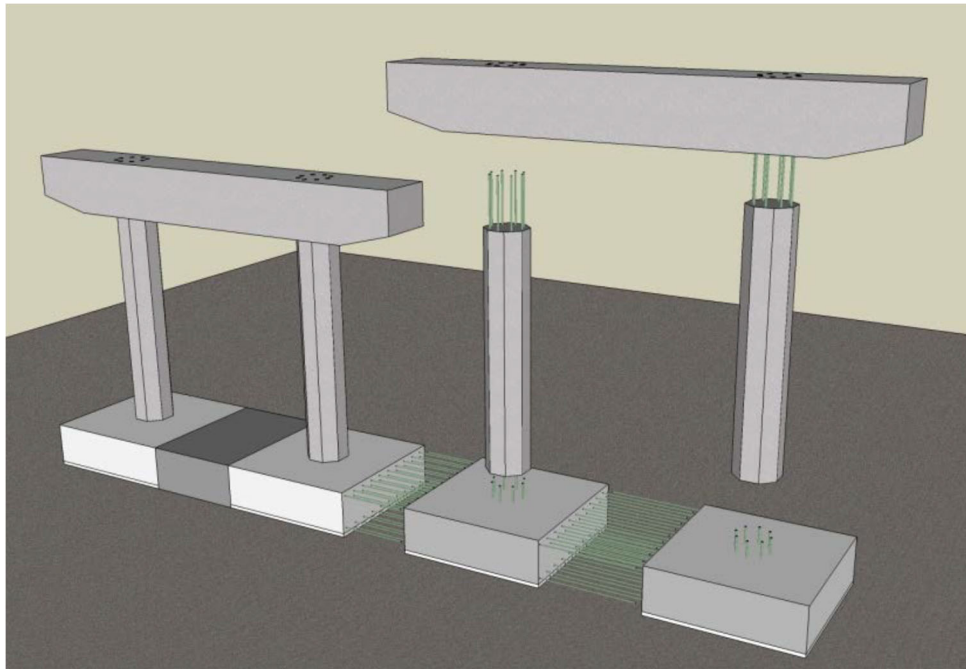
Accessed 23 Oct 2012

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

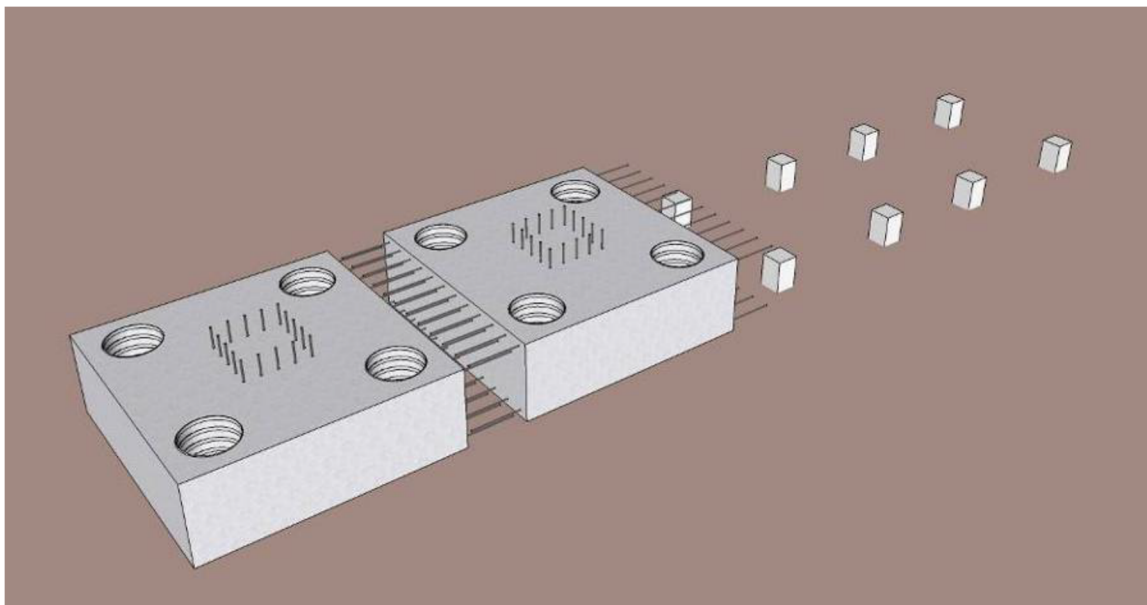


Spread Footings Beneath Columns and Column Caps
“ABC—Experience in Design, Fabrication, and Erection of PBES”

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”



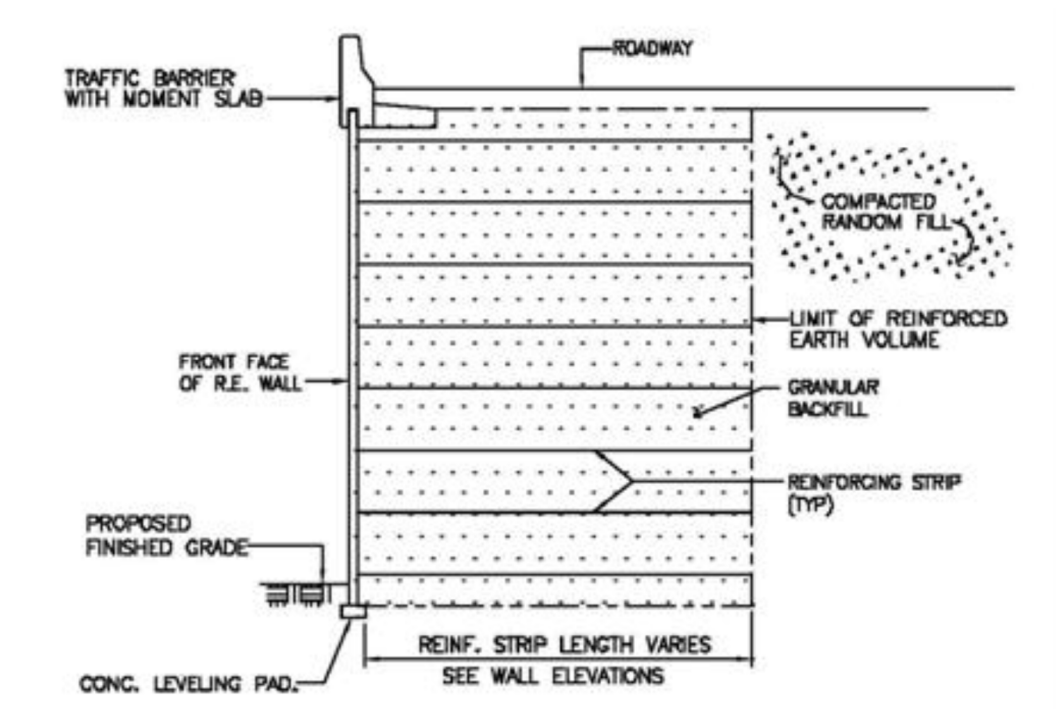
Prefabricated Full Height Wall Panels
“ABC—Experience in Design, Fabrication, and Erection of PBES”

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



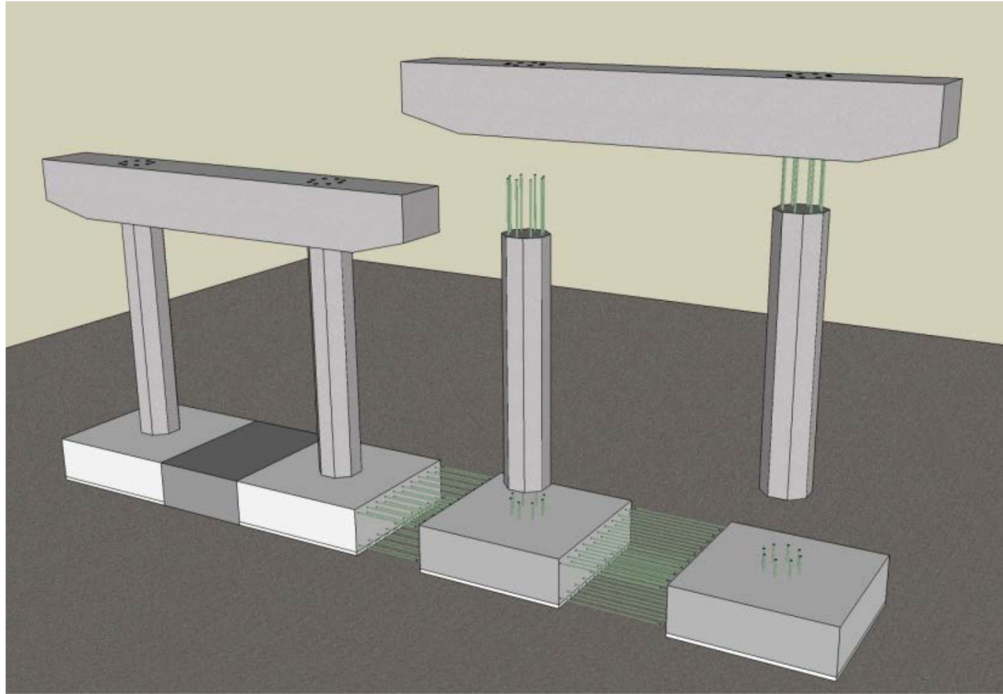
Proprietary Retaining Wall Layout
<http://www.fhwa.dot.gov/bridge/prefab/if09010/03a.cfm>
Accessed 23 Oct 2012

Prefabricated Columns

Description: This element is very 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

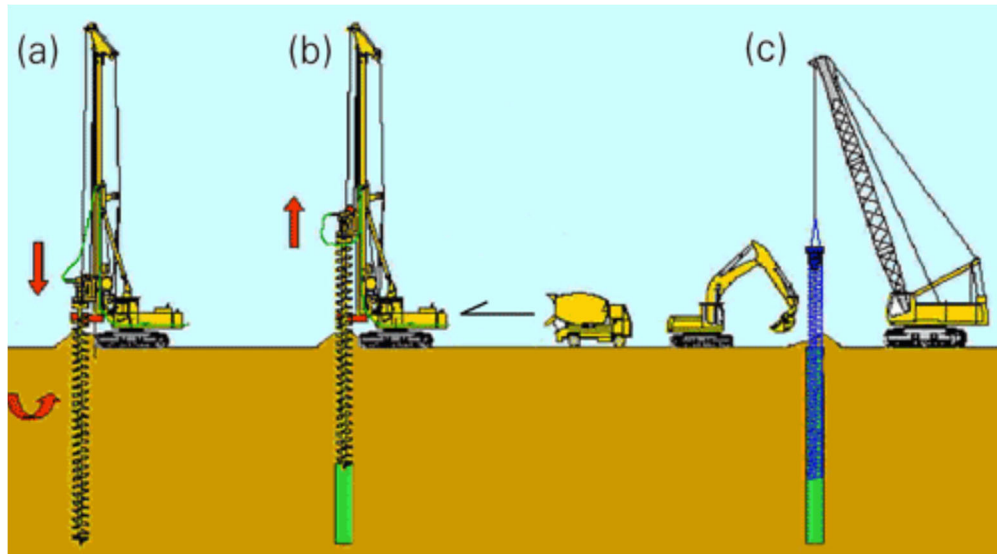
Continuous Flight Auger (CFA) Piles

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



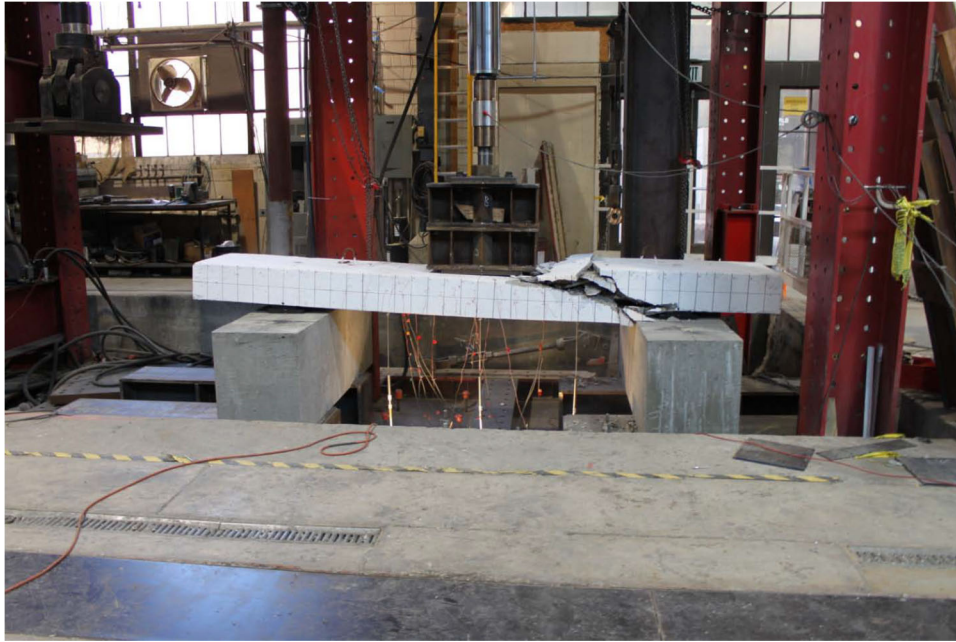
Steel Grid System with Full-Depth Precast Concrete Deck Installation
“ABC—Experience in Design, Fabrication, and Erection of PBES”

Lightweight Precast Deck Panels

Description: This technique is very 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 not 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 not 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

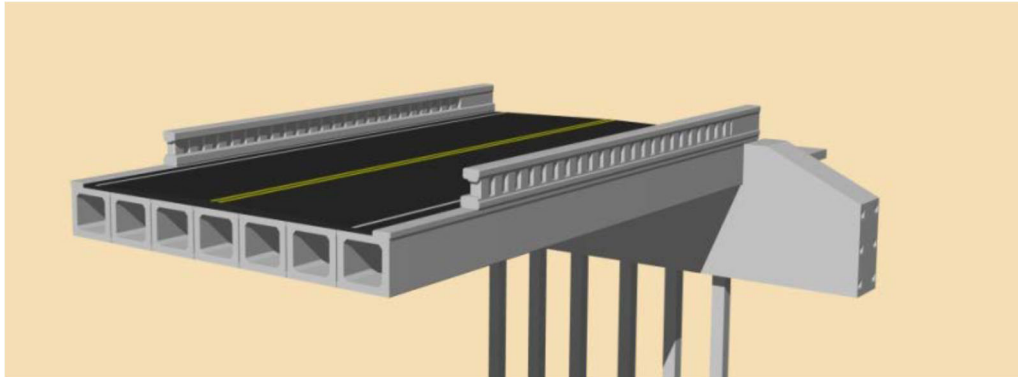
Accessed 23 Oct 2012

Precast Box Girders

Description: This technique is not 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



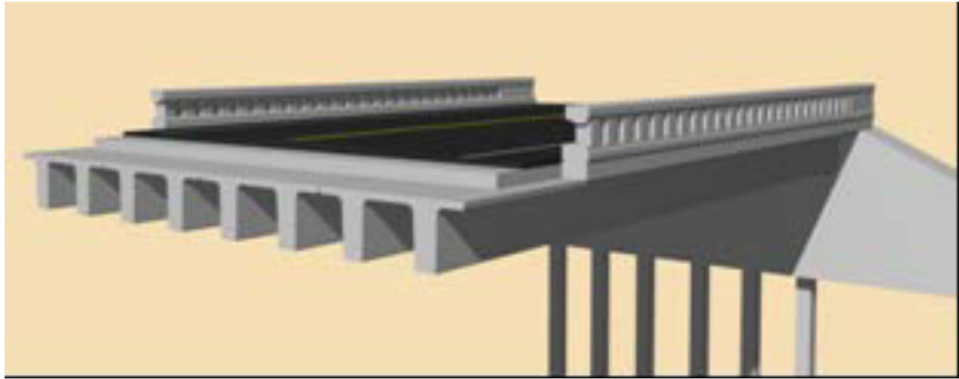
Inverted T Bridge System
<http://www.fhwa.dot.gov/bridge/prefab/slab.cfm>
Accessed 15 Nov 2012

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, it reduces or eliminates the cost of transporting fresh concrete, and it 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

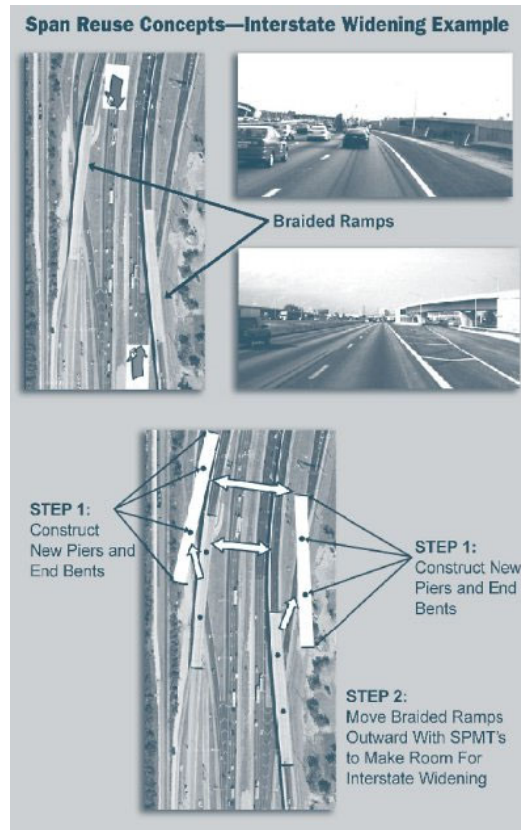
Span Reuse

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 the deflection of the cantilevered end of the superstructure during the launching and to account for the deflection 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 that 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 aesthetic 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:

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	Eliminate the need for removable concrete forms; prevents future failure by sealing bottom of deck the strongest portion	N/A	Crew needs experience in leveling and sealing the panels
Accelerated Bridge Construction	Superstructure	Decks and Panels	HP Deck Panels	Profiles PDFs\HP Deck Panels.pdf	High tensile strength, lightweight, high fatigue resistance, corrosion resistance because the composites don't deteriorate; 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 angle, 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):

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. Carriageway wear is going on underneath the deck (i.e. cracks, ruts)	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 tires (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 the light 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)	15 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 63	
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

Accelerated Bridge Construction	Placement	SPMTs	Profiles PDF's SPMT's.pdf	Significantly reduces traffic disruption, improves work zone safety, and improves quality and constructibility, and increases contractor 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		Profiles PDF's 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		Profiles PDF's 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		Profiles PDF's 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

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 (5 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 (5 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 cross street is quite important for bridge prefabrication	N/A	Bridge can be replaced in as little as 3.2 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	Headings, MN Tied Arch Bridge on Hwy 61	Though SPMTs are normally not required for barge use, SPMTs were used on the project in Headings, 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	Dependent on wall size	Crane transport and operation
	Proprietary Retaining Wall Systems	INF	1/3 of original labor costs	Fifefold 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)