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16. Abstract

The Michigan Department of Transportation (MDOT) is committed to provide the highest level of safety and mobility during each step of a project's development and delivery. To fulfil the above commitment, MDOT embraces technology and uses innovations. One such example is the implementation of the Accelerated Bridge Construction (ABC) project delivery process. MDOT is planning to implement the Slide-In and Self-Propelled Modular Transporter (SPMT) project delivery methods. MDOT foresees the future ABC projects to be design-bid-build; thus, they require the contracting industry and those delivering the projects to be knowledgeable of the methods. Also, this process requires the owners, in this case MDOT, to consider the means and methods that are required to complete an ABC project. ABC is a paradigm shift in bridge engineering and requires a change in bridge design engineers' thinking process to that of a contractor.

Hence, MDOT hosted the workshop on December 9, 2013 at the Williams Auditorium in Lansing, Michigan. The objective was to leverage knowledge and experience developed in other state highway agencies, and to encourage the involvement of local consultants, contractors, prefabricators, and other highway agencies during implementation of innovative project delivery techniques in Michigan. This report provides summaries of all the presentations and a strategic plan for promoting ABC in Michigan.

17. Key Words
Accelerated bridge construction, ABC, bridge, PBES, slide, self-propelled modular transporter, SPMT

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Accelerated Bridge Construction and Structural Move - Workshop

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- Matthew J. Chynoweth, P.E., Bridge Field Services Engineer, MDOT.
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- Bala Sivakumar, P.E., Vice President and Director of Special Bridge Projects, HNTB.
- John Almeida, P.E., General Manager, Aecon Group Inc.
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- Brent Archibald, P.E., Senior Principal and Technical Director, Delcan.
- Kenneth Price, P.E., Vice President, HNTB.
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EXECUTIVE SUMMARY

The Michigan Department of Transportation (MDOT) is committed to provide the highest level of safety and mobility during each step of a project's development and delivery. To fulfill the above commitment, MDOT embraces technology and innovations. One such example is the implementation of the Accelerated Bridge Construction (ABC) project delivery process. After completing the first ABC project in 2008 using prefabricated bridge elements, MDOT built several bridges using the same technology.

MDOT is planning to implement the Slide-In and Self-Propelled Modular Transporter (SPMT) project delivery methods. MDOT foresees the future bridge slide-in projects to be design-bid-build; thus, they encourage the contracting industry and those delivering the projects to develop deep knowledge on this technology. Also, this process requires MDOT to consider the means and methods that are required to complete an ABC project. ABC is a paradigm shift in bridge engineering and requires owners to think like a contractor.

MDOT hosted an ABC workshop on December 9, 2013 at the Williams Auditorium in Lansing, Michigan. The workshop emphasis was on bridge slides and structural moves. The objective was to leverage knowledge and experience developed in North America, and to provide in-depth information to the Michigan consulting, construction and prefabrication industry as well as MDOT and local agency engineers. The long-term goal was to encourage the involvement of local consultants, contractors, prefabricators, and other highway agencies during implementation of innovative project delivery techniques in Michigan.

Based on the information presented during the workshop and the expertise of the authors, a strategic plan for promoting ABC in Michigan is proposed with the following steps:

- Organize an expert group of owners, designers, academicians and contractors with experience in accelerated bridge construction to provide feedback on specifications, guidelines, and details for implementing a specific ABC technology.
- Incentives and disincentives typically tend to motivate contractors, but when the project completion is delayed due to unforeseen events, the contractors are penalized twice: the first for their increased cost due to the delay, and the second the owners' delay penalty. Owners may incentivize continuing education of the contractor's

engineering staff as well as their length of tenure with the company. This may assure contractors developing and retaining experience in ABC.

- Develop a performance management strategy for ABC projects to assure that quality and durability are expectations as well as the speed of construction.
- Conduct ABC projects as demonstration projects, for their educational value to the local contractors, local agencies, and public.
- Document ABC project activities to develop case-study examples. These examples can be included in workshops. The following information describes the minimum documentation needs of ABC projects:
  - Scoping, decision-making, planning, and cost
  - Structural analysis and design
  - Contracting
  - Equipment selection
  - Scheduling
  - Contingency plans
  - Demolition methods
  - Construction
  - Testing bridge moves
  - Monitoring bridge moves, deformations and stresses
  - Maintenance of traffic (MOT)
  - Workforce management
  - Observations and lessons learned.
- Develop research to continually review the literature for domestic and international ABC implementations, and the information presented in the resources listed in chapter 5. Also, develop workshops co-sponsored by industry associations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 OVERVIEW

MDOT is committed to provide the highest level of safety and mobility during each step of a project development and delivery (MDOT 2010). To fulfil the above commitment, MDOT embraces technology and innovations (MDOT 2007). One example is the implementation of the Accelerated Bridge Construction (ABC) project delivery process. After completing the first ABC project in 2008 using prefabricated bridge elements and systems (PBES), MDOT constructed several additional bridges using PBES. Using Self-Propelled Modular Transporters (SPMT) or a slide-in technique to replace a bridge is another innovation in the ABC project delivery. According to the data provided in the National ABC/PBES Project Exchange database, as of May 2014, in the U.S., only 9 projects were completed using SPMTs, and an additional 14 projects were completed using the slide-in technique (FHWA 2014). However, with the current trends in implementing ABC techniques, the number of projects delivered or being delivered today using SPMTs and slide-in may exceed the numbers reported to the National ABC/PBES Project Exchange database.

The emphasis of the first phase of Every Day Counts Initiative (EDCI) was on PBES (FHWA 2013a). The second phase (EDC2) is focused on continuing with PBES while promoting implementation of slide-in as an additional ABC option (FHWA 2013a, b). As the mobility managers in the state, MDOT is committed to deploying ABC technologies. In 2014, two bridge slide-in projects will be delivered in the Grand region using the Construction-Manager – General-Contractor (CM/GC) contracting method. These projects will be the first slide-in implementations in Michigan. For the first two slide projects, the CM/GC contracting method will bring a contractor to participate on the project team with MDOT during the design phase. MDOT foresees the future bridge slide-in projects to be design-bid-build; thus, they encourage the contracting industry and those delivering the projects to develop deep knowledge on this technology. Also, this process requires MDOT to consider the means and methods that are required to complete an ABC project. In ABC design, the owner considers and stipulates a majority of the means and methods that a contractor would undertake in a conventional project, such as demolition drawings, erection drawing, schematics of temporary works, etc. The complete ABC process is laid out by the owner prior to bidding, including the construction activities. ABC is a paradigm shift in bridge engineering and requires the designer to think like a contractor.

The industry needs to understand that slide technology is not a specialized tool; rather, it is a project delivery alternative that will be included as an option in future programs, and can be deployed as needed and dictated by the site conditions. The SPMT technology, as a project delivery alternative, is also very new to Michigan. In order to advance the knowledge of those involved in the bridge project delivery, MDOT hosted an ABC workshop on December 9, 2013 at the Williams Auditorium in Lansing, Michigan. The workshop emphasis was on bridge slides and structural moves. The objective was to leverage knowledge and experience developed in North America, and to provide in-depth information and materials to the Michigan consulting, construction and prefabrication industry as well as MDOT and local agency engineers. The long-term goal was to encourage the involvement of local consultants, contractors, prefabricators, and other highway agencies during implementation of innovative project delivery techniques in Michigan.

1.2 WORKSHOP GOALS

The specific goals of the workshop were to educate the participants on the following topics:

- Specifications for design and construction and how these are different between ABC and conventional construction
- Jacking operations and Self-Propelled Modular Transporter (SPMT) moves
- Design of temporary structures and geotechnical aspects of SPMT and structural moves
- Observations and lessons learned from completed ABC projects that involved slides and structural moves.
- Educating participants on the ABC project delivery and differences from conventional construction.

1.3 WORKSHOP PRESENTERS

The workshop was one day long and included seven morning and three afternoon presenters followed by a question and answer session. The list of presenters is given below with their affiliation and the presentation topic:

- Gregory C. Johnson, Chief Operations Officer, MDOT
  Welcome/Michigan Department of Transportation (MDOT) Plans for ABC
- Matthew J. Chynoweth, P.E., Bridge Field Services Engineer, MDOT
  Upcoming ABC Projects
- Rebecca Nix, S.E., Bridge Program Manager, Utah Department of Transportation
  Implementing New Technology and Construction Practices
- Bala Sivakumar, P.E., Vice President and Director of Special Bridge Projects, HNTB
  Rapid Renewal Project (SHRP-02 R04) Findings
- John Almeida, P.E., General Manager, Aecon Group Inc.
  Overcoming Obstacles and Comparison to Traditional Construction Practices
- Frido De Greef, P.E., Procurement Manager, Mammoet USA Inc.
  Jacking and SPMT Operations: Quality Control and Quality Assurance
- Brent Archibald, P.E., Senior Principal and Technical Director, Delcan
  Proven Bridge and Structure Sliding Techniques
- Kenneth Price, P.E., Vice President, HNTB
  Advances and New Options
- Benjamin Beerman, P.E., Senior Structural Engineer, Federal Highway Administration
  Nationwide Perspective on ABC Implementation
- Haluk Aktan, Ph.D., P.E., Professor, Western Michigan University
  Processes and Tools for Alternative Analysis of ABC for Project Delivery

1.4 REPORT ORGANIZATION

The report contains five chapters and five appendices:

Chapter 1 provides an overview of MDOT needs and goals of the workshop.

Chapter 2 presents the workshop participants' background.

Chapter 3 describes the key ideas learned from the workshop.

Chapter 4 presents a summary and a strategic plan for promoting ABC in Michigan.

Chapter 5 presents the resources on ABC.

Appendix A provides the workshop exit survey.

Appendix B provides detailed summaries of each presentation.

Appendix C provides a list of questions asked during the panel discussion held at the conclusion of the workshop and the answers provided by the panel members.

Appendix D provides presentation slides.

Appendix E lists workshop participants' names, affiliations, and contact information.

2 BACKGROUND OF THE WORKSHOP PARTICIPANTS

At the conclusion of the workshop, participants completed a survey. The survey template is provided in Appendix A. Out of 145 participants, 65 responded to the survey (i.e., 45%). As shown in Figure 2-1, 65% represented local agencies and contractors while 35% represented state agencies including MDOT.

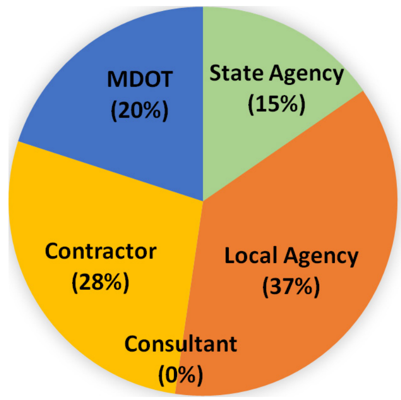
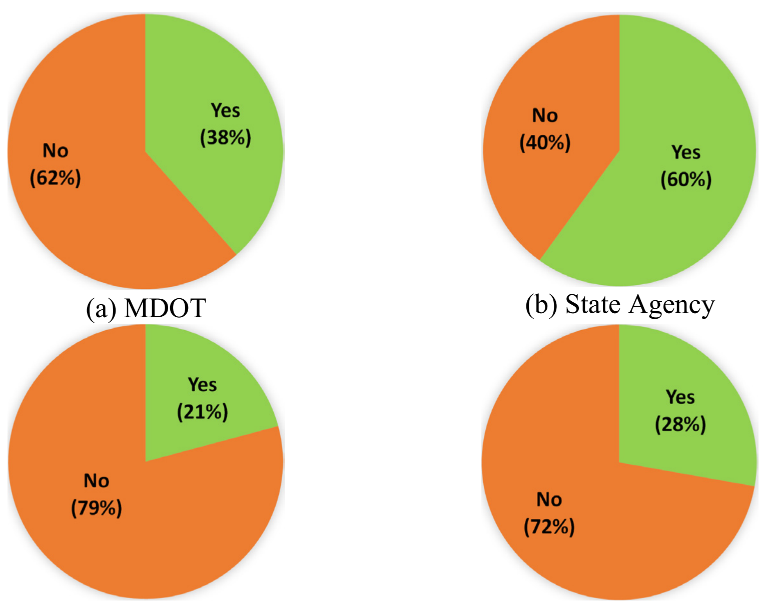


Figure 2-1. Affiliation of the participants

The second question of the survey asked participants' involvement in previous ABC projects. The response is analyzed and presented in Figure 2-2. As shown below, less than 30% of the local agencies and contractors had the opportunity to participate in previous ABC projects. State agencies were most involved in previous ABC projects.



(a) MDOT (b) State Agency

(c) Local Agency (d) Contractor

Figure 2-2. Participation in previous ABC projects

The third question of the survey asked participants' involvement in previous ABC demonstration projects. The response is analyzed and presented in Figure 2-3. Even though more than 75% of MDOT engineers participated in previous demonstration projects, local agencies and contractors did not.

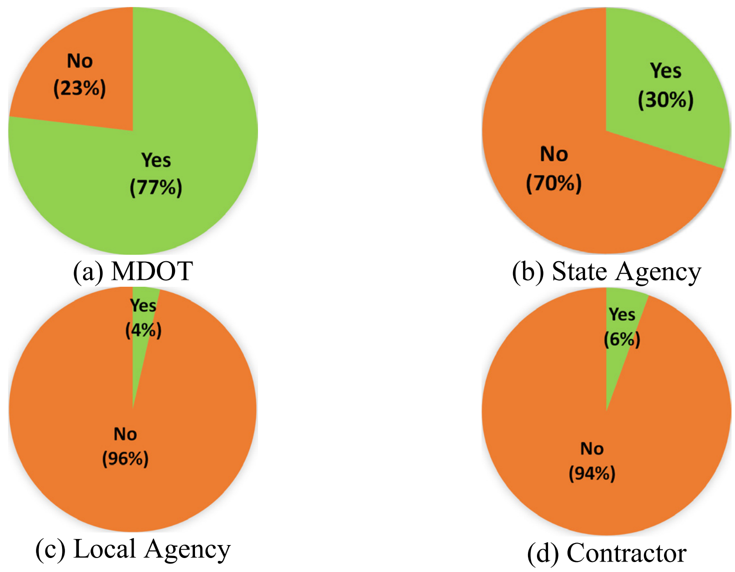


Figure 2-3. Participation in previous ABC demonstration projects

The third question of the survey asked participants' involvement in workshops, meetings or presentations on ABC. The response was analyzed and presented in Figure 2-4. While MDOT engineers had the highest participation in previous workshops/meetings/presentations on ABC, about 40% of local agencies and contractors also participated in such events to learn about ABC.

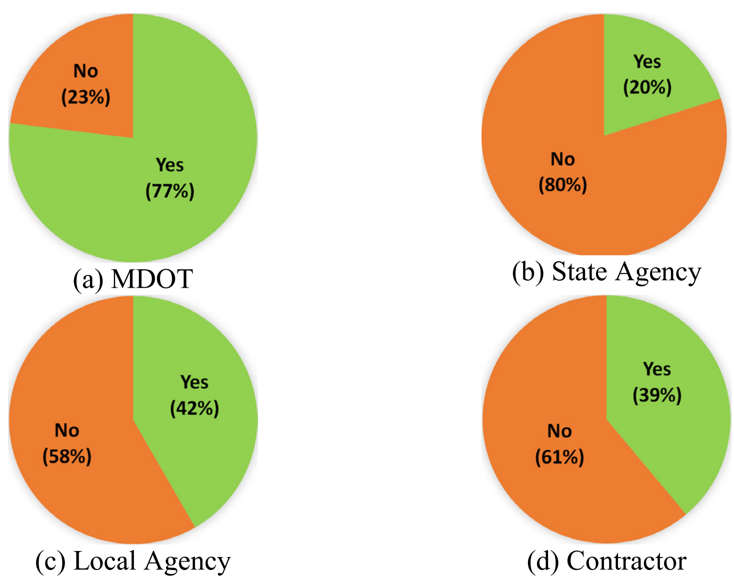


Figure 2-4. Participation in workshops/meetings/presentations on ABC

3 SUMMARY OF PRESENTATIONS

Detailed summaries of each presentation are provided in Appendix B. This chapter presents the key information extracted from the presentations under the following topics:

- Scoping, decision-making, planning, and cost
- Contracting
- Rapid demolition methods for ABC projects
- Structural analysis and design
- Structural move plans
- Contingency plans
- Construction
- Monitoring during moves
- Maintenance of traffic (MOT)
- Workforce management
- Observations and lessons learned.

3.1 SCOPING, DECISION-MAKING, PLANNING, AND COST

3.1.1 Scoping

MDOT approved the first ABC policy document in October 2012. The policy made ABC/PBES part of MDOT's business process. In the call for projects, MDOT requires the project selection to be based on the feasibility of ABC for project delivery. If ABC is not justified for a project, a rationale is required. MDOT's current mobility policy deals with defining a major project. Currently, the criteria included in the mobility policy are (i) Volume to capacity ratio of more than 0.80, (ii) Work zone travel delay of more than 10 minutes, (iii) Any corridors of significance, and (iv) LOS is D/E or during construction drops from A to C. MDOT's ABC focus is primarily on user delay and work zone safety which will be further emphasized as additional performance criteria standards are set. The most recent update includes (i) User delay costs, (ii) Project schedule (lengths/events), and (iii) Part-width construction, detours, or temporary bridge construction (MDOT 2014).

3.1.2 Decision-Making

The decision to implement ABC should be strategic and not solely for the purpose of trying it out. If the decision is not based on a deliberate analysis, then the contractor may propose to use conventional construction after winning the bid. Hence, the site evaluation for ABC is made by a decision-making tool that utilizes project specific data. Currently, a software platform developed for the Michigan Accelerated Bridge Construction Decision-Making (Mi-ABCD) based on site specific data is being evaluated by MDOT.

Mi-ABCD incorporates project-specific data. Moreover, it includes life-cycle cost (LCC) and user cost (UC) models and allows collaborative input from multiple users. Analysis methodology of the Mi-ABCD improves usability and efficiency of the decision-making process along with addressing the sensitivity of results through an automated process, and it is based on mathematically sound and validated concepts (Aktan et al. 2013).

3.1.3 Planning

Planning activities need to be performed, and detailed schedules need to be prepared prior to performing the work. The activities are grouped under: (1) pre-ABC procedures, (2) ABC procedures, and (3) post-ABC procedures. From the contractors' perspectives, this work requires approximately 6 months for most projects.

Considerations during the planning process are as follows:

- Perform ground surveys and geotechnical surveys. Surveys require experienced personnel to use technologies to document underground utilities such as Ground Penetrating Radar (GPR).
- Evaluate slide or structural move alternatives by considering site constraints, allowable closure duration, maintenance of traffic, etc.
- Consider the logistics of deploying the selected slide or structural move technology.
- Develop detailed plans from start to completion. The equipment and number of workers required for each job activity and associated specific time durations are critical. Planning

needs to include small details, such as installing transition rails at the approach that may require a temporary concrete barrier. It should also include identifying proper equipment, tools, and procedures for each activity.

- Select appropriate methodology, type of equipment, and personnel with specific skills for the work to be performed. The potential for using the same equipment for removal and installation needs to be considered. This may lead to major cost savings for the project.
- In the early planning phase of an ABC project, communicate with a heavy lift or heavy haul contractor about potential means and methods. Providing the heavy lift contractor with clear expectations of the project may save funds in the long run by selecting methods that can be executed with cost effective equipment.
- Provide bracings for structural stability while implementing vertical move technologies such as climbing jacks. Specialty contractors may try to avoid bracings to save costs, yet this increases the risk of failure. The climbing jacks in conjunction with SPMTs can provide additional raising or lowering in the final position or staging area. The need of climbing jacks should be evaluated and communicated with the heavy lift/haul subcontractor early in the project to preplan for providing sufficient bracings. For example, a heavy lift/haul subcontractor may decide to use climbing jacks instead of specialized frames for falsework to reduce cost.
- Deploying specialty equipment such as SPMT or slide rails, temporary structures for staging new and/or removed superstructure, etc., can limit the space available in the work zone and significantly impact the use of the general contractor's/owner's resources such as cranes and forklifts. Hence, a detailed analysis of the work zone is essential in positioning the crane considering the lifting and placing radius.
- Speed of implementing a particular slide or structural move method needs to be defined as limited time is available with bridge replacement projects. Thus, the time frame must be coordinated with the specialty contractor beforehand.

- Structural move or slide can be completed in a very short time frame. However, approach work could take a considerably long time if not planned in detail. After the bridge superstructure is in place, there is still a significant amount of work to tie the approach to some degree prior to opening to traffic. A few examples of such activities are backfilling at the abutment, pavement restoration, pavement markings, and installing guardrails. Some of these activities take place simultaneously and require detailed plans. As an example, the backfilling in proximity to the slide-in, or moved structure, is a time consuming operation and a critical activity in the ABC time window. The quantity of asphalt and fill removed directly impact the amount of post-ABC work for backfilling and pavement restoration. An approach is to use marker tapes to define the excavation area.
- The saw-cutting of abutment walls is a critical activity. A highly skilled worker is required for this operation because a slight deviation in the cutting angle may lead to unintended damage to the structure as well as unsafe conditions.

3.1.3.1 Planning for pre-ABC work

- Prior to sliding or structural move operations, at least six-months of detailed planning and other work need to be performed. The planning includes minute-by-minute details with *5-minute* milestones, including detailed contingency plans.
- Detailed planning needs to include the number of employees needed and their associated responsibilities. As an example, several field engineers, who are solely responsible for keeping track of progress, need to be on-site. Unexpected events can happen such as SPMTs failing due to bearing pressure or any other operational issues. These events are highly complex and require skilled workers to tackle them. It is very critical to select appropriate specialty contractors and highly skilled crews.
- The detailed planning is also essential for strategic equipment management. For example, it may be more practical to specify rubber tired excavators which are light and fast with small footprints. These machines can move on freshly placed asphalt; whereas, the track-mounted equipment, while excavating, will damage the asphalt and may

require padding, etc. Conversely, the use of rubber-tired equipment will require asphalt to be cooled prior to access.

- It is necessary to maintain accurate tolerances at the abutment location when the new structure is brought in, especially if the new superstructure is being placed on an existing substructure. This is to ensure accurate grouting operation to connect the existing abutment with the new superstructure. Employing highly skilled workers to saw cut the abutments is important.
- Adequate lighting needs to be provided at the site for safety during quick moving work. Illumination needs to be designed specifically for the equipment at the site and site layout. As an example, use of rubber-tired equipment may require additional lights due to low reflectivity.

3.1.4 Cost

- Approximately 25% of the project cost is for specialty subcontractors' activities when ABC projects involve heavy lifting or moving. One-third of the specialty subcontractor's cost is for mobilization and demobilization. Hence, planning and designing to move a structure with the least possible weight will require less equipment, and it reduces the cost of mobilization and demobilization operations.
- Deployment of a SPMT unit, which includes 6 axles, requires one truck. Transportation cost for each truck today is about $4-$5 per mile.
- Heavy lifting crane deployment cost is proportional to the number of boom sections because each boom section requires one truck for transportation. Also, load permits are required because of the heavier and wider sections. In this case, transportation cost of each truck today is about $7-$8 per mile.
- Lifting and transportation costs can be up to 2%-3% of the total project cost.
- Savings of up to 20% to 30% of a specialty subcontractor's contract can be achieved by implementing the following practices:
    - Involving a lifting/ transportation contractor during the design phase
    - Including specialized engineers to review the lift and/or transport method

  - Designing elements that are relatively light or using voided sections
  - Designing support and lifting points during the early design stages
  - Constructing the structure as low to the ground as possible with sufficient space for transportation or lifting access
  - Combining removal and installation of structures using the same equipment
  - Providing bracings between structural components, barges, SPMTs, jacks, etc. Bracings are an extremely crucial aspect for a structure move.

- In addition to minimizing risks and unforeseen costs, the following need to be avoided:
  - Adding extra weight at the last moment. This requires bringing extra equipment, engineering staff, and resubmittal of the structural move plan, monitoring plan, contingency plan, etc.
  - Using falsework such as containers with unknown load-bearing capacities for the staging area. The containers need to be tested, certified, and approved by the lifting contractor.
  - Using custom made rigging, towers, etc. This is because the construction works, as well as moving operation activities, are performed around these structures, and requires significant engineering.
  - Establishing extreme deadlines. This may lead to extra labor cost, especially if the deadlines are communicated late.

3.2 CONTRACTING

The traditional contracting methods do not provide opportunity for leveraging contractor experience during project planning and development. With the introduction of ABC techniques, highway agencies are evaluating various contracting methods such as Best Value, CM/GC, Design Build, A+B, A+B+C, and Warranties for delivering successful bridge projects. The following sections present Utah and Michigan contracting experience.

3.2.1.1 Utah Experience

The following are the three different levels of contracting documents used in Utah:

- ABC means and methods are not provided. In this case, the structural plans are provided by the DOT similar to Cast-In-Place (CIP) structure and the contractor can decide on the mobilization method and develop any associated details. This was mostly useful for design-build projects.

- Show a schematic of one viable option. In this case, the DOT will choose and provide one viable method for mobilization of the structure, but will not provide the process of mobilization and associated details to the contractor. This was also useful for design-bid-build projects.

- Show permissible move details. In this case, the DOT will provide the viable method of mobilization along with associated details. The documents in this case are detailed. This was mostly useful for CM/GC projects.

In the contract documents, the goals, limitations, and requirements of the project should be defined. The specifications should include the following:

- Submittal requirements: Specify design and other associated details such as temporary support details, etc. Provide guidance on the level of design and details under the contractor's responsibility.

- Contractor flexibility: This can be done by limiting to one prescribed method and associated details or allowing the contractor to select a method.

- Tolerance limitations: Tolerance requirements are relaxed a bit compared to conventional construction. However, the contractor needs to identify and understand the precision required when the bridge is brought to its final location.

- MOT requirements: For example, on several projects Utah DOT allowed lane closures a day before the SPMT move in order to demolish one lane of the bridge. The contractors were also permitted to move the bridge a short distance a day before the move in order to perform a system check during daylight hours.

- Incentives and disincentives: Several projects in Utah were awarded with incentives when the roadway was opened to traffic ahead of schedule. However, contractors incurred disincentives in some projects in Utah because of delays in roadway opening. Utah DOT has a tier system for penalties, wherein a reduced disincentive is imposed within the first 2 hours to assure structure quality is not impacted. After 2-4 hours beyond the schedule, higher disincentives are imposed.
- The contract documents should indicate that the schedule must allow for review time. Also, the design team and the contractor are to be notified about the level of effort required in submitting and reviewing the following items:
    - Changes to contract plans
    - Temporary supports including geotechnical evaluation
    - Staging areas
    - Hour-by-hour schedule
    - Communication plan
    - Contingency plan.

3.2.1.2 MDOT Special Provisions for Sliding

MDOT developed special provisions for sliding a prefabricated structure, an ABC method. It is MDOT's intent to make these "previously approved" special provisions available on its website. The following are some of the requirements of the slide-in special provisions:

- Working drawings, calculations, and submittals
- Move operations manual: This is to ensure that MDOT inspectors, MDOT engineers, contractor, superintendent, and contractor's engineer are coordinated. Thus, if any issue arises during the slide, all the associates on-site will be clear on their responsibilities in mitigating that issue.
- Geometry control and monitoring plan
- Contingency plan
- Trial horizontal slide
- Movement of superstructure requirements
- Allowable tolerances.

3.2.1.3 Contingency Plan

The contingency plan ensures that the hour-by-hour schedule is observed. This provides an interpretation of the move or slide progress and allows for prompt issue mitigation. In addition, public involvement needs to be coordinated well. Additionally, a couple of hours of contingency are reserved beyond the contractor's proposed time. The closure time advertised to the public is a couple of hours longer than the contractor's proposed time.

There should be a contingency plan for means to pull the bridge back. Pull back may be required if the bridge is moved in at an inappropriate angle and/or is rubbing on the substructure. In addition, there should be a plan as well as an ability to adjust the bridge horizontal alignment, such as, if the structure is very close to one abutment compared to the other.

Also, for critical equipment such as jacks, control units for SPMTs, and parts with short life, it is essential to have spare equipment and/or parts in stock, on-site.

3.3 RAPID DEMOLITION METHODS FOR ABC PROJECTS

The following three potential methods were discussed:

  - Use of SPMT
  - Sliding out
  - Saw cutting and removing with cranes
  - Use of explosives.

- When SPMTs are used to replace a bridge, temporary shoring can be used to support the existing bridge for demolition. The cost effective approach is to cut the old bridge on the temporary shoring, lift, place on the ground, and demolish.
- It is critical to document the extent of deterioration of structural members, weight and center of gravity of the structure before implementing any move technology for removal.

- Extreme consideration must be given for prediction capabilities while using explosives for demolition. Alternatives to using explosives, such as cutting the structure and moving for safe demolition, must be investigated. .

3.4 STRUCTURAL ANALYSIS AND DESIGN

ABC is a paradigm shift in bridge engineering. ABC requires that the bridge design engineers think like a contractor. Also, the design engineers must evaluate constructability of the structure during the design phase.

3.4.1 Prefabricated Bridge Elements and Systems (PBES)

When PBES are specified, three separate designs are prepared for a project. One is final bridge design in its final alignment/construction (similar to conventional bridge). The second design is when the bridge is being fabricated, and the third design is when the bridge is being lifted and erected in place or moved or slid into the final place. Each of the designs include additional loading and stress requirements. Most of the time, the governing design may not be the final bridge design but the design including lifting and erection or moving or sliding conditions.

Limit states shall be considered in the design for the following stages: (1) prefabrication process, (2) shipping process, (3) erection process, and (4) final as-built state of the bridge.

In prestressed concrete design, strand release stresses may control the design of the beam, and they are mitigated accordingly to ensure sufficient capacity for the operational life of the structure. In ABC, additional checks are required for stresses/deflections during shipping and handling. This is because heavier and longer girders are often used. In addition, camber and deflections need to be checked at release, erection, and final as-built state. Design documents need to specify the time duration the girders are allowed to remain in the staging area or prefabrication yard before being erected. The schedule for fabrication, curing, and transporting the elements also needs to be specified.

A challenge for most designers is the erection concepts for PBES. For constructability, the designer should understand the site and contractors' capabilities. This requires sufficient planning time to evaluate the site and communicate with the contractors.

The following are challenges to designing PBES:

- Insufficient knowledge and experience in detailing connections, specifying tolerances, tracking durability, designing curvilinear geometry, and accounting for negative moment continuity
- Availability of precast contractors
- Designing a component size suitable for transport and erection.

In order to address the component size and weight adequacy for transport and erection, the SHRP-02 R04 project team identified the weight of 200 kips as the optimal for shipping and handling/erecting with conventional equipment. When the 200 kips weight limit is exceeded, the contractors need to deploy heavy lifting equipment. Also, shipping the component becomes complex and requires permits increasing the project cost.

An ABC toolkit was developed to provide assistance to the bridge engineering community with PBES implementation. The components of the tool-kit are as follows:

- ABC standard design concepts
- ABC erection concepts
- ABC design examples
- Recommended modifications to AASHTO LRFD
- ABC construction specifications.

3.4.2 Bridge Slide

The critical aspects of slide projects are as follows:

- The coefficients of friction (static and dynamic) are critical estimates as they define the required jacking hydraulics for mobilizing the structure. MDOT is involved in developing jacking force calculations based on static and kinetic friction coefficients. This will allow selecting appropriate sliding surface and jacks for the jacking operation.

- Project slide-in systems consisted of structural steel track beams supported on a temporary substructure. A series of Teflon laminated neoprene steel reinforced pads are set on the steel track beams with the Teflon facing upwards. Then, welded steel carriages with a stainless steel surface are placed on top of the Teflon pads. The kinetic friction is typically around 1-2%.

- When the sliding surface is bronze on steel, static friction of 15% and kinetic friction of 8% is expected.

- Lateral restraint needs to be provided to the structure during the slide-in operation.

- Sliding a multi-span structure introduces additional complications. These complications include keeping the structure aligned and guided. Multi-spans require more precise operation than sliding a single span structure.

- Utah DOT and the Michael Baker Corporation prepared a slide-in bridge construction (SIBC) guide for Federal Highway Administration's (FHWA) Every Day Counts Initiative. The guide can be downloaded from FHWA website (FHWA 2013b). Topics included in the guide are listed below:
    - Introduction of Slide-In Bridge Construction
    - Owner Considerations
    - Design Considerations
    - Construction Considerations
    - Case Studies
    - Sample Plans
    - Sample Special Provisions.

3.4.3 Self-Propelled Modular Transporter (SPMT)

Resources for SPMT implementations are available through the Federal Highway Administration (FHWA) website (https://www.fhwa.dot.gov/bridge/abc/spmts.cfm). The workshop presenters primarily discussed the geotechnical aspects of the project that they worked on. The following are some of the considerations presented:

- The temporary supports located in the staging area need to provide an adequate bearing area to control settlement. In general, the factored bearing capacity of the soil shall be twice the applied bearing pressure in the staging area (i.e. Factor of Safety of 2). Organic clay or weak soil at the staging area needs to be removed, and a granular base is placed to achieve the required bearing capacity.
- Loads from shoring and the SPMT moves and the bearing capacity of existing soil need to be considered for calculating the granular base thickness.
- Concrete sill pads (precast blocks) and reinforced concrete footings are potential solutions for temporary support footings. The reinforced concrete footings can be recovered. The concrete sill pads are reusable.
- In addition to preparing a temporary staging area, a travel path needs to be thoroughly investigated and prepared to assure the stability of the SPMT. Weak soils such as organic clays need to be removed and a granular base prepared. The granular base thickness is calculated based on the loads from the SPMT and the bearing capacity of the existing soil underneath the granular base.

3.5 CONSTRUCTION

3.5.1 The Technologies for Moving Structures

The available technologies can be categorized into two groups as vertical and horizontal (Table 3-1).

Table 3-1. Technologies for Moving Structures

Vertical Technologies	Horizontal Technologies
Cranes	Trailers - SPMT - Conventional Trailers
Tower Systems - Strand Jacks - Gantry Systems	Skidding (sliding)
Jacking - Climbing Jacks - Titan Systems - JS 500	Barging

3.5.1.1 Cranes

The following are the key considerations when cranes are used in a project:

- Ground bearing pressure
- Lifting points
- Swing radius
- Weight chart for respective cranes. Preplanning is with respect to structure weight and any excess weight because of lifting/placing radius.

3.5.1.2 Strand Jacks

The following are the key considerations when Strand Jacks are used in a project:

- Useful for limited access areas (hard to reach areas)
- Leads to cost savings when planned early in the design phase
- Mobilization and demobilization costs are low. Each piece of equipment weighs about 4 ton (8 kips), and 5 to 6 jacks can be transported with one truck without requiring load permits.
- Jacks are integrated with a computer controlled system. Lifting velocity is slower than cranes.
- Jacks can be used for bridge removal without requiring additional equipment for lifting or lowering the bridge. However, engineering design is required.
- Jacks can lift a bridge about 3 ft in one stroke in about 10-12 minutes.

3.5.1.3 Multiple Strand Jacks per Tower

The following are the key considerations when implementing Multiple Strand Jacks per Tower in a project:

- Strand jacks with 100 ton (200 kips), 300 ton (600 kips), and 900 ton (1800 kips) capacities can be combined per tower.
- Hammer head tower design required for this technology is applicable for bridge projects.
- Electrical power can be used.
- Light load support cranes are needed for transporting the materials to the tower.

3.5.1.4 Gantry Systems

The following are the key considerations when Gantry Systems are used in a project:

- Capacities up to 1250 ton (2500 kips) are available.
- Ideal for lighter deck removal with gantry-skidding beams mounted on girders
- Limited lift height
- Only 3 or 4 hydraulic jack mounts are available for lifting operation.
- Requires extremely stable ground
- Needs providing temporary strengthening or post-tensioning to mitigate the stresses developed in the structural elements.

3.5.1.5 Climbing Jacks

The climbing jacks are large hydraulic cylinders supported by hard wood cribbing or blocking. The climbing process involves the hydraulic cylinder integrated with the jack to push the outer housing up and allow for placing blocking supporting the housing. Then, the housing pulls the cylinder up, and hard wood blocking is placed under the hydraulic cylinder. This process is repeated in a sequence to further advance the jack upwards.

The following are the key considerations when Climbing Jacks are used in a project:

- Pressure points for both structure and support shall be calculated.
- Height restricted: Can go up to 2-3 ft per stroke
- Labor intensive and slow: Every stroke takes about 2-3 minutes based on the access of the jacks to place jacking wood.
- Low mobilization and demobilization costs
- Low engineering cost
- Structural demolition is possible.
- Good quality of jacking wood blocking (hard wood) for bracing is required for safe operation.

3.5.1.6 Titan Systems Jacks

This is Mammoet's proprietary system. A photo of the Titan system is shown in slide 20 of Mammoet presentation given in the Appendix D. The following are the key considerations when Titan Systems Jacks are used in a project:

- Ideal in combination with SPMTs
- Lift capacity up to 2,400 tons (4,800 kips)
- Extremely stable and support friendly.

3.5.1.7 JS 500 Jacks

Refer to slide 22 of Mammoet presentation given in the Appendix D for a photo of a JS 500 jacks. The following are the key considerations when JS 500 Jacks are used in a project:

- Ideal in combination with SPMTs
- Stable
- Computer controlled jacking: Differential tolerance of 4 mm (0.16 in.) between the jacks can be achieved.
- 500 ton per tower
- Lifting above 33 ft requires additional bracing.
- Fork lifts and labor are required for faster lifting. The process requires the bracing blocks to be moved on the JS 500s rapidly for increased speed of the operation.
- Tie down to structure is required at temporary of fixed points.
- The application needs to be specified during the design phase.

3.5.1.8 Conventional Trailers

The following are the key considerations when Conventional Trailers are used in a project:

- 10 ft wide (i.e., 2 ft wider than SPMT); therefore, more stable than SPMTs, if used as a single trailer
- May require load permits because of extra width. However, in general, mobilization and demobilization for this technology is low cost as they are pulled behind the trucks. This technology will be lower cost if equipment is available locally.
- Limited maneuvering possibilities compared to SPMTs
- Different loading charts are available for different types and brands. They are more flexible than SPMTs.

3.5.1.9 Skidding or Sliding

The following are the key considerations when a Skidding or Sliding technique is used in a project:

- Very low cost way of moving
- Is slower than other horizontal move methods
- Push or pull points needs to have sufficient capacity.
- Combination/Installation with jacking is possible. Short stroke pushing jacks can be used in combination with pulling jacks to overcome the initial braking friction.
- Capacity ranges from 100 ton (200 kips) to 750 ton (1500 kips).
- If the new bridge cannot be constructed close enough and/or on the same elevation with the existing bridge, then Skidding or Sliding technology may not be applicable.

3.5.1.10 Barging

The following are the key considerations when barging is used in a project:

- Project schedule may be impacted by weather conditions that affect the water level/current of the waterway.
- Additional equipment is needed such as ballasting, winching, mooring, tugs, etc.
- Engineering is required with the use of additional equipment.
- Building a barge is very expensive, but they can be rented.
- Dead load calculations govern the type of barge being selected.
- In addition to the typical loads, buoyancy forces must be considered.

3.5.1.11 Self-Propelled Modular Transporters (SPMTs)

The following are the key considerations when SPMTs are used in a project:

- Ground bearing pressure. Steel bearing plates are often required along the move path.
- Can also be used for structural demolition
- The structure needs to be braced while on the SPMTs.
- Tires are air filled.
- Capacity is about 30 ton (60 kips) per axle line.
- 360° steering capability

- Can be incorporated into the Titan system presented in section 3.5.1.6
- Hydraulic systems can be customized for 3 or 4 point set up.
- Spacers (connection elements) are used for mechanical side-by-side coupling of transport units. Spacers are available in different configurations. An example is shown in Figure 3-1. Other spacer configurations are available for connecting multiple transport units as needed. Spacers can be used to combine multiple transport units to distribute loads among the transport units; hence, to reduce mobilization/demobilization costs and equipment rental costs.

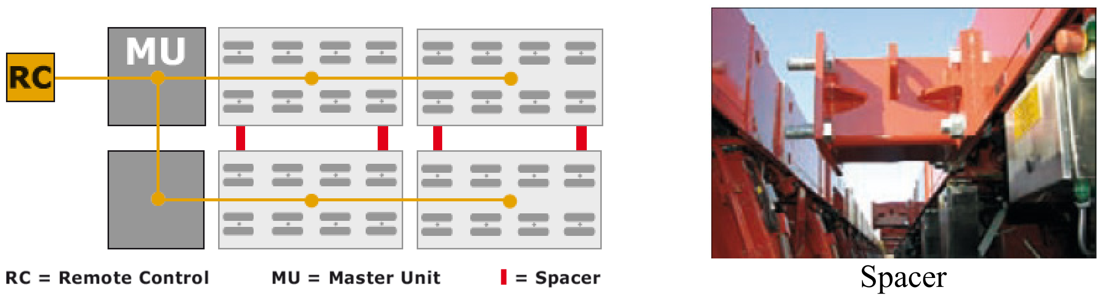


Figure 3-1. Mechanically coupled vehicle combination (Source: SCHEUERLE 2014)

In SPMT implementations, the following is a list of typical activities required in a pre-ABC lift operation:

- Remove approach slabs and pavement.
- Demarcate the excavation area using marker tapes to avoid extensive excavation.
- Excavate backfill.
- Saw-cut and stabilize the abutment walls and/or backwalls.
- Backfill the existing abutment walls and/or backwalls including sub-drain installation and connection.
- Divert the sub-drain below.
- Place temporary pavement.
- Mark the SPMT move path to direct its movement along the intended path, and supported over rolled steel plates and/or sufficiently protected utilities when needed.
- Install bearings before move (using tie downs, friction clamps, etc.).

The following is a list of typical steps involved during the ABC lift operation:

- Excavate backfill.
- Remove existing superstructure and transport to staging area.
- Transport new superstructure from staging area and erect to final position.
- Backfill with granular material.
- If an asphalt approach pavement as well as an overlay is used, place hot mix asphalt on bridge deck and approaches.
- If a concrete approach pavement is used, place precast concrete slabs to expedite the approach roadway work.
- Install temporary concrete barriers.

The following is a list of typical steps involved in a post-ABC lift operation:

- Excavation
- Grading and placement of granular base for approach slabs
- Construction of approach slabs using rapid set concrete or with precast panels
- Placement of hot mix asphalt on approach slabs and on exterior portions of the structure
- Placement of median barrier walls on approach slabs using rapid set concrete and embedded electrical work.

3.5.2 Incremental Launching

A simple cast-in-place post-tensioned structure with launching technology is ideal for reconstructing a bridge over a very busy railway that limits access of cranes. The procedure eliminates the need for interruption of railway traffic. Concrete bridges with spans up to 80 ft can be launched conveniently without a nose but with temporary piers or with a very small launching nose but without temporary piers. However, a typical steel launching nose is required for bridges with spans over 80 ft long with temporary piers. In addition, king post and stays are included for spans up to 210 ft. Bridges have been successfully launched up to 4500 ft (0.85 mile) in length. When the spans get longer, new challenges are introduced.

Generally, post-tensioning of the structure in a longitudinal direction is required for implementing launching technology. In addition, it is essential for the launching nose design to accommodate/limit the stresses on the structure due to the cantilever action. The length of launching the nose can be up to half-a-span. However, the launching noses can be designed for a limited length provided that the span is designed to accommodate large deflections and accommodate the angle of curvature and deflection at the landing point within limits. In these cases, a “rocker” (i.e., a temporary bearing at pier location) can be utilized, on which the curved launching nose is landed, rolled up and rotated onto the piers.

The hydraulic jacks required for incremental launching technology are readily available. Launching track, launching bearing, and hydraulics are obtainable. Bridges with complex geometry, such as horizontal and vertical curvature, can also be replaced using launching technology. Implementing launching technology on spiral geometry bridges and varying-width deck bridges is also possible by using wider launch bearings.

Additional information on incremental launching can be found in LaViolette et al. (2007), a report developed as part of NCHRP Project 20-07.

3.5.3 Prefabricated Bridge Elements and Systems (PBES)

The ABC Toolkit developed under the SHRP-02 R04 project provides erection drawings (detailed erection plans) for the contractor to erect the PBES using conventional cranes. The toolkit also provides different crane placement and erection scenarios for typical bridge projects (SHRP-2 2013). It is important to be familiar with different types of cranes available for ABC. This helps identifying an appropriate crane for erection based on the site conditions.

The toolkit provides a constructability analysis considering conventional crane-based erection. The factors that are considered during the analysis are: (1) weight of a prefabricated element, (2) pick radius, (3) crane set up locations, (4) ground access/ barge/ causeway/ work trestle, and (5) truck access for delivery. The constructability analysis is recommended to be performed by preparing the site plan including all the crane locations and access options.

In most cases, construction from below (ground) is costly and time consuming. This difficulty arises in projects dealing with interstate expressways or railroads as the feature intersected. Thus, to address this issue, the toolkit considered the following ABC technologies that allow construction from above:

- Above deck driven carriers: Mostly suitable for sites with limited ROW. However, it is cost effective for bridges with 10 to 15 spans but not for bridges with 1 or 2 spans.
- Launched temporary bridge (LTB): Useful in environmentally sensitive areas or any restricted areas with limitations to on-ground placement of cranes. The LTBs increase the possibility of erecting longer spans. They are launched across or lifted over a span to act as a temporary bridge and can be used to deliver heavy prefabricated elements without inducing large erection stresses. The temporary bridge can also support transverse gantry frames.
- Transverse gantry frames: This includes gantry girders on either sides of the bridge and on which the gantry moves. The gantry then moves back and forth to pick the old span out and install the new span.
- Longitudinal gantry frames: This includes two SPMTs with long longitudinal gantry truss that lifts the old span and moves it out, and the new span is moved in and installed in a sequence. The gantry carries two spans at the same time.
- Regular cranes with sufficient reach.

3.5.4 Substructure and Foundations

- For piers, there are two concepts: (i) conventional pier with cantilever bent cap, and (ii) straddle bent. The straddle bents are preferred because new bridges are commonly wider than the old bridges, and straddle bents allow using drilled-shafts/piles and constructing foundations outside the footprint of the existing bridge.

3.6 MONITORING DURING MOVES

Accurate elevations and proper placement of the structure with frequent precision surveys are the purpose of monitoring. Also, double-checking is critical for the skew angles, bearing elevations, and span lengths.

The following are the typical technologies and methods used in structural monitoring during bridge moves:

- Load cells ranging from 5 ton (10 kips) to 750 ton (1500 kips) are placed to monitor the loads imposed on the structure.
- Lasers are used for measuring and/or comparing distance based on critical points marked on the structure for monitoring yaw (rigid body rotation about vertical axis) in order to control direction of bridge movement. Lasers are also used for measuring structural deformations when controlling lateral stresses.
- Strain gauges are used for monitoring strain and the associated stresses.
- Pressure indicators are used for monitoring hydraulic cylinder pressure.
- Surveys are performed to check the levels, string lines, and measuring gaps.
- Vertical deflections are monitored to control bridge superstructure twisting during the move.

During bridge slide, the following actions can be performed:

- CCTV cameras can be used to monitor the slide path.
- The scale markings can be marked on the slide path to inform the operator about the progress of slide-in movement.
- Monitoring can be as simple as drawing a chalk line on the abutment and diaphragm to track the slide.
- In cases when the superstructure is slid with the approach slab, frequent measurements need to be taken throughout the move to maintain the required gap between the sleeper slab and the end of approach slab.

3.7 MAINTENANCE OF TRAFFIC (MOT)

MOT requirements are critical, and the contractor needs to be focused on these activities.

Utah DOT discussed strategies used during several projects to manage traffic during one of the projects. Utah DOT allowed lane closures on features intersected a day before the SPMT move for partial removal of the bridge. The contractors were also permitted to move the bridges half-way a day before the move.

3.8 WORKFORCE MANAGEMENT

Even though it would have been valuable to learn practices related to worker training, safety management, managing workforce to reduce work related fatigue, and task assignments, presentations were limited on the given topics.

ABC projects sometimes require managing a large number of employees on site. As an example, Aecon needed to manage 110 employees, at peak, working on the Highway 417 rapid bridge replacement project in Ottawa, Canada.

Numbers and qualifications of workers required to successfully complete ABC projects are critical. The contracting community needs to make sure that sufficient numbers of workers are available. Moreover, the workforce needs to know that a majority of the work activities will be during evening and weekend hours.

It was also mentioned that, to perform a limited amount of work, at least 50 workers are required. It is indeed necessary to ensure that the workers are available for all the weekends during construction duration.

3.9 OBSERVATIONS AND LESSONS LEARNED

As with any new technology, lessons are learned during the project activities. As an example, Aecon Infrastructure Group, Inc. (as the contractor of the Highway 417 rapid bridge replacement project in Ottawa, Canada) took the lessons learned from first weekend into the second weekend and improved their performance. This highlights the need for developing detailed lessons-learned reports following post-construction meetings with all the parties involved in the project.

3.9.1 Contracting Methods and Contractor Involvement

Table 3-2. ABC Contracting Methods: Advantages and Drawbacks

Design-bid-build	Design-build	Construction Manager/ General Contractor
• Traditional contracting method. • No contractor involvement during design. • In-house or consultant design. • Higher level of risk to the owner. • Increased level of change orders. • Strong team partnering and coordination needed.	• Concurrent design and construction. • Early knowledge of cost: This is because the project is bid on type of work rather than individual items. • Reduction in delivery time. • Improvements to constructability. • Encourages innovation. • Risk is transferred to the contractor.	• Contractor on board to consult during design. • Owner able to decide on innovations. • Reduced design errors, constructability issues, and change orders. • Ability to identify and mitigate risk. • Allows for early procurement. • Limits negotiation on project costs because the owner (DOT) understands the rationale behind the contractor's pricing.

Utah DOT's preference is the CM/GC method. Through this contracting method, an independent cost estimate is performed in-house and compared with the contractor's estimate. Utah DOT defined a limit that if the contractor's estimate exceeds the in-house estimate by a defined percentage, then the DOT has an option to convert to traditional bidding. The DOT, in this case, is not limited to the contractor on the design team.

Utah DOT did not have concerns from the contractors for the submittals. In the first few projects, DOT allowed a 14-day review period for the contractors, and later with electronic submittals a 7-day review period was allowed. The owners should consider the time required for preparing the submittal documents while developing the owners' construction schedule. Also, the owner's schedule needs to be flexible to accommodate any revisions to the submittals, especially when a temporary work plan, a communication plan, and an hour-by-hour schedule are requested. The owner needs to communicate with the contractor regarding progress to submittals. Also, the owner shall realize that, for new contractors, there will be a learning curve in preparing the submittals. Similarly, the owner's schedule should allow for additional review time from their side as well.

During the SHRP-2 R04 projects in Iowa and New York, the project team engaged all the local contractors (by working through AGC) from the start of the ABC project and had one-on-one meetings to get their input at 30% and 60% design phases. An information session with all the contractors was conducted later prior to the bidding date. This worked very well, and competitive bids were received because of the input from the local contracting industry, rather than engaging one single contractor as in case of CM/GC.

3.9.2 Construction Methods

3.9.2.1 Self-Propelled Modular Transporter (SPMT)

- Moving the bridges with SPMT in most of the projects is not a time consuming activity, and it proceeds relatively quickly. The time consuming activities are (i) details such as backfill and (ii) time required for paving and other operations, such as lane markings, placing barriers, guard rails, etc. Adequate considerations need to be given to all the details including each and every minute activity.
- If initial cost is justified, multiple SPMTs can be used to expedite a bridge replacement activity. As an example, during the Highway 417 rapid bridge replacement project in Ottawa, Canada, the plan was to remove the existing superstructure using a set of SPMTs to transport it and place it on the temporary supports of the new superstructure while the new superstructure was supported on another set of SPMTs adjacent to the bridge site.
- In using the same temporary supports for shoring the new and the existing bridge superstructure, re-design is required considering the loads and support locations of the new and the existing superstructure. The details that need to be considered are the bearings, bearing distances, and differential elevations between the bearings.
- Following replacement with SPMT's, temporary shoring can be used to support the existing bridge for demolition. However, this option is not cost effective in terms of the

loads that temporary shoring needs to withstand during demolition. The cost effective approach is to cut the old bridge on the temporary shoring, lift, place on the ground, and then demolish.

- When two sets of SPMTs are used to support and move the new and the existing bridge superstructures simultaneously, it is necessary to consider the dimensions of the existing and new bridges to prevent conflicts on the move path and in/out of staging area.

- To assure having sufficient stroke for the lift (at the final location), consider incorporating self-climbing towers that lift/drop in 6 in. increments to the SPMT system that has jacking capability in the carrier.

- When SPMTs are not locally available, to reduce the mobilization cost, identify projects with seven to eight bridges that need replacement at the same time using SPMTs.

- Equipment availability to accomplish the project activities is critical. As an example, Utah DOT was trying to limit the tie-in lengths as much as possible to reduce the amount of filling and paving at night. However, with only large equipment available, limited excavations could not be accomplished which ended up extending the tie-in lengths.

- The following suggestions are presented based on the lessons learned from the SPMT projects in Utah:
    - The contractor should not reuse components from a demolished bridge for any load bearing activity.
    - Survey is critical.
    - Account for all utilities in travel path.
    - Specifications need to clearly outline the expectations.
    - Account for varying load paths.

3.9.2.2 Slide-in

- Test slides should be performed to test the entire setup before the final sliding operation.
- For lateral slides, the basic equipment such as tracks, rollers, and hydraulic jacks (or post-tensioning jacks to serve the purpose of hydraulic jacks) can be used to reduce the project cost.
- Implementation of a continuous sliding operation using tandem jacks can achieve a rate of 65 ft (20 m) per hour, compared to a conventional single jack that provides a rate of 33-40 ft (10-12 m) per hour.
- Even though a millimeter level tolerance is indicated by the strand jack manufacturer, it was not achievable. This was because of practical issues such as a strand/tendon release effect that exceeds the braking friction and cannot be controlled by the jack.
- The following suggestions are presented based on the lessons learned from the lateral slide projects in Utah:
  - Slide-in technology needs to be specified following analysis of the site constraints.
  - Interaction between temporary and permanent supports needs to be considered: Utah had one slide project where the temporary structure settled at the connection point with the permanent substructure. Additional supports were installed to the temporary structure to obtain appropriate transition to the permanent substructure.
  - Structures can be slid with approach slabs. An inverted-T shaped sleeper slab is used to support one end of the approach slab while the other end is connected to the bridge superstructure. Hence, the sleeper slab is placed prior to bridge slide. The approach slabs slide on the sleeper slabs while the end diaphragms slide on the abutments. A flowable fill is placed underneath the approach slab. This process eliminated the time required for compacting approach soil and constructing approach slabs. The approach slabs are designed for their full span to ensure proper support in case the fill underneath undergoes settlement.
  - Adequate roadway tie-in lengths must be provided.

3.9.2.3 *Prefabricated Bridge Elements and Systems (PBES)*

Most issues are related to connections and connectivity between prefabricated elements and systems. Utah DOT experienced durability problems with the closure pours and transverse joints between the panels. Utah DOT was using UHPC or HPC for the closure pours and grout for transverse connections because of difficulty in identifying a true non-shrink grout. The connections cracked and leaked after 6 months of project completion. For some of the projects, Utah DOT did request warranty for the grout connections. When the connections started leaking, it could not be verified whether the failure was the contractor's fault (due to improper installation) or a flaw in grout properties and installation instructions in datasheets (the grout manufacturer's/supplier's fault). Rather than identifying the perfect grout and requesting warranty, Utah DOT specified longitudinal post-tensioning in all the precast decks. Overlay was also placed on the deck to enhance durability.

3.9.3 Quality Control

To ensure quality of the project, the following practices were recommended:

- Education and experience requirements, such as training, testing, and certifications of employees, need to be defined for all employees involved in preparation and execution of the project.
- Safety shall be pro-active and include (1) training, (2) pre-employment and random drug screening, and (2) kickoff, regular, and lessons-learned meetings that address safety issues.
- A detailed contingency plan needs to be developed that takes into consideration equipment maintenance and repairs according to guidelines of manufacturers, along with spare part management, documentation, and certification.
- A 7-day wet cure of the concrete superstructure in the staging area should be scheduled for SPMT or slide projects. This results in improved concrete quality in comparison to traditional construction that limits wet curing duration because of lane rental penalties.
- The prefabricator should not assume that the designer has full responsibility in specifying the tolerances and camber. This is the key issue while dealing with PBES, especially on prestressed elements. In ABC projects, the DOT needs to enforce the requirement for the prefabricator to work together with the designer in achieving proper tolerances and camber.

4 SUMMARY AND STRATEGIC PLAN FOR PROMOTING ABC IN MICHIGAN

4.1 SUMMARY

Highlighting their commitment to integrating ABC project delivery methods into the regular business process, MDOT approved an ABC policy document in October 2012. The MDOT ABC policy requires documented justification for each bridge project not delivered by ABC.

In 2008, MDOT constructed the first fully prefabricated bridge, the Parkview Avenue US-131 crossing in Kalamazoo, MI. Since then, MDOT has constructed several additional bridges with prefabricated elements. Moving ahead by demonstrating their commitment to integrate other project delivery options, MDOT is planning to implement slide technology for three projects during 2014. In addition, MDOT is analyzing sites to identify bridges for replacement using SPMTs.

MDOT foresees the bridge move or slide projects to be implemented using the traditional contracting method of design-bid-build. This requires the contracting industry to be knowledgeable about the ABC technologies. A workshop survey, summarized in chapter 2, showed that less than 6% of local agencies and contractors had the opportunity to participate in ABC demonstration projects. Further, less than 30% of the local agencies and contractors had the opportunity to participate in completed ABC projects with prefabricated elements. Hence, the local bridge engineering community has limited exposure to slide and move technology implementation.

Understanding the need, MDOT is using the CM/GC contracting method for their first two slide-in projects. These projects will provide an opportunity for the contracting industry and those delivering the projects to gain experience and knowledge. Also, as part of knowledge sharing and technology transfer, MDOT sponsored this workshop featuring experts with significant experience on ABC to share their experience, observations, and lessons learned. This workshop also provided opportunities for participants to learn about available ABC resources.

4.2 STRATEGIC PLAN FOR PROMOTING ABC IN MICHIGAN

The envisioned strategic plan for promoting ABC in Michigan is expected to include the following steps:

- Organize an expert group of owners, designers, academicians and contractors with experience in accelerated bridge construction to provide feedback on specifications, guidelines, and details for implementing a specific ABC technology.

- Incentives and disincentives typically tend to motivate contractors, but when the project completion is delayed due to unforeseen events, the contractors are penalized twice: the first for their increased cost due to the delay and, the second, by the owners' delay penalty. Owners may incentivize continuing education of the contractor's engineering staff as well as their length of tenure with the company. This may assure contractors developing and retaining experience in ABC.

- Develop a performance management strategy for ABC projects to assure that quality and durability are expectations as well as the speed of construction.

- Conduct selected ABC projects as demonstration projects, for their educational value to the local contractors, local agencies, and public.

- Document ABC project activities to develop case-study examples. These examples can be included in workshops. The following information describes the minimum documentation needs of ABC projects:
    - Scoping, decision-making, planning, and cost
    - Structural analysis and design
    - Contracting
    - Scheduling
    - Structural move plans
    - Contingency plans
    - Demolition methods
    - Construction

- Monitoring bridge moves, deformations and stresses
- Maintenance of traffic (MOT)
- Workforce management
- Observations and lessons learned.

- Develop research to continually review the literature, domestic and international ABC implementations, and the information presented in the resources listed in chapter 5. Also, develop workshops co-sponsored by industry associations.

5 RESOURCES

Aktan, H., Attanayake, U., and Mohammed, A.W. (2013). *The Michigan Accelerated Bridge Construction Decision-Making (Mi-ABCD) model – Users' Manual,* Report: MDOT RC 1602 (Appendix E), Michigan Department of Transportation (MDOT), Kalamazoo, MI. <http://michigan.gov/documents/mdot/RC-1602_Appendices_DE_444149_7.pdf>

FHWA (2013a). *Public Roads*, Publication: FHWA-HRT-13-003, Federal Highway Administration (FHWA), March/April, 76(5). <http://www.fhwa.dot.gov/publications/publicroads/13marapr/01.cfm> (Last accessed: March 30, 2014)

FHWA (2013b). *Slide-In Bridge Construction Implementation Guide,* Project: F-ST99 (232), Federal Highway Administration (FHWA) and Utah department of Transportation, <http://www.fhwa.dot.gov/construction/sibc/pubs/sibc_guide.pdf > (Last accessed: March 30, 2014)

FHWA (2014). "The National ABC/PBES Project Exchange database." *Federal Highway Administration (FHWA),* <https://www.transportationresearch.gov/dot/fhwa/default.aspx> (Last accessed: March 30, 2014)

Note: For accessing the ABC/PBES Project Exchange database, prior registration and site access requesting is required following the instructions presented in ABC Project Exchange User's Guide: <http://www.abc.fiu.edu/wp-content/uploads/2013/07/ABC-User-Guide-for-posting1.pdf> (Last accessed: March 30, 2014)

LaViolette, M., Wipf, T., Lee, Y., Bigelow, J., and Phares B. (2007). *Bridge Construction Practices Using Incremental Launching,* Project: NCHRP 20-07 (229), National Cooperative Highway Research Program (NCHRP), Transportation Research Board. <http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/20-07(229)_FR.pdf> (Last accessed: March 30, 2014)

MDOT (2007). *State Long-Range Transportation Plan 2005 – 2030*, Michigan Department of Transportation, Lansing, MI.

MDOT (2010). *Work Zone Safety and Mobility Manual*, Michigan Department of Transportation (MDOT), Lansing, MI.

MDOT (2014). *Project Scoping Manual*, Michigan Department of Transportation (MDOT), <http://www.michigan.gov/mdot/0,4616,7-151-9622_11044_11367-243045--,00.html> (Last accessed: March 30, 2014)

SCHEUERLE (2014). "SCHEUERLE SPMT's Roll-lift." *SCHEUERLE,* <http://www.roll-lift.nl/files/download/148> (Last accessed: March 30, 2014)

SHRP-2 (2013). *Innovative Bridge Designs for Rapid Renewal – ABC Toolkit,* Report: S2-R04-RR-2, The Second Strategic Highway Research Program (SHRP-2), Transportation Research Board, <http://www.trb.org/Main/Blurbs/168046.aspx> (or) <http://www.fhwa.dot.gov/goshrp2/> (Last accessed: March 30, 2014)

5.1 OTHER RESOURCES FOR ABC/PBES IMPLEMENTATION

Publications that include FHWA ABC manual, Connections details for PBES, Manual for use of SPMT, etc., which can be accessed from:
<http://www.fhwa.dot.gov/bridge/prefab/pubs.cfm> (Last accessed: March 30, 2014)

Regional/DOT websites:
<http://www.pcine.org/> (Last accessed: March 30, 2014)
<http://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:1991> (Last accessed: March 30, 2014)

Regional Peer Exchange Meetings documents that include around 150 presentations related to ABC. The forum can be accessed from: <http://p2p.ara-tracker.com/> (Last accessed: March 30, 2014)

TRB Subcommittee on ABC – AFF10 (3) website:
<https://sites.google.com/site/trbaff103/> (Last accessed: March 30, 2014)
Note: This website is planned to contain the entire ABC related work in the US.

Webinar training sessions that can be accessed from:
<http://www.fhwa.dot.gov/everydaycounts/technology/bridges/pbeswebinartraining/> (Last accessed: March 30, 2014)

Future publications: Planning and Policy, Engineering Materials, and Construction Contracting (expected summer 2014)

MDOT RC-1610

Research

Accelerated Bridge Construction and Structural Move - Workshop

MARCH 2014

Department of Civil & Construction Engineering
College of Engineering and Applied Sciences
Western Michigan University

Accelerated Bridge Construction and Structural Move - Workshop

Appendices

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Submitted to:

MDOT

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APPENDIX A

WORKSHOP SURVEY

WESTERN MICHIGAN UNIVERSITY

Department of Civil and Construction Engineering
College of Engineering and Applied Sciences

Centennial 1903·2003 Celebration

Assessment Survey

Accelerated Bridge Construction (ABC)/Structural Slide and Move - Workshop
December 09, 2013

Your feedback is important to us; please rate your experience before, during, and after the workshop.

1. What was your ABC knowledge level coming into the workshop? ____________________

2. Were you involved with previous ABC projects? ____________________

3. Have you ever participated in ABC demonstration projects? ____________________

4. Have you ever participated in any workshop/meeting/presentations on ABC? ____________

5. What is your affiliation? State agency ☐ Local agency ☐ Consultant ☐ Contractor ☐ MDOT ☐

6. What is your current position? ____________________

How do you agree to the following statements? (Please leave answerer blank if it does not apply)	Agree 1	2	3	4	Disagree 5
7. I received information about this workshop in a timely manner	①	②	③	④	⑤
8. The dates and times offered worked well for me	①	②	③	④	⑤
9. I had the appropriate background knowledge for this workshop	①	②	③	④	⑤
10. Material was presented at an appropriate level	①	②	③	④	⑤
11. Handouts were useful and relevant	①	②	③	④	⑤
12. Material was presented clearly	①	②	③	④	⑤
13. The workshop was an appropriate length	①	②	③	④	⑤
14. The workshop increased my understanding of this topic	①	②	③	④	⑤
15. Instructors were knowledgeable	①	②	③	④	⑤
16. Instructors were well prepared	①	②	③	④	⑤
17. Facilities were adequate	①	②	③	④	⑤
18. I would recommend this workshop to others	①	②	③	④	⑤
19. Overall, I am very satisfied with the workshop	①	②	③	④	⑤

20. Comments:

____

____

____

____

Thank you for your participation.

APPENDIX B

WORKSHOP PRESENTATION SUMMARIES

GREGORY JOHNSON, MDOT CHIEF OPERATIONS OFFICER

Please use the presentation slides given in Appendix D while reviewing the information presented in this section.

MDOT is 108 years old and has been designers and constructors of the interstate system. MDOT's role as mobility managers is to recognize the impact to the economy and strengthen the economy by getting the projects delivered in a faster manner. Thus, MDOT is interested in deploying ABC technologies in future projects. In addition, MDOT is working at the national level through the AASHTO subcommittee on Bridges and Structures to advance ABC/PBES technologies. Slide technology is a tool for MDOT to become efficient mobility managers. The slide projects are expected to be tools in MDOT's tool box that will provide customer service and customer expectations for a future MDOT. The slide technology will be considered for projects where an extensively long detour, such as 70 miles, is required to get around a closed bridge.

In 2014, two bridge slide projects will be delivered in the Grand region using the CM/GC contracting method. MDOT is implementing the slide technology for the first time. Hence, for the first two slide projects, the CM/GC contracting method will bring a contractor to help MDOT. MDOT foresees the future bridge slide projects to be design/bid/build; thus, it requires the contracting industry and those delivering the projects to be knowledgeable of the technology. The industry needs to understand that slide technology is not a specialized tool; rather it is a project delivery alternative that will be included in the future program, which can be deployed as needed based on site conditions.

One of the major drivers behind the implementation of slide technology in Michigan is FHWA through its initiative Every Day Counts (EDC). EDC's goal is that 25% of bridges constructed with Federal Aid need to incorporate at least one ABC component. MDOT has been stepping on the path of that process, and the implementation of slide technology is another step in that process.

MDOT in October 2012 approved an ABC policy document. The policy made ABC/PBES part of MDOT business. The MDOT ABC policy makes a proactive statement to the MDOT scoping personnel to identify the components of a project that are appropriate for ABC, or to indicate why a bridge will not qualify for the ABC program. The personnel are doing an outstanding job to identify projects that are fit for ABC and are providing a good response.

MATTHEW CHYNOWETH, MDOT BRIDGE FIELD SERVICES ENGINEER

Please use the presentation slides given in Appendix D while reviewing the information presented in this section.

MDOT has the ABC policy engaged and is working towards making it part of their normal business practice. This work is being administered by a committee/partnership that includes members from MDOT, consultant and industry staff, and it was established by David Juntunen in 2011. The committee supervised the selection of a few in-progress MDOT ABC projects and is regulating the means and methods of selection for performing the slides-in projects.

The purpose of this workshop and MDOT's on-going work towards ABC is to learn from demonstration projects. This will help in standardizing the new technologies. MDOT needs to gain more knowledge and additional experience in order to develop a program approach. In the call for projects, MDOT requires the project selection to be based on the feasibility of ABC for projects. If ABC is not justified for a project, then MDOT requires a rationale for that decision.

Section 7.01.19 of the Bridge Design Manual includes ABC and PBES considerations. This section will be updated in the future with additional information after evaluating additional means and methods for ABC. MDOT also needs to develop a performance management strategy for ABC projects. For example, additional standards may be required for inspecting UHPC joints, post-tensioning, launching technology, etc., for assuring the quality and durability.

MDOT has two slide-in projects scheduled for the summer of 2014 in the Grand region. MDOT, with consultant and industry input, has developed a special provision for sliding a prefabricated structure. This special provision is sufficiently general and in the future will be labeled as *previously approved*. Moreover, it will be on MDOT's website to be used on ABC projects. MDOT is also involved in developing jacking force calculations based on static and kinetic friction coefficients. This will allow selecting appropriate material and jacks for the jacking operation. In addition, MDOT is working on SPMT special provision. A few of the requirements in the slide-in special provision are the following:

- Working drawings, calculations, and submittals
- Move operations manual. This is to ensure that MDOT inspectors, MDOT engineers, contractor, superintendent, and contractor's engineer are coordinated. Thus, if any issue arises during the slide, all the associates on-site will be clear on their responsibilities to mitigate that issue.
- Geometry control and monitoring plan
- Contingency plan
- Trial horizontal slide
- Movement of superstructure requirements
- Allowable tolerances.

MDOT is currently working on updating the Project Scoping Manual for evaluation of ABC/PBES techniques with respect to: (1) Site and Structure Considerations, (2) Work Zone Safety and Mobility, (3) Cost, (4) Technical Feasibility, (5) Seasonal Constraints and Project Schedule, and (6) Environmental Issues. MDOT's current mobility policy deals with defining if a project is a major project. Currently, the criteria included in the mobility policy are: (i) Volume to capacity ratio of more than 0.80, (ii) Work zone travel delay of more than 10 minutes, (iii) Any corridors of significance, and (iv) LOS is D/E or during construction drops from A to C. However for ABC, MDOT is focusing more on the user delay and work zone safety and will be including the criteria: (i) User delay costs, (ii) Project schedule (lengths/events), and (iii) Part-width construction, detour, or temporary bridge.

The MDOT recommended activities in progress are the following:

- Achieve industry buy-in. MDOT will be conducting workshops and technical conferences of this nature and will allow enough time for the local industry to become comfortable and knowledgeable using new ABC technologies. At this time, MDOT will be using the CMGC contracting method for the first two slide-in projects. Following these projects, based on the contractors' experience and perspective, the Design-Bid-Build contracting method will be used.

- Think like a contractor. Traditionally the means and methods were a contractor's responsibility. However, for ABC, the owner (MDOT) needs to develop means and methods thoroughly during the design phase itself by considering equipment capabilities/capacities.
- Plan a program of projects. This will inform the local industry that MDOT's business model is changing.

MDOT currently identifies the following barriers and challenges to ABC implementation:

- Thinking like a contractor, considering constructability during the design phase
- Insufficient knowledge and experience in detailing connections, specifying tolerances, tracking durability, designing curvilinear geometry, and accounting for negative moment continuity
- Availability of precast contractors
- Construction staging difficulties
- Designing a component size adequate for transport and erection
- Contractor proposing CIP instead of PBES following award
- Ability to innovative during design without becoming too prescriptive on means and methods
- Costs. User delay cost versus construction cost, and the equipment cost based on availability

MDOT is also involved in the process of developing guidelines for choosing ABC. The Michigan Accelerated Bridge Construction Decision-Making (Mi-ABCD) process was developed and a software platform was developed under MDOT's research project by Western Michigan University. Dr. Haluk Aktan is the Principal Investigator of the research project. (The details of the project are presented in a later section under Dr. Aktan's presentation.) The tool developed from the research project is planned to be used during MDOT's call for projects process and project scoping. The research is continuing at Western Michigan University under Dr. Aktan to expand the program so that slide-in and SPMT ABC methodologies are included.

MDOT, from their past ABC projects, learned the following aspects that prompted them to initiate the process of partnering and shared risk:

- Choose suitable projects and associated material applications.
- Target capabilities of contractors/fabricators.
- Analyze effects of cost and schedule.

So far, MDOT has constructed 3 bridges utilizing ABC techniques. These projects utilized PBES and are listed below:

- Parkview Avenue over US 131 in 2008
- US 31 BR over White Lake in 2011
- M-25 over the White River in 2011

The future of ABC at MDOT includes the following activities to be performed in 2014 and thereafter:

- Implementing three structural slide-in projects during 2014
- Implementing one bridge project involving PBES with IBRD funding
- Identifying a suitable candidate bridge for first SPMT move and implementing
- Evaluating standard joint and connection details
- Developing Decked I-beam using Carbon Fiber Prestressing Strands and UHPC under the ongoing pooled fund research project approved by FHWA (participating states: IA, MI, MN, OR, WI, and one pending)

MDOT PANEL REPRESENTING TRANSPORTATION SERVICE CENTERS

The MDOT panel discussed expectations, anticipated field operations, and public outreach and input for the three slide-in projects in Michigan scheduled for 2014. The MDOT panel consisted of associates (Eric, Tom, and Greg) from MDOT Transportation Service Centers that were responsible for the slide-in projects. The panel provided expectations or concerns related to respective slide-in projects and answered questions that followed.

As mentioned earlier, there are two projects in the Grand region that are: (1) US 131 over 3-mile road NB and SB: superstructure slide-in of two single-span structures, and (2) M-50 over I-96: a two-span structure slide-in project. Another slide-in project is: M-100 over the railroad.

US 131 NB and SB over 3-Mile Road Project

Two-lanes will be maintained on US 131 except in special situations. Uninterrupted traffic flow will be maintained on US 131 during the construction of the replacement bridge that is built on temporary supports adjacent to existing structure. One-lane will be maintained when the traffic is diverted off the freeway onto the new bridge. The traffic will remain on the new structure for a period of 5 days or less before the slide-in. Both the projects in Grand region are on high profile corridors. The major parameters leading to slide-in technology at these locations were the detour and Maintenance of Traffic (MOT) considerations.

M-50 over I-96 Project

The project involves a complete interchange reconstruction. This is a main intersection for the local community along with one of the largest Park & Ride Lots. The main goal of the project is to keep the traffic open to the extent possible. The new bridge will be built adjacent to existing bridge. Before the slide, the traffic will be diverted to the new bridge to demolish the old bridge, and construct the new substructure. MDOT TSC conducted the first public engagement meeting in November 2013 for this project and obtained a very positive response. The project required significant coordination with the public and emergency services. Developing and presenting animated videos of the slide-in process benefited the public outreach. From the public perspective, the mobility was the primary factor for the positive response. The bridge is planned to be maintained while other activities at the original alignment are completed, and then the bridge slide-in will be performed with a very minimal weekend closure.

M-100 over the Railroad Project

The site is in Potterville, MI. Currently; the project is in its design stages under MDOT's in house design team. The existing structure is a 3-span bridge with a total length of 155 ft and 70° skew. The site requires increasing underclearance. The new bridge will be a single span structure of around 107 ft long. The M-100 is not a high profile corridor. However, the bridge replacement project will be a significant impact to local community since the bridge connects a school and all the emergency services to Potterville. In this project, the planned detours are significantly longer. These constraints dictated the selection of slide-in technology for this project. The MOT scheme at this project is that the new bridge superstructure will be built on temporary supports and will be used to maintain traffic while the M-100 Bridge is demolished. After building new CIP abutments, the new bridge will be slid into place. MDOT is planning to perform the slide in a 6-hr window.

In all three slide-in projects, diverting traffic onto a new structure allows maintaining traffic on the same route during existing bridge demolition, pile driving, and substructure construction. In Michigan, common practice is to use piles for the bridge foundations.

JOHN ALMEIDA, AECON INFRASTRUCTURE GROUP INC., CANADA

The key points presented are the lessons learned from the contractors' perspective in performing ABC projects using SPMTs. Please use the presentation slides given in Appendix D while reviewing the information presented in this section. The presentation is a case study: HWY-417 Rapid Bridge Replacement (FHWA terminology for ABC).

Background

Highway 417 bridge, located in Ottawa, Ontario under the jurisdiction of the Ontario Ministry of Transportation, was replaced using SPMT technology. Two bridges located at Krikwood Avenue and two bridges located at Carling Avenue in Ottawa were originally constructed in 1959. After minor repairs and rehabilitation in 1983 and 2002, the Ontario Ministry of Transportation procured an $18M rehabilitation contract. Aecon Infrastructure Group, Inc. was the contracting agency for this project. The scope of work was (1) rapidly replacing four bridges, (2) widening of substructures to accommodate an extra traffic lane, (3) construction of four replacement bridges in an adjacent lay down areas, and (4) resurfacing of asphalt and site restoration.

Two discrete moves of two bridges included the following: Location 1 was replaced during July 6th to 7th, 2013, and Location 2 was replaced during 13th to 14th, 2013. Each new steel multi-girder bridge with a cast-in-place concrete slab weighed 400 t (440.90 ton or 881.85 kips). Aecon had 110 employees, at peak, working on this project. The contractor took the lessons learned from first weekend into the second weekend and improved the performance. To assure having sufficient stroke for the lift (at the final location), the contractor incorporated an SPMT system that had jacking in the carrier but also self-climbing towers that lift/drop in 6 in. increments. The SPMT moves enabled minimal traffic disruption to an estimated ADT of 136,000 compared to another project delivery alternative that was to stage the construction with long-term lane closures. In one case, two bridges were moved with a construction window of 14 hours (Saturday 6pm to Sunday 8am).

Moving the bridges is not time consuming in these types of projects, and proceeds relatively quickly. The time consuming activities are details such as backfill, time requires for asphalt to cool down to commence other operations, such as lane markings, placing barriers, guard rails, etc. The plan was to remove the existing superstructure using a set of SPMTs, transport, and place it on the temporary supports of the new superstructure while the new superstructure was supported on another set of SPMTs adjacent to the bridge site. However, the temporary supports were wider than the existing superstructure. A thorough investigation was performed to identify suitable modifications to the temporary substructure to shore the existing bridges. The details considered were the bearings, bearing distances, and differential elevations between the bearings.

The number and type of people required to make these kinds of jobs happen are critical. The lane closures are allowed only at night to perform the work. Several activities need to be performed, and detailed schedules need to be prepared prior to performing the work. The work includes: (1) pre-ABC procedures, (2) ABC procedures, and (3) post-ABC procedures. This work takes around 6 months from the contractors' perspective. The contracting community needs to check their courage based on the number of people they have and the number among those who will be willing to take a season of night work.

The Ontario Ministry of Transportation specified operational constraints are as follows: Close one lane at 5pm; full closure at 6pm (Saturday).

- Median lane in each direction open by 11am (Sunday); Lane 2 in each direction open by 12pm (Sunday)
- Remaining lanes and ramps open by 6am (Monday)
- Only base course asphalt required when the bridge is first opened to traffic.

Incentives and Disincentives

The incentives and disincentives typically tend to motivate contractors, but when things go wrong, they actually demotivate the contractors.

The following is a list of penalties or disincentives specified by the Ontario Ministry of Transportation:

- Penalty for early closure: An initial penalty of $1000, and thereafter a further penalty of $100 per minute for the time outside the permitted closure window that the traffic lanes are not open to traffic
- Penalty for late opening: On each occasion when the contractor fails to reopen the traffic lanes by the specified time, an initial penalty of $10,000. Then, if the traffic lanes are not open within next 15 minutes a further penalty of $1000, and thereafter, a further penalty of $100 per minute
- Total disincentives of $280,000 per weekend if the lanes are not opened to traffic according to the specified constraints.

The Ontario Ministry of Transportation incentivized the bridge move. The contractor can earn up to $80,000 as an incentive per weekend if the lanes are opened to traffic within the specified time window.

Planning

Detailed planning is required from start to completion. It is very important to select appropriate methodology, type of equipment, and workers with specific skills for the work to be performed. For example, identifying proper equipment, tools, and procedures for pavement marking when the asphalt is hot. Planning needs to include minute details such as installing transition rails at the approach that may require a temporary concrete barrier. Here it is crucial to identify the equipment and number of workers required for the job and at specific times. Although these details seem to be simple, these are the ones that will consume the time and may lead to crossing the construction time window.

Things can happen such as SPMTs failing due to bearing pressure or any other issue. These events are highly complex and require highly skilled workers to tackle them. It is very crucial to select appropriate specialty contractors and highly skilled crews.

Planning for pre-ABC work: At least six-months of non-stop detailed planning and work need to be performed. The planning was performed with *5-minute* milestones including if-else mitigation measures. Several field engineers, who are solely responsible to keep track of progress, need to be present on-site. In addition, strategic resource management of equipment and labor is essential. For example, it is important to choose rubber tired excavators as they are light, about 20 t (22.05 ton or 44.09 kips), fast, and leave a small footprint. They can be used on freshly placed asphalt; whereas, the track mounted equipment while excavating will rip-off the asphalt and may require padding, etc. In addition, details such as sufficient lighting on rubber tired equipment and a water truck to cool down asphalt need to be considered.

Geotechnical

The temporary supports located in the staging area shall have adequate bearing capacity to prevent any settlement. The Ontario Ministry of Transportation had a specification limiting the maximum differential settlement to 2 mm (0.079 in.) between two points in the temporary structure.

Concrete sill pads (precast blocks) or reinforced concrete footings were utilized to limit the settlements. After the project, the reinforced concrete footings are dug out and disposed. However, the concrete sill pads (part of a proprietary shoring system) are reusable. In general, the factored bearing capacity of the soil shall be twice the applied bearing pressure in the staging area (i.e., Factor of Safety of 2). During this project, the organic material at the staging area was removed and a granular base was placed to achieve the required baring capacity. The distributed load from the concrete sill pads (3.94ft × 3.94ft) and the granular base was adequate to limit temporary support settlement. Further, the granular base was critical for SPMT moves. The thickness of the granular base was calculated based on the loads from shoring and the SPMT moves, and the bearing capacity of the soil.

During the moves, at any given instance, the load from SPMTs was estimated to be 100 kPa (2.09 ksf). A 0.6 m (2 ft) thick granular base was laid on the move path to reduce the effective pressure on existing ground (i.e., from 100 kPa (2.09 ksf) to 40 kPa (0.84 ksf)). Lines for the move path were marked to direct SPMTs in planned path. Also, these lines aid in ensuring the SPMTs are traveling on sufficiently thick rolled plates and/or sufficiently covered utilities.

Frequent precision survey is critical. Double-checking is critical for the skew angles, bearing elevations, and span lengths. In addition, bearings were installed (using tie downs, friction clamps, etc.) on the bottom flange of the girder before the move. These processes ensure accurate elevations and proper placement of the structure.

The temporary shoring was selected considering the needs for controlling elevation differences and the existing bridge demolition. Note that the existing bridge needs to be demolished on the temporary shoring. However, this option is not cost effective in terms of the loads that temporary shoring needs to withstand during demolition. Another approach is to cut the old bridge on the temporary shoring, lifting, placing on the ground, and then demolishing it.

Sequence of Operations of the Ontario Projects

Three sets of 24 axle lines of SPMTs were used for the complete operation of two bridge moves at each location in Ottawa, Ontario. Detailed planning of SPMT moves was performed. It was necessary to consider the dimensions of existing and new bridges to prevent conflicts on the move path and in/out of the staging area. It is essential to keep in mind that all the operations involved in ABC are at nights or on the weekends.

Pre-ABC Lift Operations

The pre-ABC lift operations were completed in 3 weekends of lane closures. The following is a list of pre-ABC lift activities:

- Remove approach slabs and asphalt.
- Excavate backfill.
- Saw-cut and stabilize the abutment walls and/or backwalls.
- Backfill the existing abutment walls and/or backwalls including sub-drain installation and connection.
- Divert the sub-drain below.
- Place temporary hot mix asphalt.

Operations during ABC Lift

The ABC operation was completed on a weekend with full lane closure. The following is a list of ABC activities:

- Excavate backfill.
- Remove existing superstructure and transport to staging area.
- Transport new superstructure from staging area and erect to final position.
- Backfill with granular material.
- Place hot mix asphalt on structures (lanes and shoulders).
- Place hot mix asphalt on approaches.
- Install temporary concrete barriers.

The backfilling is a time consuming operation and a critical activity in the ABC window. A minimum amount of asphalt and backfill should be removed to assist bridge move because it will reduce the amount of post-ABC work on backfilling and pavement restoration. A prudent approach is to use marker tapes to demarcate the excavation area to prevent extensive excavation.

The saw-cutting of abutment walls is another critical activity. A highly skilled worker is required for this operation because a slight deviation in the cutting angle may lead to unintended damages to the structure as well as unsafe conditions. It is necessary to maintain accurate tolerances at the abutment location when the new structure is brought in. This is to ensure accurate grouting operation to connect the existing abutment with the new superstructure.

The Post-ABC Operations

The post-ABC lift operations were completed in 3 weekends of lane closures. The following is a list of post-ABC lift activities:

- Excavation
- Grading and placement of granular base for approach slabs
- Construction of approach slabs using rapid set concrete or precast approach slabs

- Placement of hot mix asphalt on approach slabs and on exterior portions of the structure (future lane 4 and shoulder)
- Placement of median barrier walls on approach slabs using rapid set concrete and embedded electrical work.

It should be understood that to perform a minute amount of work on a weekend at least 50 workers are required. Mangers need to ensure that the workers are available for all the weekends during construction duration.

Future of ABC in Ontario, Canada

ABC is becoming the standard practice on high ADT facilities due to less traffic disruption, grater public satisfaction, and cost and time savings.

A pilot project is being contemplated to move a rigid frame bridge. In this case, a new set of footings and pedestals are cast on top of old footings. The rigid frame that includes the superstructure and substructure is built in the staging area, moved onto the pedestals, and connected using a dry-fit mating process. The structure in this case is lifted via precast lifting pockets in the vertical members of the frame. Another pilot project is being contemplated to build the full structure including the footings in the staging area and moving to the final position. The new footings are pressure grouted and doweled into the existing footings at the final position. In these cases, the bridge may weigh up to 1400 t (1543.24 ton or 3086.47 kips).

FRIDO DE GREEF, PROCUREMENT MANAGER, MAMMOET USA INC.

This presentation describes procuring transport and lift solutions. The section presents information about the process and timing for dealing with specialty subcontractors such as Mammoet USA, Inc.

Background

Planning is the critical aspect for accomplishing successful ABC projects. It is also essential to communicate with a heavy lift or heavy haul contractor in early planning phase of an ABC project. A lack of detailed planning may lead to delay in the project as well as a financial loss.

It is important to indicate that there will be a shortage in available heavy lift/move equipment such as SPMTs during 2015 to 2020 due to a boom in the gas industry. An alternative to using SPMT is skidding.

For *clustered ABC projects* involving heavy lift/moving specialty subcontractors, about 25% of the project cost goes to the specialty subcontractors, and one-third of the specialty subcontractor's cost goes to mobilization and demobilization. Planning is essential to have reduced weight of the structure that requires less equipment that will lead to significant cost savings in terms of mobilization or demobilization costs.

Advantages of ABC from Mammoet Experience

Project managers at Mammoet save about 10% on their contracts' costs by implementing the concept of *"Planning it right and doing it right will save money."* Mammoet USA in Rosharon, TX moved to a 32000 ft^2, 1200 ton (2400 kips) office building consisting of 2 stories. This building, while being mostly furnished during the move, was moved into place using SPMTs. The facility was fully functional within 2 weeks of the move. During the move only a 2° (maximum limit) forward slant was allowed for the facility. The project resulted in 8-9% of savings in the project cost (including the transportation costs) because of implementing the SPMT move. Other benefits realized from the project were not requiring a temporary office site while the new structure was being built, and preventing extra liability due to construction exposure in limited space of the existing facility.

ABC Move Methods

The available technologies related to moving structures are divided into: (1) vertical methods, (2) horizontal methods, and (3) monitoring methods for movement/ stresses of structures. Considering the vertical move methods, the technologies available are the following:

- Cranes
- Tower Systems
  - Strand Jacks
  - Gantry Systems
- Jacking
  - Climbing Jacks
  - Titan Systems
  - JS 500

Considering the horizontal move methods, the technologies available are the following:

- Trailers
  - SPMTs
  - Conventional Trailers
- Skidding or slide
- Barging

In addition, various inexpensive monitoring technologies are utilized to ensure the bridge is moved or transported in a safe manner.

To explain the ABC move methods, we will consider an example project consisting of a bridge weighing 2500 tons (5000 kips) and located about 500 miles from a major equipment hub. In this example, the bridge is transported from land to a barge, and then at the final destination, the bridge will be lifted up 60 ft from the barge to its final position. For this project, available technologies and their associated costs are compared.

The following tables present the impact level on owner's budget associated with various parameters involved in respective move methods (based on Mammoet's previous projects):

Table 1 Vertical Move using Cranes

Parameters for Move methods \ **Impact on Owner's budget**	**Extremely high**	**Very strong**	**Strong**	**Moderate**	**Very low**
Typical required engineering hours			✓		
Training and experience level for engineers, operators, and support staff				✓	
Availability (2015 to 2020)		✓			
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)	✓				
Installation of specialty equipment		✓			
Speed of execution				✓	
Demolition possibilities				✓	
Rating for Overall Impact to Budget	**40 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when cranes are used in a project:

- Ground bearing pressure
- Lifting points
- Weight chart for respective cranes. This is essential as it shall be preplanned with respect to structure weight and any overweight because of lifting/placing radius.

Table 2 Vertical Move using Strand Jacks

Parameters for move methods \ **Impact on owner's budget**	**Extremely high**	**Very strong**	**Strong**	**Moderate**	**Very low**
Typical required engineering hours		✓			
Training and experience level for engineers, operators, and support staff	✓				
Availability (2015 to 2020)		✓			
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)				✓	
Installation of specialty equipment			✓		
Speed of execution			✓		
Demolition possibilities			✓		
Rating for Overall Impact to Budget	**36 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when Strand Jacks are used in a project:

- Ideal for limited access (hard to reach areas)
- Leads to extreme savings when implemented early in the design phase
- Mobilization and demobilization is very cheap: Each equipment weighs about 4 ton (8 kips), and 5 to 6 equipment can be transported on one truck without load permits.
- Computer controlled and has a *slow* lifting process. The process is not as fast as Cranes.
- Can be used for bridge removal. Additional equipment is not required for lifting or lowering the bridge. However, extreme engineering design is required.
- Stand jacks can lift a bridge about 3 ft in one stroke that takes about 10-12 minutes.

Table 3 Vertical Move using Multiple Strand Jacks per Tower

Impact on owner's budget / **Parameters for move methods**	**Extremely high**	**Very strong**	**Strong**	**Moderate**	**Very low**
Typical required engineering hours		✓			
Training and experience level for engineers, operators, and support staff	✓				
Availability (2015 to 2020)			✓		
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)				✓	
Installation of specialty equipment				✓	
Speed of execution			✓		
Demolition possibilities				✓	
Rating for Overall Impact to Budget	**42 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when implementing Multiple Strand Jacks per Tower in a project:

- Strand jacks with 100 ton (200 kips), 300 ton (600 kips), and 900 ton (1800 kips) capacities can be combined per tower.
- Hammer head tower design required for this technology is ideal for bridge projects.
- Use of electrical power is possible.
- Light load support cranes are needed for bringing the materials on to the tower.

Table 4 Vertical Move using Gantry Systems

Parameters for move methods \ Impact on owner's budget	Extremely high	Very strong	Strong	Moderate	Very low
Typical required engineering hours needed			✓		
Training and experience level for engineers, operators, and support staff			✓		
Availability (2015 to 2020)			✓		
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)				✓	
Installation of specialty equipment			✓		
Speed of execution			✓		
Demolition possibilities			✓		
Rating for Overall Impact to Budget	**44 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when Gantry Systems are used in a project:

- Requires extremely stable ground
- Capacity up to 1250 ton (2500 kips)
- Ideal for lighter deck removal with gantry-skidding beams mounted on girders
- Limited lift height
- Project with 3 or 4 hydraulic points only (not 2, or 5 or more) for lifting operation.

Table 5 Vertical Move using Climbing Jacks

Parameters for move methods \ Impact on owner's budget	Extremely high	Very strong	Strong	Moderate	Very low
Typical engineering hours needed			✓		
Training and experience level for engineers, operators, and support staff			✓		
Availability (2015 to 2020)				✓	
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)					✓
Installation of specialty equipment				✓	
Speed of execution		✓			
Demolition possibilities		✓			
Rating for Overall Impact to Budget	**46 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when Climbing Jacks are used in a project:

- Pressure points for both structure and support shall be well calculated and/or predictive.
- Height restricted: Can go up to 2-3 ft per stroke.

- Labor intensive and *slow*: Each stroke takes about 2-3 minutes based on the access to the jacks.
- Cheap for mobilization and demobilization
- Cheap in engineering
- Structural demolition is possible.
- Good quality of Jacking Wood that is used as bracing is crucial for safe operation.

Table 6 Vertical Move using Titan Systems Jacking

Impact on owner's budget / Parameters for move methods	Extremely high	Very strong	Strong	Moderate	Very low
Typical engineering hours needed			✓		
Training and experience level for engineers, operators, and support staff		✓			
Availability (2015 to 2020)				✓	
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)			✓		
Installation of specialty equipment			✓		
Speed of execution		✓			
Demolition possibilities			✓		
Rating for Overall Impact to Budget	**40 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when Titan Systems Jacking is used in a project:

- Ideal in combination with SPMTs
- Lift capacity up to 2400 ton (4800 kips)
- Extremely stable and support friendly.

Table 7 Vertical Move using JS 500 Jacking

Impact on owner's budget / Parameters for move methods	Extremely high	Very strong	Strong	Moderate	Very low
Typical engineering hours needed			✓		
Training and experience level for engineers, operators, and support staff			✓		
Availability (2015 to 2020)				✓	
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)		✓			
Installation of specialty equipment			✓		
Speed of execution		✓			
Demolition possibilities			✓		
Rating for Overall Impact to Budget	**40 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when JS 500 Jacking is used in a project:

- Ideal in combination with SPMTs
- Stable
- Computer controlled jacking: Differential tolerance of 4 mm (0.16 in.) can be achieved between the jacks.
- 500 ton per tower
- Lifting above 33 ft requires additional bracing.
- More fork lifts and labor are required to increase the speed, because the bracing blocks need to be moved on the JS 500s quickly for increased speed of the operation.
- Tie down to structure is required at temporary of fixed points.
- The technology shall to be considered during the design phase itself.

Table 8 Horizontal Move using SPMTs

Impact on owner's budget / **Parameters for move methods**	**Extremely high**	**Very strong**	**Strong**	**Moderate**	**Very low**
Typical engineering hours needed		✓			
Training and experience level for engineers, operators, and support staff		✓			
Availability (2015 to 2020)	✓				
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)	✓				
Installation of specialty equipment			✓		
Speed of execution				✓	
Demolition possibilities				✓	
Rating for Overall Impact to Budget	**34 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when SPMTs are used in a project:

- Ground bearing pressure: Steel plates are very essential for the move path.
- Extremely versatile
- Structural demolition is possible.
- Bracing between SPMTs and structure is extremely important.
- Air filled tires
- Capacity of about 30 ton (60 kips) per axle line
- 360° steering capability

- Titan system combination feasibility
- Hydraulic systems can be customized for 3 or 4 point set up.
- Spacers can be incorporated for cost savings. Spacers are 6-line bases that can take load similar to SPMTs, but do not have wheels. These can be used for staging areas and can save some money for mobilization/demobilization and equipment rental.

Table 9 Horizontal Move using Conventional Trailers

Parameters for move methods / **Impact on owner's budget**	**Extremely high**	**Very strong**	**Strong**	**Moderate**	**Very low**
Typical engineering hours needed			✓		
Training and experience level for engineers, operators, and support staff				✓	
Availability (2015 to 2020)				✓	
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)			✓		
Installation of specialty equipment			✓		
Speed of execution			✓		
Demolition possibilities			✓		
Rating for Overall Impact to Budget	**46 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when Conventional Trailers are used in a project:

- 10 ft wide (i.e., 2 ft wider than SPMT); therefore, more stable than SPMTs, if used as a single trailer
- May require load permits because of extra width. However in general, mobilization and demobilization for this technology is cheap as they are pulled behind the trucks. This technology will be much cheaper if equipment is available locally.
- Less steering possibilities in most conventional trailer types
- Different loading chart for different types and brands: These are more flexible than SPMTs.

Table 10 Horizontal Move using Skidding or Sliding

Parameters for move methods \ Impact on owner's budget	Extremely high	Very strong	Strong	Moderate	Very low
Typical engineering hours needed			✓		
Training and experience level for engineers, operators, and support staff			✓		
Availability (2015 to 2020)				✓	
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)					✓
Installation of specialty equipment				✓	
Speed of execution		✓			
Demolition possibilities			✓		
Rating for Overall Impact to Budget	**48 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when a Skidding or Sliding technique is used in a project:

- Great solution for value engineering: Very cheap way of moving
- It will be slower than other horizontal move methods.
- Push or pull points shall be strong enough.
- Combination/Installation with jacking is possible.
- Capacity ranges from 100 ton (200 kips) to 750 ton (1500 kips).
- If the new bridge cannot be constructed close enough and/or on the same elevation of the existing bridge, then the Skidding or Sliding technology may not be applicable.

Table 11 Horizontal Move using Barging

Parameters for move methods \ Impact on owner's budget	Extremely high	Very strong	Strong	Moderate	Very low
Typical engineering hours needed		✓			
Training and experience level for engineers, operators, and support staff		✓			
Availability (2015 to 2020)		✓			
Mobilization and Demobilization (Transport of specialty equipment to and from the project site)	✓				
Installation of specialty equipment				✓	
Speed of execution	✓				
Demolition possibilities		✓			
Rating for Overall Impact to Budget	**28 out of 100** (Note: low rating means least preferred)				

The following are the key considerations when Barging is used in a project:

- May be affected by weather related issues such as heavy rain and water level/current of the waterway.
- Additional equipment needed such as ballasting, winching, mooring, tugs, etc.
- Engineering is required on most additional equipment needed.
- Building a barge is very expensive and if rented, then the cost can be a minimum of $5000 a day.
- Deck load calculations considerably govern the type of barge being selected.
- Can be used for spacing between other barges.

Considerations related to move technologies

Installation of specialty equipment can significantly impact the general contractor's/owner's resources such as cranes, forklifts, etc., because of the required activities underneath the bridge and installation area.

Speed of implementing a particular move method is of concern as limited time is available with bridge replacement projects. Thus, the time frame shall be coordinated with the specialty contractor beforehand. Skidding is slower than SPMTs which are, in turn, slower than Cranes. However, detailed analysis of the work zone is required in positioning the crane and associated lifting and placing radii.

The possibility of using the same equipment for removal and installation needs to be considered. This may lead to major cost savings for the project.

Deployment of every 6 lines of SPMT requires one truck, and each truck requires $4-$5 per mile of transportation cost.

Heavy lifting crane deployment cost is proportional to the number of boom sections where each section requires one truck for transportation. Also required are load permits because of the heavier and wider sections. In this case, each truck requires $7-$8 per mile of transportation cost. Mammoet owns a few large cranes that require around 130 trucks for transportation.

Vertical move technologies, such as Climbing Jacks, require bracings for their operation. Usually, the specialty contractors try to avoid the use of bracings and such technologies to save cost. However for ABC projects, while using SPMTs, these jacks provide extra stroke for extra raising or lowering at the final position or staging area. Therefore, this aspect shall be properly communicated beforehand with the heavy lift/haul subcontractor so that they can preplan to provide sufficient bracings for this technology. For example, they can decide to use Climbing Jacks instead of specialized frames for falsework to reduce cost.

Ground surveys and geotechnical surveys are extremely important and require experienced personnel. Generally, specialty subcontractors have their own staff for these activities.

Specialty subcontractors such as Mammoet are best included during the early design phases. This will allow them to provide recommendations for the type of move method applicable for a particular project. This can save 1%-1.5% of the project cost and will ensure that all means and methods are adequately planned.

Monitoring

The following are the typical technologies used in structural monitoring during bridge moves:

- Load cells range from 5 ton (10 kips) to 750 ton (1500 kips) are used to identify the load imposed on the structure, such as due to jacks.
- Lasers are used for measuring and/or comparing distance.
- Strain gauges are used for measuring strain; thus, stresses.
- Pressure indicators are used for measuring hydraulic cylinder pressure.

Mammoet has software developed for monitoring special projects. Also, a generic software is available. Threshold for warnings can be set based on parameters indicated by the engineer or the owner.

Removal of Existing Structures

It is essential for the owner/DOT to evaluate methods for removing/demolishing existing structures. Major cost incurred to heavy lifting/moving subcontractors is mobilization and demobilization. Using the same heavy lifting equipment for removal of an existing structure and placing a new structure will lead to cost savings. In addition, it is necessary to identify the extent of deterioration of structural members, weight and center of gravity of the existing structure before implementing any move technology for removal. Cost savings can be realized when the structure is lowered to a manageable height for demolition.

Extreme consideration must be given for prediction capabilities while using explosives for demolition. Alternatives to using explosives must be investigated, such as cutting the structure and moving for safe demolition.

Procuring ABC Lifting and Transportation Solution

"Procuring any lift and transport solution is not about how to get the cheapest solution; it is about how your procurement will fit best in the entire project." Lifting and transportation costs can account up to 2%-3% of the project cost. Proper communication is needed between the DOT and the heavy lift/move subcontractor about the potential means and methods. The owner's/DOT's plans on the *"procurement"* aspect at the inception of the project will define clear expectations. The engineer can define the need for bracing, falsework, lifting and loading points. In addition, involving the heavy lift/move subcontractor early in the design phase will be beneficial. From the specialty subcontractor's perspective, the overall project cost will increase without using modern technology or transportation methods.

Savings of up to 20% to 30% of specialty subcontractor's contract value can be achieved by implementing the following practices:

- Reviewing method of lift and/or transport by specialized engineers
- Designing support and lifting points during the early stages of engineering

- Constructing the structure as low to ground as possible with sufficient space for transportation or lifting access
- Combining removal and installation of structures using same equipment
- Involving lifting/ transportation contractor during the design phase
- Providing bracings between Structure, Barges, SPMTs, Jacks, etc. Bracings are extremely crucial aspect for a structure move.

In addition to achieving the best possible cost, the following need to be avoided:

- Adding extra weight at the last moment. This requires bringing extra equipment, engineering staff, etc.
- Falsework such as containers for staging area: The containers need to be tested, certified, and approved by the lifting contractor.
- Custom made rigging, towers, etc. This is because the construction work as well as activities for moving operations are performed around these structures, and thus, requires engineering.
- Extreme deadlines. These may lead to extra labor cost, especially if the deadlines are communicated very late to the specialty subcontractor.

To ensure good quality of the project the following practices shall be ensured:

- Education and experience needs to be documented for all employees involved in preparation and execution of the project such as, training, testing, certification of employees, etc.
- Safety shall not be reactive but pro-active in terms of training, pre-employment and random drug screening, kick off, toolbox, and lessons learned meetings.
- Having a good contingency plan that takes into consideration aspects such as, equipment maintenance and repairs according to guidelines of manufacturers, spare part management, documentation and certification
- Communications during entire project through available and clear lines: Appropriate engineers shall be communicating with each other and following up regularly during the entire project duration.

BRENT ARCHIBALD, DELCAN INC., CANADA

Delcan Inc. is a Canadian design and consulting firm with its head office in Toronto, Ontario. Please use the presentation slides given in Appendix D while reviewing the information presented in this section.

Ontario is slowly starting to adapt the ABC blueprint from its neighbors. The main driver for ABC in Ontario has predominantly been durability and quality control issues with cast-in-place projects. This led to a wide use of precast components with field cast joints using ultra-high performance concrete. The Ontario Ministry of Transportation had performed a handful of accelerated replacement projects, but still they are trying to figure out how ABC fits in with their program.

In Canada, bridge sliding is not a new initiative. On Oct 20, 1957 a 3000 t (3306.93 ton or 6613.87 kips) truss was laterally slid into position when the bridge clearance was increased over the St. Lawrence Seaway in Montreal, Quebec. This project illustrates that even without ABC initiatives the construction industry has been greatly involved in bringing forth these ideas to fruition and demonstrating the economic benefits.

Three slide-in project details will be discussed. The projects are:

- Dundas Street Bridge (lateral slide),
- Don Valley Parkway Underpass (jacking and mining), and
- West Toronto Diamond (lateral slide).

The major constraints that led to the implementation of slide-in technology were: (1) maintenance of traffic, (2) maintenance of utilities, and (3) interference of existing transportation structures and buildings.

Dundas Street Bridge Project

The Dundas Street Bridge is a 3-span continuous box-girder bridge located in Trenton, Ontario. The bridge is 600 ft long and weighs 3000 t (3306.93 ton or 6613.87 kips). Interestingly, the weight of Dundas Street Bridge was same as the truss weight that was laterally slid during the St. Lawrence Seaway project in 1957. Additionally, the inspiration to perform a lateral slide for Dundas Street Bridge project was taken from

Qauibrucke Bridge in Switzerland. For the Qauibrucke Bridge project, a 4000 t (4409 ton or 8818.5 kips) multi-span new bridge was constructed adjacent to existing 3800 t (4189 ton or 8377.6 kips) bridge, and both bridges were slid together in a 54 hour slide-in operation in 1984. The bridge deck carried traffic lanes as well as light rail tracks. The Qauibrucke Bridge was constructed by VSL Heavy Lifting Inc., who was involved in the sliding of several major and complex structures in Europe. Therefore, Delcan Inc. developed a relationship with VSL Heavy Lifting Inc., to understand detail aspects of a slide-in process to be applied on Dundas Street Bridge.

In 1990, the Dundas Street Bridge was slid laterally 10 m (33 ft) in 4 hour slide-in operation. This was the first lateral slide of a multi-span bridge in North America. It was completed as a conventional design-bid-build project, and the details for slide-in were included in the contract documents. VSL Heavy Lifting Inc. was identified as the preapproved slide-in sub-contractor to be retained by the general contractor. The total duration of the roadway closure was 8 days. The project reduced social costs as well as business losses inherent with conventional staged construction.

The new bridge was built adjacent to the existing bridge while maintaining traffic on the old bridge. Once the new bridge construction was complete, the traffic was diverted on to the new bridge. Then the old bridge was demolished and removed. Afterwards, the substructures and jacking paths were constructed for the original alignment of the bridge. Finally, the bridge was laterally slid into its final position.

The bridge, being 3-span, was slid using 4 jacking tracks on each line of support (2 on piers and 2 on abutments). The abutments utilized a single strand jack arrangement, and the piers utilized double strand jack arrangement. This was because of the extra load at the mid-span. A central computer control station was set up on the mid-span of the structure to allow for single point control of the jacking operations. The jacks used for the operation were double-acting plunger type jacks capable of developing a safe load of 70 t (77.16 ton or 154.32 kips).

Each slide-in unit consisted of a structural steel track beam supported on the RC substructure (fully closed bents or piers). A series of Teflon laminated neoprene steel reinforced pads were set on the steel track beams with the Teflon facing upwards. Welded steel carriages with stainless steel bottoms were placed on top of the Teflon pads. The permanent bearings of the bridge were laid on the welded steel carriages, and the bridge was slid along with the carriages. Typical pot bearings were used, and there were provisions for locking up the bearings and for providing lateral restrain to the structure during the slide-in operation. The bridge was slid at an average rate of 2.4 m (7.87 ft) per hour. The slide-in movement was monitored using CCTV cameras. There were scales attached on the slide path to notify the operator about the progress of side-in movement. The friction that was observed during the slide-in operation was 1-2%; this was when the bridge was in continuous movement. Synchronous control of the hydraulic system by computer was implemented to shut down the system automatically if any element malfunctioned or if displacements between the substructures exceeded the allowable limit. The system was also programmed to stop every 20 mm (0.79 in.) of sliding for checking. In addition, short stroke pushing jacks were used in combination with pulling jacks to overcome the initial braking friction.

Once the bridge was in its final position, the substructure was completed and the slide path was encased in concrete leaving the permanent bearings exposed. In the meantime, expansion joints were installed, concrete backwalls were cast, and the roadway transition was completed. The total duration for all the aforementioned work was around 8 days.

Don Valley Parkway (DVP) Underpass Project

The DVP underpass consisted of a new arch tunnel through an existing railroad embankment. Delcan proposed the unique method of jacking and mining to advance the structure underneath the railroad. The inspiration for DVP underpass project was acquired from other projects performed by Cementation Inc., a United Kingdom based Construction Company. Cementation Inc, was heavily involved with jacking and mining short tunnels through embankments. Another inspiring project at that time was the Bochum underpass project located in Germany. This project was a twin cell concrete box structure, which was encased in a concrete shield and jacked under 5 electrified railway lines using the jacking and mining operation. Three slide paths were utilized under the main structural walls of the structure. At the final position, the structure had 3-4 m (9.84-13.12 ft) of overburden of the embankment.

The DVP underpass project was a single cell tunnel structure weighing approximately 2000 t (2204.62 ton or 4409.25 kips). The project was located immediately adjacent to a major expressway and underneath a railroad in Toronto, Ontario. In 1989, the structure was successfully jacked 30 m (98 ft) into its final position. The jacking and mining were simultaneous operations. The jacking and mining operation took 11 days. The project was successful in terms of minimizing impact to the railroad operation and preventing settlement of the railway tracks. In addition, the expressway traffic and the existing adjacent expressway tunnels were not impacted. The project was completed 6 months ahead of schedule. This project introduced the simultaneous jacking and mining technology to North America for sliding bridges.

The single cell tunnel structure was constructed adjacent to the embankment. The embankment was cut as much as possible to minimize the jacking and mining operation. A railroad protection headwall was installed at the starting location of the jacking and mining operation. The tunnel structure consisted of a steel cutting shield at the front and two arch units: a leading unit and a trailing unit. There was an intermediate jacking station located in between those two arch units. The intermediate jacking allowed for the jacking to proceed without requiring excessive jacking forces and also enabled steering of the structure during the operation. The structure was constructed on a thrust base that was the main reactionary element used to advance the structure. Plastic sheeting between the thrust base and tunnel was provided to reduce the sliding friction. A jacking frame was used for advancing the tunnel using the reactionary force from the thrust base. The jacking frame was advanced along the thrust base in increments as the tunnel was advanced. A total of 4000 t (4409.25 ton or 8818.5 kips) of jacking force was applied to the jacking frame.

Rubber sheeting was provided on the roof of the excavated portion of soil and was advanced as the excavation and tunnel sliding progressed. This was to allow interaction between the rubber and concrete, which generates less frictional forces compared to soil-concrete interaction. In addition, the top surface of the tunnel was painted with high gloss paint, and other materials were injected to minimize the sliding friction.

Once the structure was at its final position, the steel cutting shield was removed and a cast-in-place concrete section was added to the front of the tunnel.

The construction sequence included the following:

- Install struts supporting the railroad protection headwall.
- Construct the thrust base.
- Install plastic sheeting between the thrust base and tunnel.
- Cast the tunnel.
- Integrate the steel cutting shield into the tunnel.
- Complete structure in pre-slide position.
- Install the intermediate jacking station.
- Install the jacking frame.
- Advance the tunnel combining the mining operation.

It is important to note that not every project requiring a roadway tunnel under a railroad can be performed using slide-in technology. For example, the Dufferin Underpass in downtown Toronto, after several attempts in planning for slide-in operation, was deemed to be very complex. Hence, the underpass was constructed using conventional staged construction. The structure was a two-cell tunnel structure that was expected to be connected to a T-intersection to make Dufferin Street a continuous roadway, where a railroad with 8 tracks was passing over. The structure could have slid under the railway tracks. The limiting constraint was getting the structure to ultimately carry the existing bridges at the end of the embankment. This was deemed to be risky due to insufficient geometric control.

West Toronto Diamond Project

The project site is one of the busiest railway intersections in Canada, and it is located within one of the oldest parts of the city. The project consisted of separating a railway freight corridor from a public transit railroad. The project consisted of 4 prestressed slab bridges that were post-tensioned together to form a large slab structure. Two bridges (NOTO) were 1800 t (1984.16 ton or 3968.32 kips) each, and the other two bridges (OWR) were 4500 t (4960.40 ton or 9920.08 kips) each. This site was identified as a suitable candidate for slide-in after evaluating site constraints. The NOTO bridges needed to be slid 28 m (92 ft) with 24 hr track possession (on a long weekend), and the OWR bridges needed to be slid 80 m (262 ft) with 40 hr track possession. One of NOTO bridges and one of OWR bridges were moved in 2013, and the remaining bridges are scheduled for 2014. The NOTO bridge was slid in to its final position in 2 hours while the OWR bridge was slid in 6 hours. These projects were successful in terms of minimizing the interference with rail traffic, and eliminating the need for track diversion and railway infrastructure/ property relocation.

Early on in the project, Delcan Inc. had discussions with VSL Heavy Lifting Inc., regarding the material and technology that shall be implemented for the project. Based on the experience and lessons learned from the Dundas Street Bridge project, Delcan realized that one of the key issues that needed to be addressed was to implement a system that allows moving the bridges within the permissible time frame of the railway. Thus, a system was required with fast sliding operation and minimal work required afterwards for fixing the bridge in its final position. A feasible solution was to implement a continuous sliding operation using Tandem jacks that provide an estimated rate of 20 m (65 ft) per hour, compared to conventional single jack that provides a rate of 10-12 m (33-40 ft) per hour. The central jacking operation control unit incorporated modern technology. HSL strand jacks of 200 t capacity (220.5 ton or 440.9 kips) were used with the Smart Cylinder control program allowing overload limits and synchronization parameters. Each jack had linear encounter allowing a computer to adjust the cylinders in real time and keep the distance travelled uniform regardless of differences in load in each jack. A millimeter level tolerance is specified by the strand jack manufacturer. However, this tolerance limit was not achievable at all stages of the project because of the strand/tendon release effect that initially overcomes the braking friction. Overall, the jacking was simpler than the Dundas Street Bridge project, because the slabs were simply supported and stiffer.

In addition, to prevent subsequent jacking forces (pushing and pulling) and any immediate work on slide path after the slide, the path was incorporated on top of a permanent wall and permanent bearings were incorporated in the sliding surface. The sliding surface comprised of bronze on steel with an estimated braking friction of 15% (i.e., static) and sliding friction of 8% (i.e., dynamic). The bearings consisted of top and bottom steel plate and an external steel plate that had bronze surface on the other side to slide on the slide path. These materials gave a suitable friction coefficient and acceptable materials for the slide path. Two guided bearings were provided on one slide path at the front and rear ends of each structure.

The slide path consisted of a series of steel plates, each approximately 8 ft long, permanently anchored on top of the permanent wall on the post-slide location. However, on the pre-slide location, the steel plates were temporarily anchored using anchors and custom bushings to facilitate removal and reuse of the plates in other slide projects. The plates were machined to a very tight tolerance. Also, a tight tolerance was stipulated for the slide path.

An alternate sub-contractor with experience in heavy lifting was selected for the sliding operation. That contractor offered to perform a full-scale slide test of one of the bearings in order to determine the friction due to different types of lubrication. The shop trial was setup with a single jack and single bearing with an estimated superimposed weight to be carried by the steel plate. The contractor demonstrated that the friction values were lower with a greased slide surface compared to an oiled slide surface. Thus, grease was selected for lubricating the slide path.

In order to provide additional assurance to the railway, 5 m (16 ft) test slides were performed for each of the actual bridges a week ahead to the actual slide. The bridges were constructed sufficiently away to allow for these test slides. The existing railway tracks were supported on temporary structures to allow for slide path construction and tendon for sliding. The bridges were slid with the railway ballast in place to reduce the work time after slide operation. The entire slide operation was successful. Only a few corrections were required mainly at the initial startup of the slide operation.

The tendons remained stationary for the entire sliding operation. The tendons were passed through the slab, and the slab was pushed with jacks being guided and supported by the tendon. The slide-in operation was successful in limiting the overall relative displacement between the two jacking paths to 2 mm (0.079 in.). It should be noted that the slide-in operation was relatively quick and completed within 2 hrs out of 24 hrs of railroad possession. The rest of the time was attributed to removal of the temporary structures and work that were required for slide-in operation. One of the key operations that needed to be complete before the bridges were opened to traffic was to anchor the bearings following the slide operation. The slide path was provided with holes for anchoring the bearings in the final position of the bridge.

KENNETH PRICE, HNTB INC., USA

This section will provide details on sliding and launching that have a potential for implementation on a typical highway or at grade separation. Please use the presentation slides given in Appendix D while reviewing the information presented in this section.

There is a potential for creativity in combining the construction methods/technologies such as floating, launching, sliding, jacking, and lifting, to address the contemporary challenges of mobility and constructability. In addition, there is no limit or constraint on the extent of combining those methods/technologies, and of collaborating among the owners, consultants and contractors to address the challenges.

Sliding Technology

The project discussed here is the reconstruction of Jamaica and Hillside Avenue Bridges over Van Wyck Expressway, a busy expressway leading to JFK International Airport in New York City.

The two bridges were in very close proximity to each other over Van Wyck Expressway. The bridges were slid-out and slid-in simultaneously. This project was completed few years ago and was the first slide-in-slide-out in the U.S. This project was a prototype of the slide-in technology implemented on a two-span bridge in Switzerland.

It should be noted that when a project is identified as feasible for slide-in technology implementation, and an opportunity exists to relocate the substructure, then the opportunity needs to be exercised. This will generate several benefits and prevent new substructure construction interfering with the existing bridge. However, for this project, it was impossible to relocate the substructure. Thus, to demolish the existing bent and reconstruct a new bent, temporary double bents (i.e., temporary bents on either side of existing bent) were utilized at the mid-span of the bridge. Another issue with this project was that the bridges needed to be slid-in at higher elevation and lowered to final elevation. This was because of existing utilities, extensive fiber-optic cables, and critical communication lines that could not be interrupted. Conventional Hilman Roller technology was utilized for the process.

In Europe, stainless steel and Teflon with a very low coefficient of friction are being used for sliding operations. The coefficients of friction (static and dynamic) are critical estimates as they define the required jacking hydraulics for mobilizing the structure. Sliding a multi-span structure introduces additional complications such as the structure needs to be aligned, needs to be guided, and requires more precise operation than sliding a single span structure.

Launching Technology

The incremental launching concept comes from segmental concrete industry. If a bridge project has site constraints, such as short spans and very difficult access, typically the launching technology is considered as the solution. However, this technology can be shrunk down to small scale for typical grade separation bridges including one or two span structures.

A simple cast-in-place post-tensioned structure with launching technology is ideal for reconstructing a bridge over a very busy railway that limits access to cranes, opposes interruption to railway traffic, and has high risk/safety considerations. Concrete bridges with spans up to 80 ft can be launched conveniently without a nose or with a very small launching nose and without temporary piers. However, a typical steel launching nose is required for bridges with spans over 80 ft along with temporary piers. In addition, a king post and stays are included for spans up to 210 ft. Bridges have been successfully launched up to 4500 ft (0.85 mile) in length. In these cases, the projects had extensive demands and considerations. However, when the spans get longer new challenges are introduced.

Generally, post-tensioning of the structure in the longitudinal direction is required for implementing launching technology. In addition, it is essential for the launching nose design to accommodate/limit the stresses on the structure due to the cantilever moment. The length of launching nose can be up to half-a-span; however, the launching noses can be designed very short, provided the span is designed to accommodate large deflections and accommodate an angle of curvature and deflection within limits at the landing point.

In these cases a “rocker” (i.e., a temporary bearing at pier location) can be utilized, on which the curved launching nose is landed, rolled up and rotated onto the piers.

The hydraulic jacks required for launching technology are readily available. Design of launching track, launching bearing, and hydraulics is readily available and is not required these days. Bridges with complex geometry, such as a horizontal and vertical curvature, can also be replaced using launching technology. However, the curvature needs to be circular instead of a second order parabolic shape. Implementing launching technology on spiral geometry bridges and varying-width deck bridges is also possible by using wider launch bearings.

The replacement of the Belleaire Causeway in Florida is an example of a smaller span bridge project that utilized launching technology. The bridge was basically on a sand island with a movable structure at one end and a channel at the other end. The proposed structure was at a higher elevation bridge to be built adjacent to an existing structure for minimizing interruption to traffic and simultaneously eliminating the movable structure. The owner, designer, and contractor decided to launch the end spans of the bridge. This was because at one end of the bridge, the draft that was immediately adjacent to the sand island was insufficient to accommodate barges, cranes, and workspace. The other end of the bridge was over a busy recreational area, and the existing parking facilities in that area could not be compromised for construction workspace.

A short launching nose that was one-half of the launching span was utilized. On one end of the bridge, the casting and launching bed had restricted space; thus, the contractor was limited to assembling one-half of the span at a time. A temporary pier was built at the center span. In the first stage, the launching nose with half of the structure was slid to the temporary piers using the launching jacks at the End Bent of the structure. In the second stage, the half-span structure was launched forward to the extent that the remaining half-span could be accommodated on the casting and launching bed. Then, the third stage and fourth stage followed to complete the launching process of that span.

BALA SIVAKUMAR, SHRP-02 R04, HNTB INC., USA

The Rapid Renewal Project (SHRP-02 R04) has been ongoing from last 6 years (2008-2013) and is at the concluding stage. The Strategic Highway Research Program (SHRP)-02 had four different focus areas; R04 is the renewal area that focuses on "*reducing congestion through incident reduction, management, response, and mitigation.*" This section presents the findings from that project as presented by Bala Sivakumar, the vice president of HNTB Inc. and the Principal Investigator of the R04 project. Please use the presentation slides given in Appendix D while reviewing the information presented in this section.

The main goal of the R04 project was *"to develop standardized approaches to designing and constructing complete bridge systems that address rapid renewal needs."* This is to address the replacement of typical highway bridges, also known as "workhorse" or "bread-and-butter" bridges. These bridges can be standardized to a point where new design may not be required for replacement. The means and methods are required to be considered for an ABC project. In ABC design, the owner considers and stipulates a majority of the means and methods that a contractor would undertake in a conventional project, such as demolition drawing, erection drawing, schematics of temporary works, etc. In a nutshell, the complete ABC process is laid out by the owner prior to bidding, including the construction process. This is the key difference between ABC and traditional CIP construction.

PBES can be classified as the foundation technology for ABC. PBES has been used for a long time, since around 1960's. The R04 project was not about to reinvent ABC; rather, it considered current impediments to the use of ABC. Then, solutions were derived to take successful technologies and make them mainstream in terms of design and replacement processes. The ABC toolkit guides the project designers in such a way that ABC design will not be different compared to designing conventional bridges in the past; however, minor differences exist and are highlighted in the report.

In this project, innovative designs were developed for replacing bridges in an accelerated manner. The initial focus was on PBES bridges, and then the project was extended to slide-in bridge projects. The project report presents all the research that was performed during the 6-year project duration. In addition, the report presents summaries of more than 200 ABC projects including the concepts in the U.S. and Europe. The project did not include SPMT as numerous documents were already available through FHWA and Utah DOT. The primary deliverable of the project is the ABC Toolkit that has been published. The toolkit includes design concepts with examples and sample specifications to guide the ABC novices to start. Using the toolkit, the designer will be able to easily complete an ABC design for a routine bridge replacement project. It shall be noted that the task of making ABC as a standard practice starts from the policy framework. The ABC toolkit appears in the task as the progress is made towards ABC implementation.

The R04 project also assembled design standards and specifications that include guideline drawings. In addition, ABC demonstration projects were completed to prove that the details presented in the toolkit are buildable. The essential components of the ABC toolkit are the following:

- ABC standard design concepts
- ABC erection concepts
- ABC design examples
- ABC design specifications (LRFD): These are recommended modifications to AASHTO LRFD so that it can better support ABC.
- ABC construction specifications: These construction specifications provide some key aspects that need to be considered while executing an ABC project.

As mentioned earlier, the focus of the toolkit is on PBES and slide-in for typical highway bridges. Another goal of the toolkit is to provide necessary resources for the owner to design ABC bridges. This provides the opportunity for the local contractors to compete on these projects and to self-perform the work to the extent possible. Every prefabricated element in the toolkit can be self-performed by a contractor with the exception of prestressed elements that require a certified precaster. The elements are simple to fabricate and easy to erect using conventional equipment. Some of the durable connection details are also included in the toolkit. All the details in the toolkit are meant for bridges that can be built over a weekend or no more than 1 to 2 weeks.

The toolkit includes conceptual drawings for the following PBES:

- Decked steel girders: Nonproprietary details, that a contractor can self-perform and use UHPC or rapid-set mix for connections.
- Decked concrete girders: Prestressed deck bulb-tee and double-tee (NEXT beam) modules.
- Abutments and wingwalls: Semi integral abutments, integral abutments, wingwalls, pile foundations, and spread footings.
- Piers: Precast conventional pier, precast straddle bent, drilled shaft and spread footing options.

It is important to note that the substructure construction takes the longest duration in ABC projects. Use of prefabricated substructure elements is an important part in ABC. However, the weight of precast substructure elements possesses shipping and handling challenges. Other time consuming activities include installing bearings and expansion joints. Eliminating bearings and approach joints from a bridge construction project can provide a better, more durable, and faster bridge. The semi-integral or integral bridges allow eliminating the bearings partially or completely, respectively. Using these abutments and piers, a bridge can be built in a day by eliminating extra (half-a-day or more) work required for installing bearings and approach joints.

With a semi-integral abutment, a suspended backwall is used to provide excellent fit-out tolerances in a very short duration. However, elastomeric bearings are required to allow for backwall movement to accommodate expansion. The abutment pile cap is essentially placed on top of the H-piles and filled with self-consolidating concrete. The integral abutment does not require bearing, but a grout pad is placed on dowels and grouted. In this case, the approach slab is supported on the backwall and requires a joint. It is preferred to move that joint to the end of the approach slab (i.e., at the sleeper slab location) so that all joints are moved away from the bridge. Approach slabs that are supported on ground require long construction time. Precasting the approach slabs and sliding them with the main-span can accelerate the construction.

For piers, there are two concepts: (i) conventional pier with cantilever bent cap, and (ii) straddle bent. The straddle bents are preferred because new bridges are commonly wider than the old bridges, and straddle bents allow using drilled-shafts/piles and constructing foundations outside the footprint of existing bridge.

The research decided that all superstructures considered in the toolkit will be designed simple spans for dead load, continuous for live load, and without open joints. The project investigated simple/ continuous span from 40 ft to 130 ft and grouped the plans in the span ranges of: (i) 40 ft to 70 ft, (ii) 70 ft to 100 ft, and (iii) 100 ft to 130 ft. The designs were standardized within these groups. The elements within these span ranges weighed less than 200 kips and were able to be conveniently shipped and erected in one piece using conventional equipment. The weight of 200 kips was identified as the optimal for shipping and handling/erecting with conventional equipment. If 200 kips weight limit is exceeded, then the contractors need to deploy heavy lifting equipment; also, shipping the component becomes challenging requiring permits. This will drastically increase the cost.

A challenge for most designers is to design the erection concepts for PBES. To overcome this challenge, the designer should understand the site and contractor's capabilities. This requires sufficient planning time to evaluate the site and communicate with the contractors beforehand. The toolkit provides erection drawings (detailed erection plans) for the contractor to erect the PBES using conventional cranes. In addition, guidance is provided if the erection requires technologies adapted from long span construction. The toolkit also provides different crane placement and erection scenarios for typical bridge projects. It is essential to be familiar with different types of cranes available for ABC. This helps selecting an appropriate crane for erection based on the site conditions.

"The designer earns his money by thinking through the constructability of the bridge, not the design that is already available." The toolkit provides constructability analysis considering conventional crane based erection. The factors that are considered during the analysis are: (1) weight of a prefabricated element, (2) pick radius, (3) crane set up

locations, (4) ground access/ barge/ causeway/ work trestle, and (5) truck access for delivery. The constructability analysis is recommended to be performed by laying out the site plan including all the crane locations and access options. This leads to the ABC cost estimation and schedule, as the owner already decided the means and methods for the project. These aspects of ABC are very time consuming and need to be considered during the design phase.

In most cases, construction from below (ground) is expensive and time consuming. This difficulty arises in projects dealing with interstate expressways or railroads as the feature intersected. Thus, to address this issue, the toolkit considered the following ABC technologies that allow construction from above:

- Above deck driven carriers: These are beneficial on sites with limited ROW. However, they are cost effective for bridges with 10 to 15 spans but not for bridges with 1 or 2 spans.
- Launched temporary bridge (LTB): These are beneficial in environmentally sensitive areas or any restricted area that prevents a crane to be placed on the ground. The LTBs increase the possibility of erecting longer spans. They are launched across or lifted over a span to act as a temporary bridge and can be used to deliver heavy prefabricated elements without inducing large erection stresses. The temporary bridge can also support transverse gantry frames.
- Transverse gantry frames: This includes gantry girders on either sides of the bridge and on which the gantry moves. The gantry then moves back and forth to pick the old span out and install the new span.
- Longitudinal gantry frames: This includes two SPMTs with a long longitudinal gantry truss that lifts the old span and moves it out, and the new span is moved in and installed in a sequence. The gantry carries two spans at the same time.
- Regular cranes with sufficient reach.

In ABC, three designs need to be prepared for a bridge project: one is final bridge design in its final alignment/construction (similar to conventional bridge); the second design is when the bridge is being fabricated; and the third design is when the bridge is being lifted and erected in place. Each of the designs have different loading and stress requirements.

Most of the time, the governing design may not be the final bridge design but the design including lifting and erection conditions.

The toolkit provides sample drawings for ABC. The drawings show typical level of detail. The plan sheets contain ABC specific details for routine bridges. These drawings guide a novice ABC designer on appropriate module configurations, connections, and erection. It should be noted that the engineer of record (EOR) is the designer not the ABC toolkit. The EOR can take guideline drawings from the toolkit and perform his/her own design and make sure that it is adequate for a particular bridge. Limit states shall be considered in the design for the following stages: (1) prefabrication process, (2) shipping process, (3) erection process, and (4) final as-built state of the bridge.

In ABC, the lowest bid is not a goal. Saving cost by avoiding stringers, etc., is not a good design. Rather the design focus needs to be achieving an optimal configuration, with both size and weight, suitable for shipping and erection. Designing a configuration suitable for prefabrication, shipping, and erection processes will provide a best bid in ABC.

In prestressed concrete design, the release is usually checked. In ABC, additional checks are required for stresses/deflections during shipping and handling. This is because heavier and longer girders are considered. In addition, camber and deflections need to be checked at release, erection, and final as-built state. The design needs to specify the time duration the girders are allowed to be in the staging area or prefabrication yard before erecting. Also, the schedule for fabrication, curing, and transporting the elements needs to be specified.

The recommended LRFD specifications for ABC are the following:

- Loads and load combinations
- Construction load cases and erection stresses
- Design of connections
- Design responsibility – EOR/ Contractor’s engineer
- Prefabrication tolerances, quality, and rideability
- Assembly plans.

Geometry and tolerances are a high priority in PBES design in the toolkit. The loads specified for the ABC design are the following:

- Loads associated with support conditions during fabrication that may be different than permanent supports
- Loads associated with member orientation during prefabrication
- Loads associated with suggested lift points
- Load associated with impact considerations for shipping and handling of components
- Loads associated with camber leveling.

It is important to indicate that the prefabricator should not assume that the designer has all the responsibility for specifying the tolerances and camber. The prefabricator needs to work with the designer to achieve the proper tolerances and camber. This is the key issue while dealing with PBES, especially on prestressed elements. In ABC projects, the DOT needs to enforce the requirement for the prefabricator that the designer and prefabricator shall work together to achieve proper tolerances and camber.

The design examples in the toolkit are organized in the following sections:

- General
  - Design philosophy
  - Design criteria
  - Material properties
  - Load combinations
- Girder design
  - Flexural strength checks
  - Flexural service checks
  - Shear strength
  - Fatigue limit states
- Deck design
  - Flexural strength check
  - Deck reinforcing design
  - Deck overhang design

- Continuity design
  - Compression splice
  - Closure pours design

The following special PBES construction specifications sections are recommended for LRFD in the toolkit:

- General
- Responsibilities: This deals with handling the responsibility for the system that gets designed in multiple arenas such as design office, contractor's engineer office, specialty contractor office.
- Materials
- Fabrication: In ABC, bridges are being built partly on-site and partly on a precast facility; thus, the fabrication and inspection are responsibilities divided to those locations.
- Submittals: There are several submittals required based on the ABC technologies compared to conventional construction.
- Quality assurance: This needs to be ensured that the prefabricated elements are assembled in a manner to achieve quality standards of the final product equal to individual elements.
- Handling, storing, and transportation
- Geometry control: This is the key issue in the assembly process. Different tolerance requirements for various PBES are to be considered based upon their respective role in a bridge.
- Connections
- Erection methods
- Erection procedures.

Two demonstration projects were implemented using the toolkit. The first was a PBES, the Keg Creek Bridge project in Iowa. In 2011, the bridge replacement was completed within a 14-day ABC closure period. MOT and user costs justified ABC at this site that required a detour of about 14 miles and a conventional design of 6 months closure period.

The PBE of this 3-span bridge were fabricated on-site by the contractor. The on-site fabrication saved approximately $0.5 M compared to outsourcing the prefabrication. UHPC closure pours and precast approach slabs were used in the project.

The second demonstration project was a slide-in construction, NY I-84 Bridge project, in New York. The bridge replacement was completed within a 20 hr ABC closure period. The old 3-span bridge was converted to a simple span as the new bridge. This project used the lateral slide technology combined with Utah DOT method of sliding in with the approaches. The approaches were supported on an inverted-T as sleeper slabs. This process was utilized as the interstate alignment needed to be raised by 2 ft overnight. The demolition and sliding was performed in a 7-hr duration. The remaining time (around 12 hr) was required for raising the approaches by 2 ft layer-by-layer. Even though this was a slide-in project, PBES was used to fabricate the new superstructure from the toolkit details, such as NEXT beams, precast approach slabs, and UHPC connections.

The toolkit also includes a one-day course on ABC. The course is a set of slides to familiarize the engineer/ participant with ABC in general and the ABC toolkit.

REBECCA NIX, BRIDGE PROGRAM MANAGER, UTAH DOT

Utah DOT has been working with their ABC program since 1999. At that time, the Utah highway system did not have very many bridges that were structurally deficient. However, bridges were aging, and one-third of the bridges required replacement in the next 30 years. Thus, ABC provided an efficient technique to replace their structures without making major impacts to the travelling public.

This section presents the Utah DOT's ABC implementation plan, different contracting methods for ABC projects, contract documents, monitoring plans, and contingency plans. This section also provides a comparison among SPMT and lateral slide, and lessons learned. Please use the presentation slides given in Appendix D while reviewing the information presented in this section.

Utah DOT's ABC Implementation Plan

Utah DOT's ABC implementation history includes: (1) Half-depth deck panels project in 1999, (2) Full-depth deck panels project in 2004, (3) Precast substructures project in 2007, (4) SPMT project in 2007, (5) Lateral slide project in 2009, and (6) Superstructure launch project in 2010.

In addition, Utah DOT implemented their first lateral slide project involving a geo-synthetic reinforced substructure in 2013. This project was over a river, and the superstructure and substructure were slid together in a single move. The structure was pulled into place using winches and a pulley system. Here the superstructure was slid via MSE wall (acting as substructure) placed on rolling tracks. Later, the structure was tied directly to the roadway approaches to develop one continuous system. The approach slabs were cast-in-place; thus a little longer closure period was required. A week later, Utah DOT implemented a second lateral slide project that utilized precast approach slabs that reduced the closure period.

Utah DOT considers the following benefits of implementing an ABC project:

- Enhanced safety
- Shortened on-site construction time

- Reduced traffic/ mobility impacts
- Potentially reduced project costs: Initially these were in terms of reduced MOT cost and user delay cost. Afterwards, the overall project costs were brought down using the economy of scale concept.
- Improved quality: The concrete superstructure components are wet cured for the full duration in staging area. This allows achieving improved concrete quality in comparison to traditional construction that limits wet curing duration because of lane rental penalties.
- Improved constructability: The constructability is improved as the workers are in a safer zone outside traffic. Also, a full-lap splice between a closure joint as in case of staged construction is not needed.

Contracting Methods for ABC Projects

The traditional contracting method of design-bid-build is used for some of the ABC projects in Utah. However, this does not allow contractor involvement during the planning and design phases of the project. This generates a higher level of risk to the owner. Also, a higher amount of change orders were documented on design-bid-build ABC projects. Thus, while dealing with ABC projects, Utah DOT decided to have a strong team partnering and coordinating with the DOT, the designer, and the contractor.

The design-build is another contracting method that Utah DOT uses for ABC projects. Through such a process, the DOT is able to contract about 30% of the design phase with a consultant and contractor team. As a result, the team is able to perform the design and construction in phases. (While the first design phase is completed and the second design phase starts, the construction of the completed design [first phase] is started.) However, a higher bidding effort, upfront in the project, is required for the contractors. Utah DOT has a short list of contractors; whenever Utah DOT requests an initial design from the contractors, it provides a stipend. This was because, at that stage, the contractor was only at 30% design and had several variables to consider in future phases of the design. The benefits of design-build method compared to design-bid-build method are the following:

- Concurrent design and construction

- Early known cost: This is because the project is bid on type of work rather than individual items.
- Reduction in delivery time
- Improvements to constructability
- Encourage innovation
- Risk is transferred to contractor.

The third contracting method is the Construction-Manager – General-Contractor (CMGC) method. This method is used mostly on slide-in projects. The project plan is developed by the owner. Afterwards, the design team, including a contractor, is allowed to be on board to provide input throughout the project. The contractor on board is able to identify and mitigate risks upfront in the project. This provides a path for innovations and agreement among the owner, the designer, and the contractor. Other benefits of this contracting method include reduced design errors, constructability issues and change orders, and it allows for early procurement for long lead-time items. The method also limits negotiation on project costs because the owner (DOT) understands the rationale behind the contractor's pricing. After design, an independent cost estimate is performed in-house and compared with the contractor's estimate. Utah DOT has set a limit that if the contractor's estimate exceeds the estimate by a defined percentage, then the DOT has an option to convert to traditional bidding. The DOT in this case is not limited to the contractor in the design team.

Contract Documents

There are three levels of contract documents in Utah. The options are the following:

- No detail regarding the ABC method used: In this case, the plans are provided by the DOT similar to CIP structure; the contractor can decide on the mobilization method and develop any associated details. This was mostly useful for design-build projects.
- Show one viable option, schematic: In this case, the DOT will choose and provide one viable method for mobilization of the structure, but it will not provide

the process of mobilization and associated details to the contractor. This was mostly helpful for design-bid-build projects.

- Show permissible move details: In this case, the DOT will provide the viable method of mobilization along with associated details. The documents in this case are detailed. This was mostly helpful for CMGC projects.

In the contract documents, it is essential to define the goals, limitations, and requirements of the project. The specifications shall include the following:

- Submittal requirements: Design and other associated details such as temporary support details, etc; level of design and details that the contractor is responsible for
- Contractor flexibility: Limiting to one prescribed method and associated details or allowing the contractor to select a method
- Tolerance requirements: Tolerance requirements are relaxed a bit compared to conventional construction. However, the contractor needs to identify and understand the precision required when the bridge is brought to its final location.
- MOT requirements: This is the critical requirement that the contractor needs to understand and focus on. Utah DOT allowed the contractors on several projects for lane closures, on feature intersected, a day before the SPMT move in order to demolish one lane of the bridge. In addition, the contractors were allowed to move the bridges half-way, a day before the move; allowing them to check their systems during daylight hours.
- Incentives and Disincentives: Several projects in Utah were awarded incentives when the roadway was opened to traffic ahead of schedule. However, disincentives incurred in some projects in Utah because of delays in roadway opening. Utah DOT has a *tier* system for penalties, wherein the first couple of hours a lower disincentive is imposed to assure quality of the structure. After 2-4 hours beyond the schedule, higher disincentives are imposed.

In the contract documents, it is essential to allow for a review time in the schedule. In addition, based on the level of detail, the design team and the contractor are to be notified about the level of effort required in regards to the following submittal items (so that their respective schedules could be customized):

- Changes to contract plans
- Temporary supports including geotechnical evaluation
- Staging areas
- Hour-by-hour schedule
- Communication plan
- Contingency plan.

SPMT vs. Lateral Slide

Utah does not have SPMT locally available, so it is difficult to get SPMTs mobilized. Thus, Utah DOT selected larger projects with 7-8 bridges that needed replacement at the same time for the SPMT move. However, for lateral slides, Utah DOT used basic equipment such as tracks, rollers, and hydraulic jacks. They used post-tensioning jacks to serve the purpose of hydraulic jacks during the slide. The equipment was cheaper and lowered the project cost significantly for slide projects. The following table summarizes the comparison among SPMT and Lateral Slide:

SPMT	Lateral Slide
Equipment cost is high	Equipment cost is low
Staging area location is flexible	Staging area needs to be adjacent to the structure
Feature intersected is less critical and is least impacted	Feature intersected is impacted
Pick points of the structure vary from final supports	The structure is slid using the same support locations as the final supports

Monitoring

In Utah, monitoring is kept simple and basic for all the moves. Usually, surveys are performed to check the levels, string lines, and measuring gaps. However, measuring deflections is not required other than basically ensuring that the bridge is not twisted. For example, in a lateral slide project, a chalk line was drawn on the abutment and diaphragm and tracked down during the slide.

In a lateral slide project where the superstructure was slid with the approach slab, frequent measurements were taken throughout the move to maintain the required gap between the sleeper slab and the end of approach slab. This measurement was helpful to ensure a consistent gap on either side of the bridge and identify any twisting of the bridge.

Contingency Plan

The contingency plan ensures that the hour-by-hour schedule is observed. This provides an interpretation of the move or slide progress and allows mitigating any issues promptly. In addition, public involvement needs to be coordinated well, and a couple of hours of contingency (beyond the contractor's proposed time) must be reserved in the project closure time that is advertised to the public.

There should be a contingency plan for means to back up the bridge, if necessary in cases when the bridge is moved-in at an inappropriate angle and/or is rubbing on the substructure. In addition, there should be plan/ability to adjust the bridge alignment, if necessary in cases such as the structure is very close to one abutment compared to other abutment.

Also, it is essential to have spare equipment and/or parts in stock on-site, for crucial equipment such as spare jacks, spare control units for SPMTs, and common failing parts.

Lessons Learned

The following are the lessons learned from the SPMT projects in Utah:

- The contractor should not reuse any beams from a demolished bridge to function as carrier beams for SPMT move.
- Survey is very crucial.
- The project team needs to account for all utilities in travel path.
- Specifications need to clearly outline the expectations.
- The project team needs to account for varying load paths.
- The project team needs to provide adequate roadway tie-in lengths. This issue came up multiple times in Utah. Utah DOT was trying to limit the tie-in lengths

as much as possible for limiting the amount of fill and asphalt that needed to be placed during the night. However, full-size equipment was not able to accommodate the limited excavations which ended up extending the tie-in lengths.

The following are the lessons learned from the lateral slide projects in Utah:

- Slide-in technology needs to be specified following several investigations of the site constraints.
- The project team must account for interaction between temporary and permanent supports. Utah had one slide project where the temporary structure settled at the connection point with the permanent substructure. Additional supports were installed to the temporary structure to obtain appropriate transition to the permanent substructure.
- The project team needs to consider moving approach slabs with the superstructure. In this case, the approach slabs are constructed and slid along with the superstructure. Here an inverted-T shaped sleeper slab is placed at the approach slab ending location prior to slide. The approach slab slides on that sleeper slab and the end diaphragms slide on the abutment. A flowable fill is placed underneath the approach slab. This process eliminated the time required for compacting approach soil and constructing approach slabs. The approach slabs are designed for their full span to ensure proper support in case the fill underneath undergoes settlement.
- The project team needs to provide adequate roadway tie-in lengths.

HALUK AKTAN, PROFESSOR, WESTERN MICHIGAN UNIVERSITY

This section provides an overview of "alternative analysis for project delivery." This relates to the decision-making framework and analysis tools that are currently being developed under MDOT's research project at Western Michigan University. Dr. Haluk Aktan is the Principal Investigator of the research project. The specifics of the framework and tool were developed with input from MDOT research advisory panel (RAP) and the project manager, David Juntunen. Please use the presentation slides given in Appendix D while reviewing the information presented in this section.

Several project delivery options are currently available, conventional construction (CC), ABC – PBES assembling, ABC – SPMT move, and ABC – Bridge Slide. The analysis is required to identify the most suitable project delivery method for a specific site.

Currently, DOTs use different procedures and methods in performing the alternative analysis. These are flowcharts, structured binary tables, scoring models, and analytical hierarchy process (AHP). The primary requirement for the alternative analysis framework and the tool is to provide an intuitive and a robust analysis tool. Specific criteria are the following:

- Comparisons should incorporate project-specific quantitative data.
- Analysis should include life-cycle cost (LCC) data and user cost (UC) models.
- The tool should allow collaborative input from multiple experts for the decision-making.
- The tool should have automation to improve usability and efficiency of the decision-making process along with addressing the sensitivity of results.
- The method used should have mathematical validity.

Considering the LCC and UC models, there are several models of various complexities available. Considering the parameters related to the LCC and UC models, some are very simplistic and some are overly complex. Therefore, when these models are adapted to ABC, only essential parameters are considered and applicable models for those parameters are selected.

The software being developed in the research project is called the Michigan Accelerated Bridge Construction Decision-Making (Mi-ABCD) model. It is guided software for the users. The software uses the Analytical Hierarchy Process (AHP) that can be used in any comparison problem. The model requires defining the major- and sub-parameters that control the problem. Then pair-wise comparisons are performed for the following on a scale of 1 to 9: (i) among the major-parameters, (ii) among the sub-parameters related to each major-parameter, and (iii) among the construction alternatives with respect to each sub-parameter. Afterwards, AHP matrices are developed and priority vectors are calculated. Finally, the preference probabilities for the decision alternatives are calculated.

In the software, the major-parameters considered are: (i) Site and structure considerations, (ii) Cost, (iii) Technical feasibility and risk, (iv) Work zone mobility, (v) Environmental considerations, and (vi) Seasonal constraints and project schedule, along with 28 sub-parameters. The sub-parameters are categorized into quantitative and qualitative sub-parameters. The important aspect to consider is to decide on the process of obtaining the user data including quantitative and qualitative data for sub-parameters. Thus a Graphical User Interface (GUI) was developed to allow the users to enter data, and behind-the-scene is the mathematics that performs the calculations and outputs the preference probabilities for the decision alternatives.

The software is developed using Microsoft Excel and Visual Basic for Application (VBA) scripts. The VBA's GUI allows interaction with the users. It includes the following:

- Pop-up menus
- Datasheets
- VBA scripts
- Embedded worksheets.

One important aspect in the software is the requirement for two levels of users. It has *Advanced User* and *Basic User* modules. The *Advanced User* is considered as the project manager or any project personnel who has knowledge on the majority of the quantitative data for a project. The *Basic User(s)* are the experienced engineers on the project team who can provide qualitative judgments for the project in comparison to the past projects of which they were a part.

The data entry needs to start with an *Advanced User* for a project and the data required from the *Advanced User* are the following:

- Project details
- Site-specific data
- Traffic data
- Life-cycle cost data
- Preference ratings.

Multiple *Basic Users* can enter their qualitative judgments on ordinal scale ratings under the *Preference Ratings* data entry section. The *Preference Ratings* section includes questions that the *Basic Users* answer. The answers are specific to the sub-parameters and render opinions on an ordinal scale of 1 to 9 in comparison to earlier similar projects. This is a major advancement implemented in the software compared to regular AHP pair-wise comparison. This is to eliminate the concern of comparing two unrelated parameters, such as Cost vs. Safety, as both are equally important. In addition, the users can provide comments for the *Preference Ratings* that are visible to future users and provide the perspective of previous users in regards to a corresponding sub-parameter. However, in this case, the preference ratings from the previous users are kept private for future users, and only the final analysis/evaluation results are visible. The mathematical formulation in the background develops AHP pair-wise comparison matrices based on the ordinal scale ratings.

The software has the capability to allow the advanced user to add or remove parameters. The analysis also requires *general data* that remains unchanged for a particular region/state. General data can be edited if the software is used for evaluating a project in a different region/state. These aspects of the software are accessible to the *Advanced User* only.

The results from the analysis/evaluation are displayed in three forms: (i) Pie charts that show the upper and lower bound results of user data, (ii) Line chart that shows the distribution of major-parameter user preferences, and (iii) Bar chart that shows *Preference Probabilities* of the project delivery alternatives. Also the data in the charts is displayed in a tabular format as numbers.

The software implementation was demonstrated using the Stadium Drive (I-94 BR) bridge over US 131 project in Kalamazoo County, MI. It is a sizable bridge replacement planned for construction in 2014. The analysis/evaluation was performed for CC and ABC, in particular PBES. The analysis/evaluation justified ABC for that project quantitatively. Currently, the software is capable of evaluating CC and PBES only and the extension of the research project will cover the slide-in and SPMT move technologies.

BENJAMIN BEERMAN, SENIOR STRUCTURAL ENGINEER, FHWA

This section presents an overview of the National perspective on ABC implementation. The information is presented based on the ongoing research under the *Every Day Counts (EDC)* initiative of FHWA. The following topics are highlighted in this section:

- Impact of EDC initiative on ABC and PBES delivery
- Prefabricated Bridge Elements (PBE) and Prefabricated Bridge Systems (PBS)
- Resources for implementation of ABC
- Realizations with ABC/PBES.

The EDC counts initiative was founded on three pillars: Safety, Quality, and Overall program delivery. The EDC phase-I was engaged from 2011 to 2012. In that phase, PBES technology was promoted throughout the US. The EDC program was termed as a deployment vehicle that allows collaborating in a national manner. Realizing the advancement gained from the program, another phase EDC-II was initiated in 2012 and is scheduled to end in 2014. There are 26 initiatives under the EDC-II program for shortening the project delivery; among them, the ones that impact bridges are the following:

- Programmatic Agreements II
- 3D Modeling
- Accelerated Bridge Construction that includes PBES, and emphasis on GRS-IBS and Lateral Slide
- Design Build
- CMGC
- Alternative Technical Concepts (ATC).

The EDC is an opportunity that allows bridge practitioners to collaborate at national level to advance ABC innovations such as PBES into the mainstream of the bridge industry. Several deployment activities were performed under the EDC initiative specific to PBES:

- Workshops
- Webinars
- Scanning Tours

- Project Reviews
- Project Showcases
- Regional Peer Exchanges.

ABC, for a program of projects, is a combination of various strategies and technologies. The following Venn diagram explains the interaction of ABC with other aspects related to bridge construction:

Focusing on PBES, it is just a technology or strategy used to develop an ABC project or group of projects or a program of projects. The definition of PBES according to AASHTO is: *"PBES are structural components of a bridge that are built offsite, or adjacent to the alignment, and includes features that reduce the onsite construction time and mobility impact time that occurs from conventional construction methods."* AASHTO separated the difference between the *Elements* and *Systems* to have consistent terminology. *Elements* are defined as single structural components of a bridge, such as deck elements, beam elements, deck-beam elements, full-width beam elements, pier elements, abutment and wall elements, and miscellaneous elements that include approach slab elements, etc. The *Systems* are defined as entire superstructure, entire superstructure and substructure, or a total bridge that has been moved or planned to be moved in a manner that traffic operations can resume once the structure is in its final position.

The definitions and terminology were engaged to assist in developing the National ABC/PBES Project Exchange database. The FHWA required each state DOT to submit at least 2 projects that used PBES and/or any ABC approach for the database. The database includes contract plans, specifications, bid tabs, schedule, and pictures from previous ABC projects in the US (over 100 projects available).

The National ABC/PBES Project Exchange database can be accesses using the following website:
<https://www.transportationresearch.gov/dot/fhwa/default.aspx>

Note: For accessing the ABC/PBES Project Exchange database, prior registration and site access requesting is required following the instructions presented in ABC Project Exchange User's Guide:
<http://www.abc.fiu.edu/wp-content/uploads/2013/07/ABC-User-Guide-for-posting1.pdf>

Other resources for ABC/PBES implementation are the following:

- Webinar training sessions that can be accessed from:
  http://www.fhwa.dot.gov/everydaycounts/technology/bridges/pbeswebinartraining/

- Publications that include FHWA ABC manual, Connections details for PBES, Manual for use of SPMT, etc., which can be accessed from:
  http://www.fhwa.dot.gov/bridge/prefab/pubs.cfm

- Regional Peer Exchange Meetings documents that include around 150 presentations related to ABC. The forum can be accessed from:
  <http://p2p.ara-tracker.com/

- Monthly FIU webinar series that can be accessed from:
  http://www.abc.fiu.edu/

- SHRP 2 R04 Toolkit that can be accessed from:
  http://www.fhwa.dot.gov/goshrp2/ (or) http://www.trb.org/Main/Blurbs/168046.aspx

- Other regional/DOT websites:
  http://www.pcine.org/
  http://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:1991

In addition, to supplement the FHWA ABC manual, future publications are expected (Summer 2014) in the areas of *Planning and Policy*, *Engineering Materials*, and *Construction Contracting*.

The Transportation Research Board granted approval for the formation of ABC subcommittee under AFF10 General Structures committee. The subcommittee is named as AFF10(3) – Subcommittee for ABC, and its website can be accessed from:
https://sites.google.com/site/trbaff103/
This website is planned to contain the entire ABC related work in the US.

Recent ABC NCHRP projects in collaboration with TRB are the following:

- Development of an ABC design and construction guide specification: NCHRP 12-102
- Guidelines for tolerances of PBES and dynamic effects in large-scale bridge moves: NCHRP 12-98.

In summary, the EDC initiative enabled spreading of the "word" ABC/PBES and resulted in deployment of ABC/PBES projects in more than 46 states in the US. It resulted in paradigm shift in deployment perspective. For example, the DOTs are comparing among PBES technologies themselves, such as among pile lagging, grouted couplers, and pile pockets for abutment walls in an ABC project. In addition, the DOTs are developing standards for PBES deployment.

APPENDIX C

WORKSHOP QUESTION/ANSWER SESSION SUMMARY

QUESTION AND ANSWER SESSION SUMMARIES

Q1: Is Utah DOT still employing the same level of effort as their first few projects for public outreach and information exchange? As the public and industry may be now accustomed with ABC.

A1: For the first few projects, Utah DOT was extensively involved with public outreach. The public was allowed to view the ABC process. Now, there is no rigorous campaign to hold demonstration projects. Presently, variable message signs are used to inform the public well ahead of a project schedule. Public meetings are still held to get communities and businesses involved. Measures are taken to inform the trucking industry about a project schedule.

Q2: How does Utah DOT deal with delays in contractor's submittals for ABC projects as there is a lot more detail to be included?

A2: Utah DOT did not have many push backs from the contractors for the submittals, as the activities were planned ahead of time and were presented to contractors upfront. Also, Utah DOT was well aware of the time required for developing the documents. Hence, the entire process was scheduled accordingly. In the first few projects, the DOT allowed a 14-day review period for the contractors. After introducing an electronic submittal process, a 7-day review period was allowed. As per the lessons learned, a DOT schedule should allow for any deviations in the submittals especially when a temporary work plan, communication plan, and an hour-by-hour schedule are requested. Also, the DOT shall ensure proper communication with the contractor regarding their progress to submittals. Further, the DOT shall realize that if new contractors are providing submittals, then the submittals will differ significantly from regular contractors. Thus, the DOT schedule shall allow for additional review time from their side as well.

Q3: MDOT is looking at standardizing precast pier columns and bent caps to have standardized plans in their Bridge Design Guide. Did other DOTs do that? If so, what do they recommend for MDOT to achieve their goal?

A3: Utah DOT developed standards for precast full-depth and partial-depth deck panels. Sample standard working drawings were made available to contractors in order to give a general idea. The drawings are available through Utah DOT's website. Utah DOT also developed some specifications for ABC projects.

The SHRP 2 R04 project toolkit contains few examples for standard substructure elements. These elements were identified from various states where these elements are used in conventional construction. Contractors are familiar with the details presented by those states, but are uncomfortable in adapting those in ABC. Hence, the purpose of incorporating such elements and details into the toolkit was to provide some guidance on using such components in ABC. Thus, it is recommended that the SHRP 2 R04 toolkit details shall be used in projects after customizing according to the local practices.

There is no standardization in Ontario, Canada. Always, the Ontario Ministry of Transportation experiments with various alternatives to identify efficient and cost effective solutions. For example, the Ministry proposed precast piers for a project, and the regular contractor proposed to build conventional piers. However, the Ministry, in its administrative procedures, does not allow changes to the proposed details and procedures; thus, the contractor's proposal was rejected.

<u>Q4:</u> MDOT is approaching its prefabricators and showing their future path of the standardizing ABC components including substructure. But the fabricators need to make an investment on forms, etc. How does one justify this aspect?

<u>A4:</u> The comment from SHRP 2 R04 project team is that standardization of superstructure works very well; especially, with prestressed components. This is because the shapes are decided, and projects are available to implement those shapes. In order to promote standardized substructure elements, first, the state has to develop standardized elements and a program of projects to utilize such elements. Secondly, present the standardized elements and the details of the program of projects to the fabricators. This is a must because the fabricators need to know the extent of utilization of standard elements before investing in the formwork. However, due to variations in site conditions, it is a challenge to develop a program of projects with similar substructure elements. However, if MDOT can develop a program of projects with the aim of using similar substructure elements, the substructure elements can be standardized and the fabricators can be convinced to invest in the formwork. This is because in future of ABC the economy of scale shall control.

For prestressed elements, standardization is very beneficial as the fixed costs are higher. However, if precast reinforced concrete columns are used, columns can be prefabricated economically on-site in the staging area by eliminating the cost of transportation. SHRP 2 R04 is promoting self-performance of non-prestressed elements to the maximum extent possible to save transportation costs by a contractor, i.e., cast the components on-site in the staging area. This contradicts with the option of standardizing non-prestressed pier columns.

The SHRP 2 R04 project considered several aspects to achieve higher cost savings in routine bridges with ABC. One option is to identify 10 or 12 bridges of a similar type requiring replacement and call for bids for that cluster of bridges. Large cost savings will be realized from the fabricators' side, as the forms will be reused for multiple bridges and brings in economy of scale. This is a way of leveraging ABC and precast technology to the maximum. In this case the owner does not need to be concerned about standardization as the contractor can make their own form and can self-perform. Thus, consideration is required in selecting the cluster of similar routine bridges for a contract package to achieve economy of scale. This will have both cost and schedule savings as the prefabrication will be performed similar to an assembly line, and the unit price will go down.

In order to standardize and to identify alternatives, it is vital to have a dialog between the bridge owners, consultants, contractors, fabricators, and the researchers. As an example, Utah DOT, in their process of standardization, conducted several workshops that included contractors, fabricators, and designers to provide their input. At that point, Utah DOT stepped away from the AASHTO PCI girder to the Utah Bulb-Tee girder that became their routine girder.

Q5: Does the design-bid-build method puts more risk on contractors/owners for ABC projects?

A5: The contractors mostly bid on the risk factor; thus, as the risk goes down the cost decreases. When the contractors gain experience, the assumed risk is reduced. Hence, the more ABC projects are performed, more experience is gained, and the cost is reduced. It is a learning curve both on the owner's side and contractor's side. It shall be noted that the DOT shall put the risk where the risk belongs to. The DOT's shall not put all the risk onto the contractor, as some risk does belong to the owner. For ABC projects, the DOTs shall think about assigning appropriate portion of risk to the contractors, rather than putting all the risk onto the contractor.

For the SHRP 2 R04 projects in Iowa and New York, the project team engaged all the local contractors (by working through AGC) from the start of the ABC project and had one-on-one meetings to get their input at 30% of design phase and 60% design phase. Then an information session with all the contractors was conducted prior to the bidding date. This worked very well, and competitive bids were received because the input was received from the local contracting industry itself, rather than one single contractor as in case of CMGC.

Q6: Regarding the connection durability in the closure pour of deck panels, Utah special provisions specify that the contractor shall work with a grout supplier to ensure connection durability. But still within 2 years cracks and leakage were documented at the connections in Utah's ABC bridges. What is Utah DOT's comment on this?

A6: Utah DOT had significant problems with the closure pours and transverse joints between the panels. Utah was using UHPC or HPC for the closure pours and grout for transverse connections. They were unable to identify a *true* non-shrink grout and the decks were cracking and leaking soon in 6 months of project completion. For some of the projects, Utah requested a warranty for the grout connections; however, when the connections started leaking, the contractor blamed the supplier and the supplier blamed the contractor for improper installation. Instead of identifying the perfect grout and trying to warranty the grout, Utah DOT decided to specify longitudinal post-tensioning in all the precast decks. In addition, they placed an overlay on the deck to ensure the connections do not leak.

Ken Price from HNTB has the perspective that the transverse joints crack not because of materials but because of live load demand. The longitudinal joints do not crack in ABC projects but the transverse joints do crack. This is because the decks bend in a longitudinal direction and *arch* in a transverse direction. This justification is based on the performance of the modular decked steel girder system implemented in SHRP 2 R04 project in Iowa. Thus, any transverse joint material subjected to tensile forces due to bending moment will eventually crack. It is recommended that a modest level of prestress or post-tensioning in longitudinal direction will ensure transverse connection durability for numerous years to come.

APPENDIX E

WORKSHOP PARTICIPANTS

Count	Last Name	First Name	Affiliation
1	Abadir	Jane	Somat Engineering Inc.
2	Adefeso	Olukayode	Michigan DOT - Metro Region
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6	Barry	Timothy	Michigan DOT
7	Bedford	Allan	Orchard Hiltz & McCliment (OHM) Inc.
8	Bellgowan	Matt	Michigan DOT - Grand Rapids TSC
9	Boeskook	Shawn	Milbocker & Sons, Inc.
10	Bower	Steve	Michigan DOT
11	Branson	Kirk	Parsons Brinckerhoff Michigan Inc.
12	Broekhuizen	Dan	URS Corporation
13	Bruinsma	Jonathon	Michigan DOT - Grand Region
14	Buchholz	Scott	Tetra Tech
15	Bukoski	Glenn	MITA Building / MCA Main Office
16	Burns	Eric	Michigan DOT - Operations Field Services
17	Chaput	Mark	Michigan DOT- University Region
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19	Chauvin	Mike	HNTB Michigan Inc
20	Chynoweth	Matt	Michigan DOT - Operations Field Services
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22	Cooper	Keith	Michigan DOT
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29	DelaFuente	Jim	Michigan DOT - Grand Region
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34	Edwards	Bryan	HNTB Michigan Inc
35	Ellens	Steve	Fishbeck Thompson Carr Huber
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38	Esmacher	Charlie	HNTB Michigan Inc
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40	Fox	Chad	Erickson's Inc.
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43	Goldsworthy	Joshua	Walter Toebe Construction Company
44	Gronowski	Andy	Wade Trim

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59	Herman	Brandon	Hardman Construction
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62	Homan	Chris	Mannik & Smith Group
63	Ingle	Valerie	RS Engineering LLC
64	Izzo	Paul	DLZ Michigan Inc
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66	Jildeh	Raja	Michigan DOT
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69	Johnson	Chris	Michigan DOT
70	Johr	Roger	Williams and Works
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103	Pratt	Tom	Milbocker & Sons, Inc.
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106	Rajala	Chad	Alfred Benesch & Company
107	Ranger	James	Michigan DOT
108	Reed	Linda	Michigan DOT
109	Reed	Jim	CA Hull
110	Rhoades	Travis	Mannik & Smith Group
111	Robbins	Jenean	Tyme Engineering Inc.
112	Rogers	Corey	Michigan DOT - Operations Field Services
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115	Schreiber	Fred	Hubbell Roth & Clark Inc
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117	Shah	Tanweer	Geotran Consultants
118	Sisson	Jasmine	Parsons Brinckerhoff
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122	Sullivan, PE	Chris	IBI Group
123	Szumigala	Mike	CA Hull
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125	Tebbe	Susan	Williams and Works
126	Tellier	Thomas	Michigan DOT - Grand Rapids TSC
127	Tenbrock	Mike	Kent County Road Commission
128	Tennes	Chris	Michigan DOT
129	Tiffany	Ken	Michigan DOT
130	Tinkey	Shawn	HNTB Michigan Inc
131	Todorova	Radka	Michigan DOT
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140	VanDrunen	Nate	Michigan DOT - Grand Region
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145	Weirauch	Catherine	Somat Engineering Inc.
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MDOT RC-1610

Accelerated Bridge Construction and Structural Move - Workshop

MARCH 2014

Department of Civil & Construction Engineering
College of Engineering and Applied Sciences
Western Michigan University

Accelerated Bridge Construction and Structural Move - Workshop

Appendices

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APPENDIX D (PART-I)

WORKSHOP PRESENTATIONS

Michigan Department of Transportation Accelerated Bridge Construction Workshop

MDOT Michigan Department of Transportation

U.S. Department of Transportation Federal Highway Administration

mita Michigan Infrastructure & Transportation Association

ACEC American Council of Engineering Companies of Michigan

County Road Association of Michigan

michigan municipal league

Gregory Johnson, P.E.
Chief Operations Officer
Michigan Department of Transportation

Accelerated Bridge Construction Workshop, December 9, 2013

MDOT ABC Policy

- Welcome to MDOT's first ABC/PBES workshop
  - We have two bridge slide projects to be done via CM/GC next year
  - Future bridge slide/structural move projects will most likely be design/bid/build, and we want the Michigan contracting industry, and those delivering the projects to be comfortable, and knowledgeable of these techniques

MDOT ABC Policy

- Every Day Counts (EDC)
  - Goal: **25% of bridges constructed/reconstructed with Federal Aid to incorporate at least one Accelerated Bridge Construction (ABC) or major precast component.**
  - Goal was to have 25% of bridges in program by December 2012
  - MDOT executive leadership approved policy document in October 2012

MDOT ABC Policy

MDOT ABC Policy

- The MDOT ABC policy was selected as a national example, and presented at the 2013 TRB meeting
- MDOT is also working at the national level, through the AASHTO Subcommittee on Bridges and Structures on the advancement of ABC/PBES methods and technologies

MDOT ABC Policy

- ABC/PBES is a part of our business practice, and must now be part of our culture when thinking about how our projects impact the public, and the economy

MDOT ABC Policy

- Why ABC, Why now?

Enjoy the workshop!

Michigan Department of Transportation
Accelerated Bridge Construction Workshop

Matthew J. Chynoweth, P.E.
Bridge Field Services Engineer
Michigan Department of Transportation

Accelerated Bridge Construction Workshop, December 9, 2013

MDOT ABC Policy

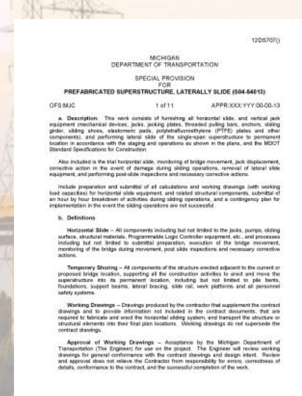
- Progress at MDOT:
  - **Committee established with members from MDOT, Consultant, and Industry staff**
  - **Goals over the Next Few Years:**
    - Move this Technology Forward from demonstration to standardized deployment
    - Gain additional experience
    - Develop a Program Approach
    - Develop Selection Criteria and a Decision Making Framework
    - Develop methods for Performance Measurement

MDOT ABC Policy

- Section 7.01.19 of the MDOT Bridge Design Manual covers ABC and PBES considerations
- This section will be further updated as means and methods are further evaluated

MDOT ABC Policy

- Special provision for Prefabricated Superstructure, Laterally Slide



MDOT ABC Policy

- Prefabricated Superstructure, Laterally Slide SP requirements:
  - Working drawings, calculations and submittals
  - Move Operations Manual
  - Geometry Control and Monitoring Plan
  - Contingency Plan
  - Trial Horizontal Slide
  - Movement of Superstructure requirements
  - Allowable Tolerances
- Also working on SPMT special provision

MDOT ABC Policy Update:

- Developing static and kinetic friction calculations and criteria for jacking force calculations:
  - $f_{max\_static} = \mu_{static} \times F_{normal}$
  - $f_{max\_kinetic} = \mu_{kinetic} \times F_{normal}$

Surfaces	μ (static)	μ (kinetic)
Steel on steel	0.74	0.57
Glass on glass	0.94	0.40
Metal on Metal (lubricated)	0.15	0.06
Ice on ice	0.10	0.03
Teflon on Teflon	0.04	0.04
Tire on concrete	1.00	0.80
Tire on wet road	0.60	0.40
Tire on snow	0.30	0.20

MDOT ABC Policy

- Currently working on updates to MDOT Project Scoping Manual and Mobility Manual for evaluation of ABC/PBES techniques with respect to:
  - Site and Structure considerations
  - Work zone Safety and Mobility
  - Cost
  - Technical Feasibility
  - Seasonal Constraints and Project Schedule
  - Environmental Issues

Why Accelerated Bridge Construction?
Reduced Time

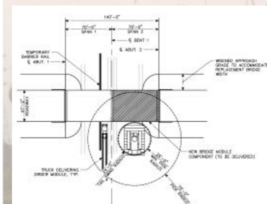
- Project Schedule (Length/Events)
- Part-Width / Detour / Temp Bridge
- User Delay Costs
- MDOT Mobility Policy
  - Volume to capacity ratio less than 0.80
  - Work zone travel delay less than 10 minutes.
  - Corridors of significance
  - Level of service shall not be D or less or drop from A to C.

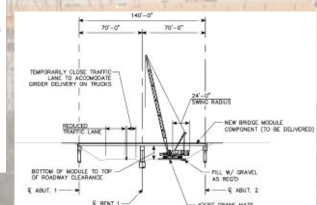
Why Accelerated Bridge Construction ?
Recommended Activities

- Achieve industry buy-in
  - Workshops and Technical Exchange Conferences
  - Allow time to become comfortable and knowledgeable using PBES.
- Think like a Contractor
  - Consider equipment capabilities and capacities
  - Means and methods to be more thoroughly developed during the design phase
- Plan a Program of Projects
  - Build Momentum – a clear signal to the industry that the business model is changing.

Barriers and Challenges to ABC

- Think like a contractor during design
  - Consider equipment capacities





Barriers and Challenges to ABC

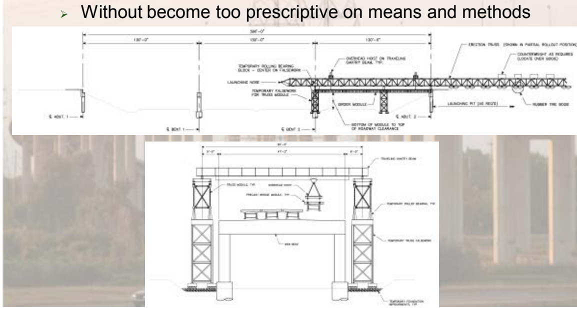
- Lack of Knowledge and Experience
  - Detailing Connections
  - Tracking Durability
  - Designing Curvilinear Geometry
  - Accounting for Negative Moment Continuity
- Availability of Precast Contractors
- Designing component size for transport and site erection
- Contractor Proposing to go Back to CIP After Award

Barriers and Challenges to ABC

- Connections
- Tolerances
- Weight of segments
- Construction Staging

Barriers and Challenges to ABC

- When to innovate during design
  - Without become too prescriptive on means and methods



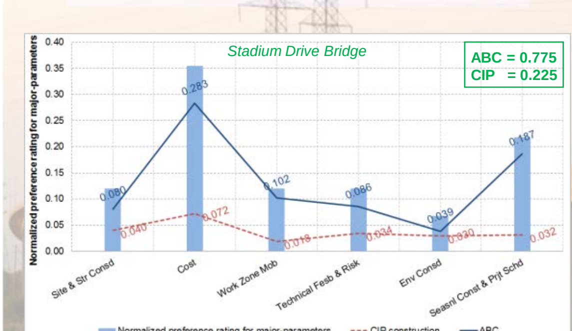
Barriers and Challenges to ABC

- Costs
  - User delay vs. construction cost, and what equipment to select

Guidelines for Choosing ABC

- Decision making frame work and analysis tools currently being developed as part of an ongoing research project
- Based on AHP (Analytical Hierarchy Process) taking into account both qualitative and quantitative values
- Tool to be used during call for projects process, and project scoping

Decision-Making Model Analysis Result

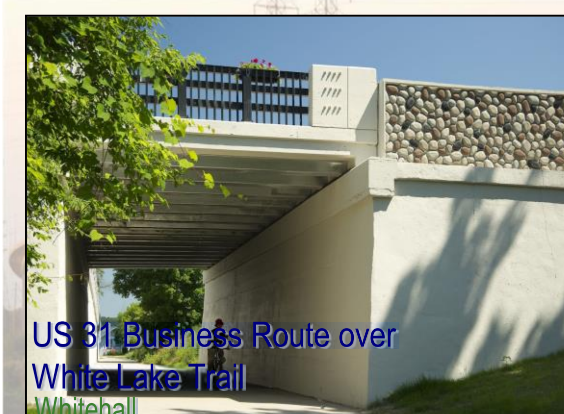


Successful ABC Projects

- Choose proper projects/material applications
- Target abilities of contractors/fabricators
- Analyze effects of cost and schedule
- Partnering
- Shared risk

MDOT's Past and Present with ABC/PBES

- Parkview Avenue over US 131 - 2008
- US 31 BR over White Lake - 2011
- M-25 over the White River - 2011



M-25 over the White River

Harbor Beach

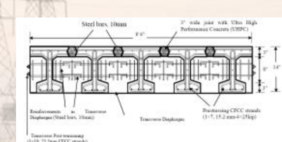
The Future of ABC at MDOT

- 2014 and beyond
  - 3 structural moves scheduled for 2014
  - 1 bridge involving PBES elements (with IBRD funding)
  - Looking for first Self Propelled Modular Transporter candidate
  - Evaluating standard joint and connection details

Future of PBES at MDOT

Decked I-Beam

- Decked I-beam being developed using Carbon Fiber Prestressing Strands and Ultra-High Performance Concrete
- Pooled Fund research project approved by the FHWA – Six States Participating so far (IA, MI, MN, OR, WI)



Thank You

Questions?

MDOT
Michigan Department of Transportation
BRIDGE FIELD SERVICES

Bridge Slides and Moves
Owner Perspective

Rebecca Nix, S.E., Bridge Program Manager
Utah Department of Transportation
MDOT Bridge Move Workshop
December 9, 2013

Presentation Outline

- ABC Implementation
- Contracting Methods
- Contract Documents
- SPMT vs. Lateral Slide
- Monitoring
- Contingency Plan
- Lessons Learned

ABC Implementation
History

- Half depth deck panels – 1999
- Full depth deck panels – 2004
- Precast Substructures – 2007
- Self Propelled Modular Transports (SPMT) – 2007
- Lateral slide – 2009
- Superstructure launch - 2010

ABC Implementation
History

ABC Implementation

History

ABC Method / Element	Number of Bridges
Slide-in	14
Self Propelled Modular Transporters (SPMT)	25
Bridge Launch	2
Heavy Lift Cranes	2
Half Depth Precast Deck Panels	63
Full Depth Precast Deck Panels	34
Precast Voided Slabs	2
Approach Slab Panels	14
Precast Sleeper Slabs	14
Precast Abutments	6
Precast Bent Caps	3
Precast Columns	1
Prefabricated Pedestrian Bridge	5
Precast Box Culvert	44

Leaders in Innovation

ABC Implementation

Benefits

- Enhanced safety
- Shortened on-site construction time
- Reduced traffic/mobility impacts
- Potentially reduced project costs
- Improved quality
- Increased constructability

Leaders in Innovation

Contracting Methods

Design Bid Build

Leaders in Innovation

Contracting Methods

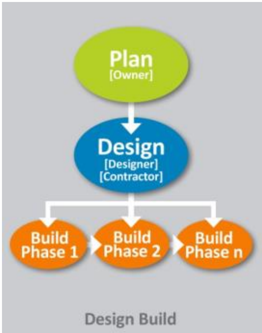
Design Bid Build

- Traditional contracting method
- No contractor involvement during design
- In house or consultant design
- Higher level of risk to owner
- High level of change orders
- Strong team partnering and coordination needed

Leaders in Innovation

Contracting Methods

Design Build



Leaders in Innovation

Contracting Methods

Design Build

- Design and construction concurrent
- Early known cost
- Reduced delivery time
- Improved constructability
- Encourage innovation
- Risk mostly transferred to contractor
- Higher bidding effort for contractor

Leaders in Innovation

Contracting Methods

Construction Manager/General Contractor

Leaders in Innovation

Contracting Methods

Construction Manager/General Contractor

- Contractor on board to consult during design
- Owner able to select innovations
- Reduce design errors, constructability issues, and change orders
- Identify and mitigate risk
- Allows for early procurement
- Limits negotiation on project costs

Leaders in Innovation

Contract Documents
Plans

- Level of detail
  - No detail regarding move
  - Show one viable option, schematic
  - Show only permissible move details

Contract Documents
Specifications

- Clearly define goals, limitations, and requirements of project
  - Submittal requirements
  - Contractor flexibility
  - Tolerance requirements
  - Maintenance of traffic requirements
  - Incentives and disincentives

Leaders in Innovation

Contract Documents
Submittals/Acceptance

- Allow for review time in schedule
- Based on level of detail of plans
  - Changes to contract plans
  - Temporary supports (including geotech evaluation)
  - Staging areas
  - Hour by hour schedule
  - Communication plan
  - Contingency plan

Leaders in Innovation

SPMT vs. Lateral Slide

SPMT	Lateral Slide
High equipment cost	Low equipment cost
Flexible staging area	Adjacent staging area
Feature crossed less critical	Feature crossed needs to allow for impacts
Pick points vary from final load path	Load path to supports remains constant

Leaders in Innovation

Monitoring

- Survey
- Levels
- String lines
- Measure gaps
- Simplistic
- Basic

Monitoring

Contingency Plan

- Hour by hour schedule
- Well coordinated public involvement
- Backup equipment
- Ability to adjust bridge alignment

Contingency Plan

Lessons Learned

SPMT

- Survey is crucial
- Account for all utilities in travel path
- Specifications need to clearly outline expectations
- Account for varying load paths
- Provide adequate roadway tie-in lengths

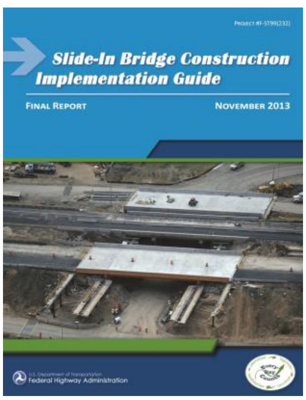
Leaders in Innovation

Lessons Learned

Lateral Slide

- Select appropriately based on site constraints
- Account for interaction between temporary and permanent supports
- Consider moving approach slabs with superstructure
- Provide adequate roadway tie-in lengths

Leaders in Innovation



Leaders in Innovation

Thank you

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Leaders in Innovation

Michigan ABC Workshop

Rapid Renewal Project (SHRP-02 R04) Findings

December 2013

Bala Sivakumar

HNTB Corp.

Outline

- SHRP2 R04 Goals
- SHRP2 ABC Toolkit
- ABC Standard Design Concepts
- ABC Erection Concepts
- ABC Design Examples
- ABC Specifications
- ABC Training Course
- PBES Demonstration Projects

SHRP2 Project R04

INNOVATIVE BRIDGE DESIGNS FOR RAPID RENEWAL

2008 -- 2013

HNTB (Prime)
Iowa State University
Structural Engineering Assoc.
Genesis Structures

SHRP2 Project R04

PROJECT GOAL

To develop standardized approaches to designing and constructing complete bridge systems that address rapid renewal needs

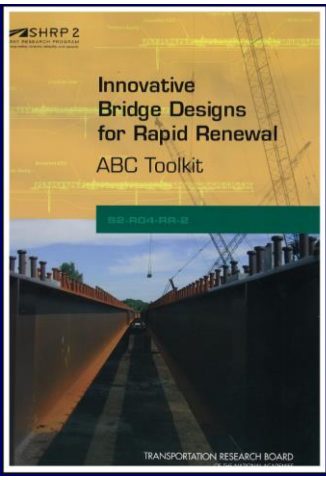
SHRP2 R-04 Tasks

- Capture current impediments to the use of ABC
- Gather successful experiences in ABC
- Propose improved ABC concepts to overcome impediments
- Develop ABC design standards / specifications
- Develop ABC Toolkit / Training materials
- Construct ABC demonstration projects

SHRP2 SOLUTIONS

SHRP2 Project R04
ABC TOOLKIT

Standardize Prefabricated Bridge Elements and Systems → Make Accelerated Bridge Construction Standard Practice



Published Dec 2012

ABC Toolkit

- ***SHRP2 ABC Tool Kit*** was developed for PBES (currently being extended to slide-in construction)
- Will bring about greater familiarity about ABC technologies
- Foster more widespread use of prefabricated elements
- Make best use of program dollars by standardizing design through pre-engineered systems

SHRP2 R04 ABC Toolkit

1. ABC STANDARD DESIGN CONCEPTS
2. ABC ERECTION CONCEPTS
3. ABC DESIGN EXAMPLES
4. ABC DESIGN SPECIFICATIONS (LRFD)
5. ABC CONSTRUCTION SPECIFICATIONS

Expected Outcome: The designer, guided by the Toolkit will be able to easily complete an ABC design for a routine bridge replacement project.

ABC Design Concepts

Guiding Philosophy

- Focus on "workhorse' bridges
- Complete bridges using prefabricated elements and modular systems
- Contractor could self-perform the work
- Simple to fabricate and easy to erect using conventional equipment
- Fast assembly in the field in 1 to 2 weeks
- Durable connections / durable bridges

Conceptual Drawings for PBES

- DECKED STEEL GIRDERS
  - Decked Steel Girder Interior Module
  - Decked Steel Girder Exterior Module
- DECKED CONCRETE GIRDERS
  - Prestressed Deck Bulb-Tee Interior Module
  - Prestressed Deck Bulb-Tee Exterior Module
  - Prestressed Double-Tee module (NEXT Beam)

Conceptual Drawings for PBES

ABUTMENTS & WINGWALSS

- Semi Integral Abutments
- Integral Abutments
- Wingwalls
- Pile Foundations and Spread Footings

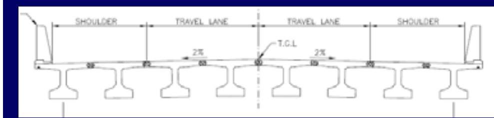
PIERS

- Precast Conventional Pier
- Precast Straddle Bent
- Drilled Shaft and Spread Footing Option

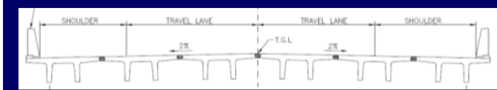
Span Ranges for Superstructures

- Simple / continuous spans from 40 ft to 130 ft.
- Simple for DL ; Continuous for LL ; No Open Joints
- Plans are grouped in the following span ranges:
  - 40 ft to 70 ft
  - 70 ft to 100 ft
  - 100 ft to 130 ft.
- Transported and erected in one piece.
- Weight < 200 Kips for erection using conventional cranes

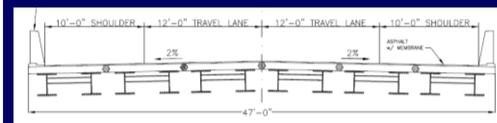
Prefabricated Decked Beam Elements



Deck Bulb Tees

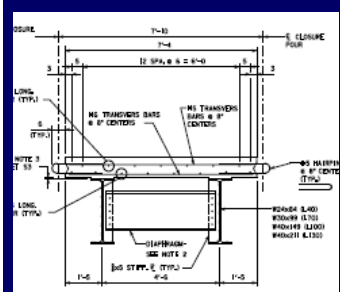


Double Tees



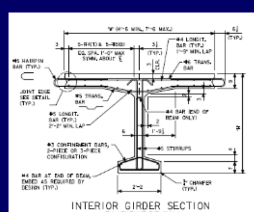
Composite Steel System

Pre-decked Modular Steel Beams

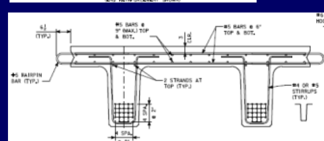


- Not proprietary
- Contractor can self-perform precasting of deck onsite
- Barriers can be precast

Precast Decked Girders



- Deck Bulb Tee
- Span lengths from 40 ft to 130 ft



Adjacent Double Tee

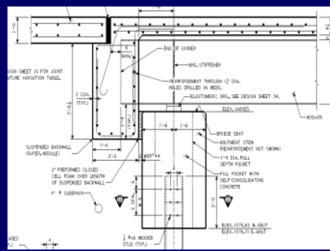
- Based on the PCI NEXT beam
- Spans to 90 ft
- Low depth alternative

Integral and Semi-Integral Bridges for Rapid Renewal

- Well suited for ABC / rapid assembly
- They allow the joints to be moved beyond the bridge
- Close tolerances required when utilizing expansion bearings and joints are eliminated
- The backwall is precast with the deck.
- Fast erection in 1 to 2 days, economical

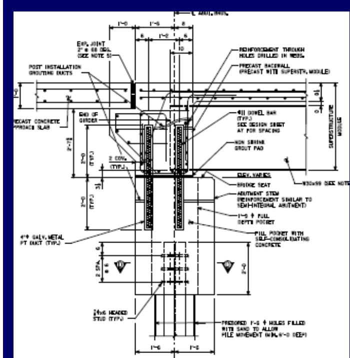
Semi-Integral Abutment

Suspended Backwall



- H piles or spread footings
- Fill pile pockets with SCC
- Easy fit-up in the field

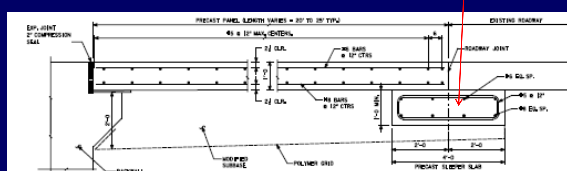
Integral Abutment



- Only one row of vertical piles
- Precast backwall - dowelled
- Fast construction

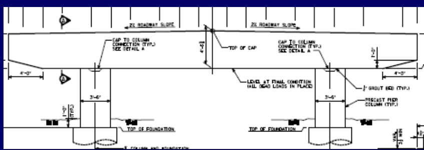
Precast Approach Slab

Precast Sleeper Slab



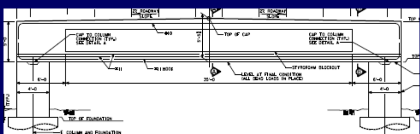
- Exp joint can be moved to sleeper slab
- UHPC / rapidset closure pours

Precast Piers



Conventional Pier

- Non-prestressed so contractor can self-perform precasting
- Fast erection using grouted splice couplers



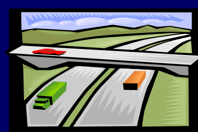
Straddle Bent

- Deep foundation may be outside existing footprint

ABC Erection Concepts for PBE

Erection Concept Drawings

1. Erection using conventional cranes.
2. Erection using ABC construction technologies adapted from long span construction



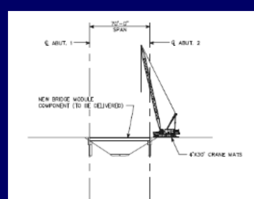
Erection Using Conventional Cranes

Most Economical

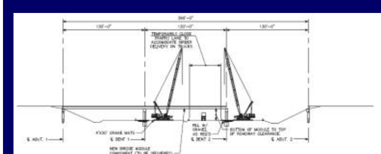
Factors to Consider

- Weight of Module
- Pick Radius
- Crane Set Up Locations
- Ground Access / Barge / Causeway / Work Trestle
- Truck Access for Delivery

Crane Placement for Erection



Short Single Span over Stream
Cranes selected for 90 Kip pick



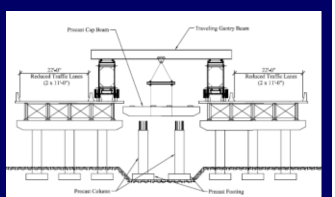
Longer Span over Roadway
Weight up to 200 kips

Crane Picks for Erection

Erection with ABC Construction Technologies

- Use where ground access for cranes may be limited.
- ABC technologies allow construction from above:
  - Above Deck Driven Carriers
  - Launched Temporary Bridge (LTB)
  - Transverse Gantry Frames
  - Longitudinal Gantry Frames
  - Regular cranes with enough reach

Above Deck Driven Carriers



- Allows fast rate of erection
- Rides on existing bridge, new bridge (check capacity to support)
- Ideal for bridges with many spans. long viaducts

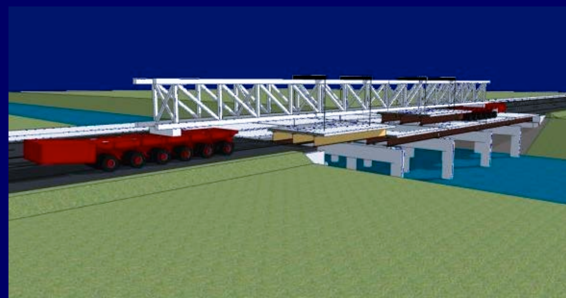
Launched Temporary Bridge

- LTTB's are launched across or lifted over a span to act as a "temporary bridge"
- Used to deliver the heavier modules without inducing large erection stresses.
- Increases the possibility of erecting longer spans
- LTTB example would be a set of standardized lightweight steel trusses that would be assembled to a specific length that suites a given project.

Launched Temporary Bridge

- Sites with limited ground access or long spans
- Launched across or lifted over a span to act as a "temporary bridge"
- Used to deliver the heavier modules without inducing large erection stresses.
- Temp bridge can also support transverse gantry frames

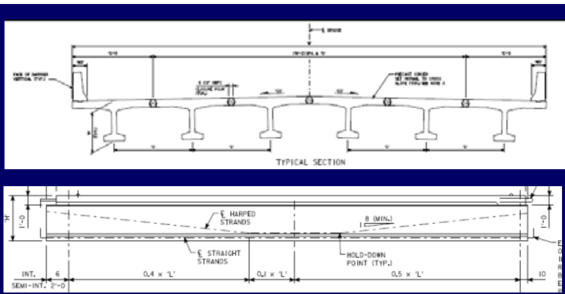
Erection Using Longitudinal Gantry Frame



Erection Using Transverse Gantry Cranes

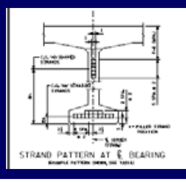
Sample Drawings from ABC Toolkit

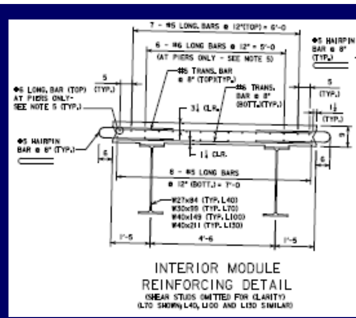
- Shows typical level of detail
- Plan sheets contain ABC specific details for routine bridges
- Guides the designer new to ABC on appropriate module configurations and connections
- Guidance on erection

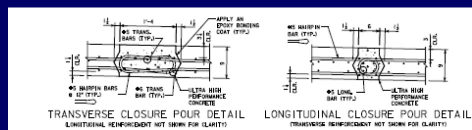


EXAMPLE STRAND LAYOUT - INTERIOR GIRDER

BEAM TYPE	'L' (FT)	'S' (FT)	f'c (KSI)	STRAND SIZE (IN)	STRAIGHT 'Ns'	STRAIGHT 'Es' (IN)	HARPED 'Nh'	HARPED 'Eh' (IN)	TOTAL 'N'	TOTAL 'E' (BRG.) (IN)	TOTAL 'E' (MID.) (IN)
DBT42	40	5	8	0.5	6	3.00	4	23.00	10	11.00	3.80
		8	8	0.5	6	3.00	6	22.00	12	12.50	4.00
	70	5	8	0.5	12	3.33	10	20.00	22	10.91	4.09
		8	8	0.5	16	3.75	14	18.00	30	10.40	4.33
DBT48	70	5	8	0.5	10	3.00	10	26.00	20	14.50	4.00
		8	8	0.5	14	3.57	14	24.00	28	13.79	4.29
	100	5	8	0.6	14	3.57	14	24.00	28	13.79	4.29
		7	8	0.6	16	3.75	16	23.00	32	13.38	4.38
DBT60	100	5	8	0.6	12	3.33	10	38.00	22	19.09	4.09
		8	8	0.6	14	3.57	14	36.00	28	19.79	4.29
	130	5	10	0.6	16	3.75	16	35.00	32	19.38	4.38
		7	10	0.6	24	4.50	16	35.00	40	16.70	4.70







SHRP2 Proposed LRFD Specs for ABC

- Prepare LRFD formatted design and construction specifications based on research
- Address impediments in LRFD Specs to ABC implementation:
  - Loads and Load combinations
  - Construction load cases, Erection stresses
  - Design of connections
  - Design responsibility --- EOR / Contractor's engineer
  - Prefabrication tolerances, quality, rideability
  - Assembly plans

Loads for ABC Design

- **Construction Loads –**
  - What kinds of loads are unique to rapid construction?
  - Loads associated with support conditions during fabrication that may be different than the permanent supports
  - Loads associated with member orientation during prefabrication
  - Loads associated with suggested lift points,
  - Load associated with impact considerations for shipping and handling of components,
  - Loads associated with camber leveling, etc.

ABC Specific Construction Loads

- **Dynamic Dead Load Allowance**—An increase in the self-weight of components to account for inertial effects during handling and transportation

- **Camber Leveling Force**—A vertically applied force used to equalize differential camber prior to establishing connectivity between the elements.

ABC Design Examples

- In ABC design the careful determination of span arrangement, girder spacings and module dimensions for shipping and erection can add significant savings.
- Span length is equally important as it is a primary factor in component length.

Decked Steel Girder Design for ABC

Organization of Design Examples in the Toolkit	
I. General: Design Philosophy Design Criteria Material Properties Load Combinations **II. Girder Design:** Flexural Strength Checks Flexural Service Checks Shear Strength Fatigue Limit States	**III. Deck Design:** Flexural Strength Check Deck Reinforcing Design Deck Overhang Design **IV. Continuity Design:** Compression Splice Closure Pour Design

ABC Design Example – Deck Bulb Tee

Organization of Deck Bulb Tee Design Example	
General: **Design Philosophy** **Design Criteria** **Girder Design:** **Permanent Loads** **Precast Lifting Weight** **Live Loads** **Prestress Losses -- Erection** **Prestress Losses -- Final**	**Concrete Stresses at Release** **Concrete Stresses at Erection** **Concrete Stresses at Final** **Flexural Strength** **Shear Strength** **Negative Moment Design** **Camber and Deflections at Release / Erection / Final**

*** Engineer of Record should perform own ABC design

Proposed ABC Construction Specifications for LRFD

Recommended Special Requirements for ABC

Proposed Section in LRFD Construction Specifications

XX.1 GENERAL
XX.2 RESPONSIBILITIES
XX.3 MATERIALS
XX.4 FABRICATION
XX.5 SUBMITTALS
XX.6 QUALITY ASSURANCE
XX.7 HANDLING, STORING, AND TRANSPORTATION
XX.8 GEOMETRY CONTROL
XX.9 CONNECTIONS
XX.10 ERECTION METHODS
XX.11 ERECTION PROCEDURES

Proposed ABC Construction Specifications

- Pertain specifically to PBES.
- Focus heavily on means and methods for PBES.
- Mainly a compilation of best practices for ABC construction
- To be updated as new information and lessons learned are accumulated from future ABC projects.
- Use as a guide could develop *Special Provisions* for an ABC project.

SHRP2
STRATEGIC HIGHWAY RESEARCH PROGRAM

SHRP2 Project R04

One-Day Course on

ACCELERATED BRIDGE CONSTRUCTION

Introduction

- The course is geared for engineers, owners, and contractors new to ABC.
- One goal of this course is to familiarize the participants with the ABC Toolkit and its use in ABC designs.
- The slides should be used in conjunction with the ABC Toolkit.
- The slides introduce and explain the use of the ABC Toolkit, which provides the "Training Wheels" for those new to ABC.
- Can be incorporated into an NHI course

Course Outline

- Structured into six lessons as follows:
  - Lesson 1 : Introduction to ABC
  - Lesson 2 : Prefabricated Elements and Systems
  - Lesson 3 : Bridge Movement Technologies
  - Lesson 4 : ABC Toolkit for Designers from SHRP2 – Part 1
  - Lesson 5 : ABC Toolkit for Designers from SHRP 2 – Part 2
  - Lesson 6 : ABC Demonstration Projects

1 day and ½ day versions for DOTs: NY, MI, PA, OK, LA, ME

SHRP2 R04 ABC Demonstration Project #1
Prefabricated Elements (IADOT)

Oct 17, 2011

14 Day ABC Period

Keg Creek Bridge

Nov 1, 2011

Prefabrication of Abutments and Piers

Erection of the Modular Beam Elements

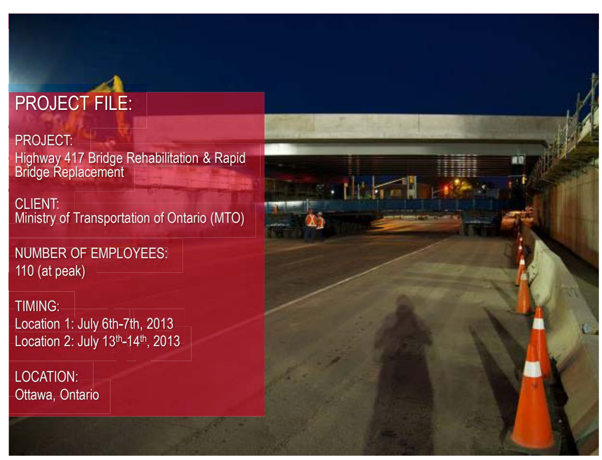

UHPC Joints in Bridge Deck
Precast Approach Slabs


SHRP2 R04 ABC Demonstration Project #2
Slide-In Construction
NY I-84 Bridges
2013
20 Hr Closure


Lateral Slide -- Oct 21 2013
7 hours to demolish exist bridge and slide-in new bridge

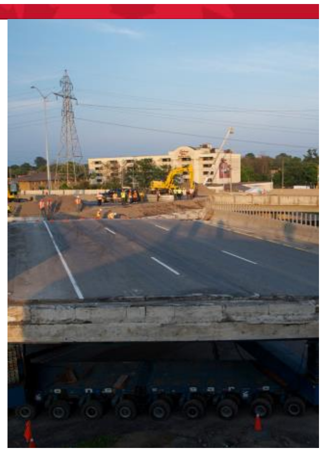

AECON
Rapid Bridge Deployment Overview
JOHN ALMEIDA P.ENG
General Manager,
Aecon Infrastructure
December 9, 2013


HWY 417 – RAPID BRIDGE REPLACEMENT
Background
Incentives & Disincentives
Planning
Geotech
Sequence of Operations
Future of RBR in Ontario


PROJECT FILE:
PROJECT:
Highway 417 Bridge Rehabilitation & Rapid Bridge Replacement
CLIENT:
Ministry of Transportation of Ontario (MTO)
NUMBER OF EMPLOYEES:
110 (at peak)
TIMING:
Location 1: July 6th-7th, 2013
Location 2: July 13th-14th, 2013
LOCATION:
Ottawa, Ontario

BACKGROUND

- 4 East and Westbound Bridges located at Kirkwood and Carling Avenues in Ottawa originally constructed in 1959
- After minor repairs and rehabilitation in 1983 and 2002 the bridge decks exceeded their design life
- Ministry of Transportation Ontario procured $18M rehabilitation contract



BACKGROUND

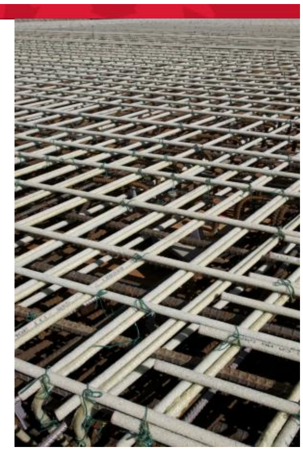
- Moving 400 Tonnes of Thin Slab Bridges
- The Procedure Lasted 14 Hours
- Fastest Rapid Bridge Replacement Time in Ontario
- 7 Rapid Replacements Carried Out in Ontario to Date
- Required a temporary limited interest(TLI) from adjacent land owner

SCOPE OF WORK

- Rapid replacement and rehabilitation of four 55-year-old bridges
- Widening of substructures to accommodate an extra traffic lane
- Construction of 4 replacement bridges in an adjacent lay down areas
- Resurfacing of asphalt and site restoration

OPERATIONAL CONSTRAINTS

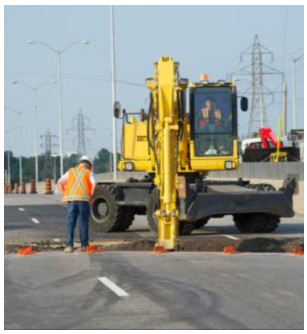
- All bridges had to be replaced between July 5th, 2013 and August 26th, 2013
- Close one lane at 5:00pm; full closure at 6:00pm (Saturday)
- Median lane in each direction must be open by 11:00am (Sunday); lane 2 in each direction to be open by 12:00pm
- Remaining lanes and ramps must be open by 6:00am (Monday)
- Only base course asphalt is required



INCENTIVES & DISINCENTIVES (Lane Closures Pre & Post Bridge Moves)

Penalty For Early Closure

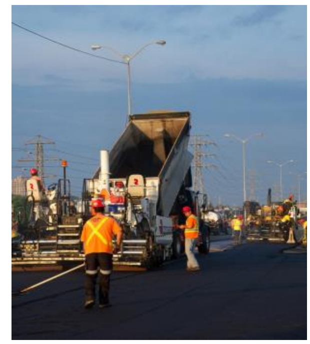
- On each occasion when the Contractor closes lanes to traffic earlier than the specified times, an initial penalty of $ 1,000.00.
- Thereafter, a further penalty of $ 100.00 per minute will be assessed against the Contractor for every minute outside the permitted closure window that the traffic lanes are not open to traffic.



INCENTIVES & DISINCENTIVES (Lane Closures Pre & Post Bridge Moves)

Penalty For Late Opening

- On each occasion when the Contractor fails to reopen the traffic lanes by the specified time, an initial penalty of $ 10,000.00 will be applied.
- If traffic lanes are not open within 15 minutes of the specified time, a further penalty of $ 1,000.00 will be assessed.
- Thereafter, a further penalty of $ 100.00 per minute will be assessed against the Contractor for every minute that the traffic lanes are not open to traffic.



INCENTIVES & DISINCENTIVES (Bridge Move Weekends)

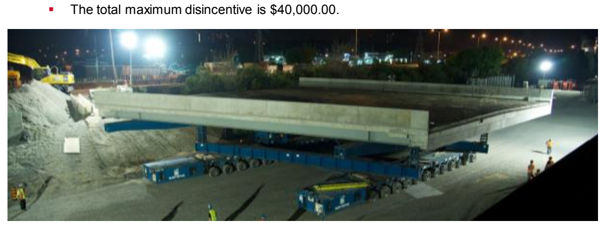
Incentive For Opening Lane 1 (Median Lanes) or Lane 3 (Outside Through Lanes)

- If eastbound and westbound median are completed to a usable facility by 11:00a.m. Sunday, the Contractor receives an incentive of $20,000.00.
- In the event that all work required in opening of either the eastbound and westbound median lanes or the outside through lanes to public traffic is completed prior to 11:00 a.m. Sunday, the Contractor receives an additional incentive of $5,000.00 per each 15-minute period earlier opening to a maximum of four periods, for a total maximum of $20,000.00.
- The total maximum incentive is $40,000.00.

INCENTIVES & DISINCENTIVES (Bridge Move Weekends)

Disincentive for Not Opening Lane 1 (Median Lanes) or Lane 3 (Outside Through Lanes)

- If eastbound and westbound median lanes are NOT completed prior to 11:01 a.m. Sunday, a penalty of $20,000.00 to the Contractor.
- After 11:01 a.m. Sunday, a additional penalty of $5,000.00 per each 15-minute period to a maximum of four periods, for a total maximum of $20,000.00.
- The total maximum disincentive is $40,000.00.



INCENTIVES & DISINCENTIVES (Bridge Move Weekends)

Incentive for Opening Lane 2 and the Ramps

- If Lane 2 and ramps are completed by prior to 12 noon, Sunday, the Contractor receives an incentive of $20,000.00.
- In the event that work required in opening lane 2 and the ramps to public traffic to a usable facility is completed prior to 12 noon, Sunday, the Ministry will pay to the Contractor an additional incentive of $5,000.00 per each 15-minute period to a maximum of four periods, for a maximum of $20,000.00.
- The total maximum incentive is $40,000.00.

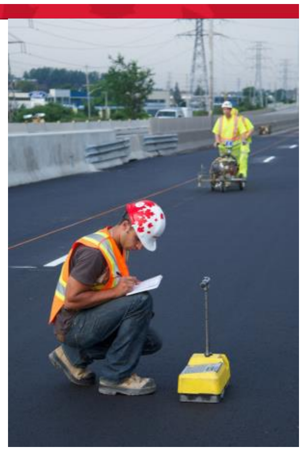
INCENTIVES & DISINCENTIVES (Bridge Move Weekends)

Disincentive for Not Opening Lane 2 and the Ramps

- In the event that all work required in opening lane 2 and the ramps to public traffic is NOT completed to a usable facility prior to 12:01 p.m. Sunday, the Ministry will deduct from its payments to the Contractor $25,000.00.
- In the event that all work required in opening lane 2 and the ramps to public traffic is NOT completed to a usable facility prior to 12:01 p.m., Sunday, the Ministry will deduct from its payments to the Contractor an additional $10,000.00 per each 15-minute period thereafter until 5:00 p.m., Sunday to a maximum of $200,000.

INCENTIVES & DISINCENTIVES

- What does all this mean?
- If things go great, the contractor receives $80,000 incentive per weekend
- If things go very badly then the contractor is penalized $280,000 per weekend



HIGHLY DETAILED PLANNING REQUIRED FROM START TO FINISH

WHY?

PRE-RAPID BRIDGE REPLACEMENT

- Six-months of non-stop planning and pre-rapid lift work
- Strategic resource management of equipment and labour
- Developed a plan with 5 minute milestones with comprehensive if-then-else mitigation measures
- Several field engineers whose sole responsibility was to track and report progress to Superintendent

GEOTECH

- "*The temporary supports located in the construction staging area shall have adequate foundation capacity to prevent settlement before, during and after the construction of the superstructure.*
- *The maximum permissible settlement at any point in the temporary structure shall be 4 mm and the maximum differential settlement between any two points in the temporary structure shall be 2 mm.*"

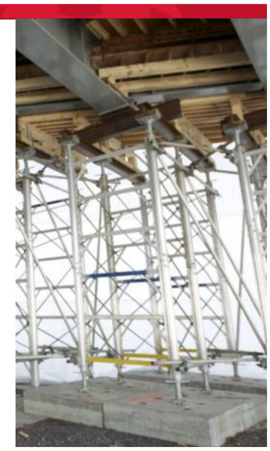
GEOTECH

- Maximum factored axial leg load, Carling Ave Structure: 183 kN
- Maximum factored axial leg load, Kirkwood Structure: 164 kN
- Self-Propelled Modular Transporters (SPMT): 100 kPa

GEOTECH

Temporary Structures

- "hi-load" concrete sill pads, size 1.2 m x 1.2m
- Using the dimensions of the sill pad and the loading values ,contact stresses of 127 kPa (Carling Ave Structure) and 114 kPa (Kirkwood Structure) were calculated at the top of the granular pad. At the natural ground surface, below a 0.6 m thick granular pad, the contact stresses were calculated to be 56 kPa (Carling Ave Structure) and 51 kPa (Kirkwood Structure).
- The ULS factored bearing resistance for the native material, based on the geotechnical information provided, was 100 kPa. Therefore, the applied bearing stresses of 56 kPa and 51 kPa were acceptable.



GEOTECH

Self-Propelled Modular Transporters (SPMT)

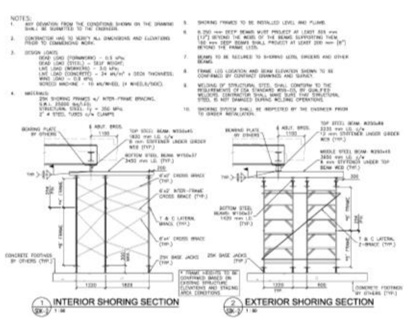
- Based on the loading provided, the SPMT, under loading during transport of the bridges, will have a maximum contact stress of 100 kPa. At the natural ground surface, below a 0.6 m thick granular pad, the contact stress is calculated to be 40 kPa.
- The ULS factored bearing resistance for the native material, based on the geotechnical information provided, is 100 kPa. Therefore, the applied bearing stress of 40 kPa is acceptable.

SURVEY PRECISION

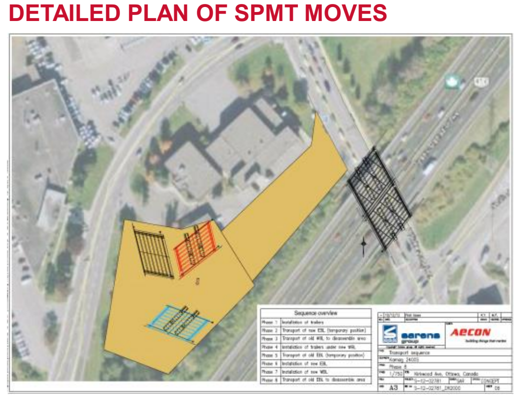
- Strategic surveying techniques
- Double-checking the numbers
  - Skew angles
  - Bearing elevations
  - Span lengths
- Ensuring the optimal level of detail & accuracy is achieved
- Getting the right fit

TEMPORARY SHORING

- Standard 25K shoring frames were used
- Differential elevation was critical
- Choice of temporary shoring system greatly impacts how old bridges will be demolished



DETAILED PLAN OF SPMT MOVES



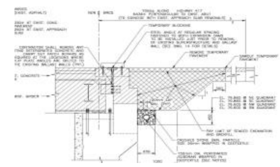
SEQUENCE OF OPERATIONS

- Pre-rapid Lift
- Rapid Lift
- Post Rapid Lift

Pre-Rapid Lift Operations

To be completed during 3 weekends in lane closures

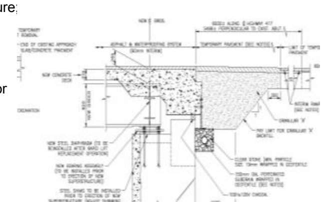
- Removal of the approach slabs and asphalt;
- Earth excavation;
- Saw-cutting and stabilizing of the ballast walls;
- Backfilling to the existing structure ballast walls including sub-drain installation and connection to
- Sub-drain below; and
- Placement of temporary hot mix asphalt.



Rapid Lift Operations

To be completed on a weekend with full lane closure

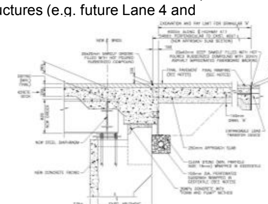
- Earth excavation;
- Removal of the existing EBL and WBL superstructures (including the attached ballast walls) from their existing location and transportation to the construction staging area for dismantling
- Transportation and erection of the new EBL and WBL superstructures from the construction staging area to their permanent location;
- Granular backfilling to the structure;
- Placement of hot mix asphalt on structures and lanes 1, 2 and 3, and corresponding shoulders;
- Placement of hot mix asphalt on approaches except for exterior portions of eastbound and westbound structures
- Installation of temporary concrete barriers



POST Rapid Lift Operations

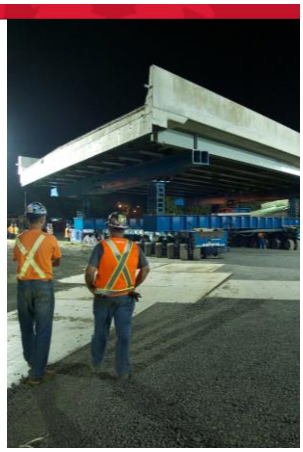
To be completed during 3 weekends in lane closures

- Earth excavation (including saw-cutting and removal of hot mix asphalt);
- Grading and placement of granular base for approach slabs;
- Construction of approach slabs using rapid set concrete (or alternatively precast approach slabs);
- Placement of hot mix asphalt on approach slabs and in the exterior portions of the eastbound and westbound structures (e.g. future Lane 4 and shoulder).
- Placement of median barrier walls on approach slabs using rapid set concrete and including electrical embedded work.



NIGHT WORK

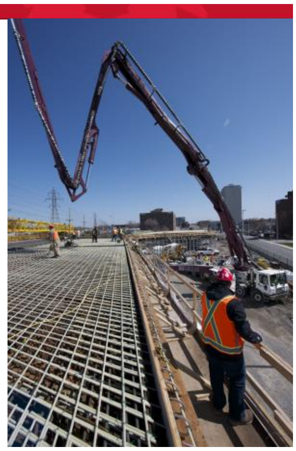
- Working at night, enabled minimal traffic disruption
  - An estimated 136,000 vehicles travel Highway 417's bridges on a daily basis
  - Commuter friendly technology
- Alternate techniques construct bridges section by section in long term lane closures, creating major traffic delays



NIGHT WORK (On Weekends)

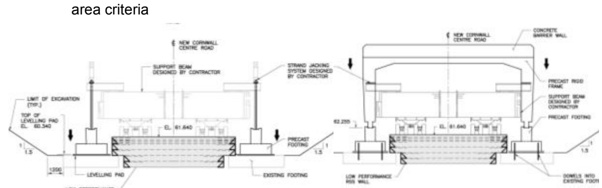
FUTURE OF RAPID BRIDGE DEPLOYMENT

- Less traffic disruption and greater public satisfaction
- Cost and time benefit savings
- Becoming the standard bridge replacement technique in heavily travelled highways



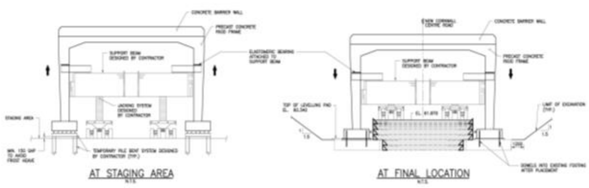
FUTURE OF RAPID BRIDGE REPLACEMENT Two Lift Pilot Project for Rigid Frame Bridge

- Lift/transport & place precast footings
- Pressure grout gaps between leveling pads and underside of new footings
- Drill & install dowels
- Lift/transport and dry-fit rigid frame on new fittings; repeat dry-fit and grinding until full contact has been made between surfaces
- Grout key immediately prior to final lowering upon attaining requisite contact area criteria



FUTURE OF RAPID BRIDGE REPLACEMENT
Single Lift Pilot Project

- Rigid frame bridge transported complete with footings from adjacent yard
- New bridge temporarily set on shim plates; space between bottom of new footings and top of existing footings is pressure grouted
- New footings are doweled into existing bridge footings



RAPID BRIDGE REPLACEMENT
Eragny France

BRIDGE REPLACMENT
Eragny France

- Finger installed in lifting pocket in wall of precast bridge

RAPID BRIDGE REPLACEMENT
Eragny France

http://youtu.be/veLp4MrljEM

MAMMOET
THE BIGGEST THING
WE MOVE IS TIME

ABC STRUCTURAL SLIDE & MOVE WORKSHOP

PROCURING TRANSPORT AND LIFT SOLUTIONS

ABC STRUCTURAL SLIDE & MOVE WORKSHOP

MDOT, DECEMBER 9TH, 2013

AGENDA

- Introduction: *Mammoet & Frido deGreef*
- Pro's of ABC: *Move by example*
- ABC move methods: *Vertical, Horizontal, Monitoring*
- What goes up must come down: *Removal of old structures*
- Procuring ABC lifting & transportation solution Cost, quality,

MAMMOET

INTRODUCTION: Frido deGreef

Frido deGreef

- Studied Ship's Engineering in Netherlands.
- Started @ Mammoet in 1990:Weighing Engineer, SPMT Equipment Engineering, Equipment manager, Procurement manager, Account Manager.
- Live in Lake Jackson, TX with wife Kim & 4 kids.

First civil job: small church in Germany; 45 x 45ft; 300 ton

MAMMOET

INTRODUCTION: MAMMOET USA, INC.

Global coordination with local experience

Incorporated 1989

Employees:	~400
Cranes:	>35 (440-3300ton)
SPMT's:	>500 axle lines
Conventional Lines:	>400 axle lines

Locations: Rosharon, TX; Houston, TX; Port Allen, LA; New Iberia, LA; Atlanta, GA; Vancouver, WA; Rockdale, IL

We live where we work!

MAMMOET

INTRODUCTION: MAMMOET GLOBAL

Mammoet: A Global Brand With Local Experience

Global Revenues:	USD $1.4B+
Employees:	~5,000
Cranes:	>1,400
SPMT's:	>2,700 axle lines
Conventional Lines:	>1,650 axle lines
Jacking & Skidding:	>40,000 ton capacity
Worldwide Offices:	80

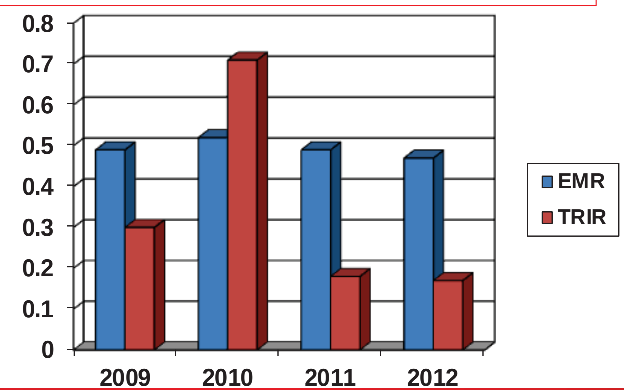
London's EYE construction time was cut in half !!

MAMMOET

"MAMMOET IS A COMPANY FULLY COMMITTED TO SAFETY"

- **Decreasing EMR/IMR As Workload Increases**

THE TARGET
0
ACCIDENTS/ INCIDENTS



Mammoet USA, Inc.: EMR October 2013: 0.41, TRIR 0.70

MAMMOET

PRO'S OF ABC: Move by example: Mammoet Netherlands

Fact Sheet:
- Weight: approx: 2500ton
- Height: 120ft
- Max 5º allowed
- 10 Stories, 45000 sqft
- Transport: 11/10/2001

Rail Bridge had to be overridden for last 3ft of clearance

MAMMOET

ABC MOVE METHODS

- **VERTICAL**
  - Cranes
  - Tower Systems
    - Strand Jacks
    - Gantry systems
  - Jacking
    - Climbing Jacks
    - Titan Systems
    - JS 500
- **HORIZONTAL**
  - Trailers
    - SPMT's
    - Conventional Trailers
  - Skidding
  - Barging
- **MONITORING**

- Possibility for use in demolition / removal projects. Major savings possible if in combination with installation!!

- **Considerations**:

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering					
Specialism					
Availability (2014-2020					
Mob / Demob					
Installing of equipment					
Speed of execution					
Demolition possibilities					
OVERALL IMPACT TO BUDGET					

MAMMOET

PRO'S OF ABC: Move by example: Mammoet USA

Fact Sheet:
- Weight: approx: 1200 ton
- Fully functional within 2 weeks after move
- Max 2º slant allowed
- 2 Stories, 32,000 sqft
- Transport: 12/17/2011

Total distance transported: ½ mile in 4 hours

MAMMOET

ABC MOVE METHODS

- **VERTICAL**
  - **Cranes**
  - Tower Systems
    - Strand Jacks
    - Gantry systems
  - Jacking
    - Climbing Jacks
    - Titan Systems
    - JS 500
- **HORIZONTAL**
  - Trailers
    - SPMT's
    - Conventional Trailers
  - Skidding
  - Barging
- **MONITORING**

- **Considerations**:
- Ground Pressure
- Lifting points
- Chart / Overweight

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering			X		
Specialism				X	
Availability (2014-2020)		X			
Mob / Demob	X				
Installing of equipment		X			
Speed of execution				X	
Demolition possibilities				X	
OVERALL IMPACT TO BUDGET		X			

Rigging needs to be engineered, tested and certified

MAMMOET

ABC MOVE METHODS

- **VERTICAL**
  - Cranes
  - Tower Systems
    - Strand Jacks
    - Gantry systems
  - Jacking
    - Climbing Jacks
    - Titan Systems
    - JS 500
- **HORIZONTAL**
  - Trailers
    - SPMT's
    - Conventional Trailers
  - Skidding
  - Barging
- **MONITORING**

- **Considerations**:
- Ideal for hard to reach area's
- Extreme savings when implemented early in design phase
- Computer controlled slow lift
- Can be used for bridge removal

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering		X			
Specialism	X				
Availability (2014-2020)		X			
Mob / Demob				X	
Installing of equipment			X		
Speed of execution			X		
Demolition possibilities			X		
OVERALL IMPACT TO BUDGET			X		

ABC MOVE METHODS

- **VERTICAL**
  - Cranes
  - Tower Systems
    - Strand Jacks
    - Gantry systems
  - Jacking
    - Climbing Jacks
    - Titan Systems
    - JS 500
- **HORIZONTAL**
  - Trailers
    - SPMT's
    - Conventional Trailers
  - Skidding
  - Barging
- **MONITORING**

ABC MOVE METHODS

- **VERTICAL**
  - Cranes
  - Tower Systems
    - Strand Jacks
    - Gantry systems
  - Jacking
    - Climbing Jacks
    - Titan Systems
    - JS 500
- **HORIZONTAL**
  - Trailers
    - SPMT's
    - Conventional Trailers
  - Skidding
  - Barging
- **MONITORING**

- **Considerations**:
- 100t-300t-900t capacity per tower, with multiples per tower possible
- Hammerhead tower design ideal for bridges
- Electrical power possible
- Support cranes needed

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering		X			
Specialism	X				
Availability (2014-2020)		X			
Mob / Demob				X	
Installing of equipment			X		
Speed of execution			X		
Demolition possibilities			X		
OVERALL IMPACT TO BUDGET			X		

ABC MOVE METHODS

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- **MONITORING**

- **Considerations**:
- Capacity up to 1250t
- Ideal for lighter deck removal with skidding beams mounted on girders
- Limited lift height
- Needs stable ground

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering			X		
Specialism			X		
Availability (2014-2020)			X		
Mob / Demob				X	
Installing of equipment			X		
Speed of execution			X		
Demolition possibilities			X		
OVERALL IMPACT TO BUDGET			X		

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- **MONITORING**

- **Considerations**:
- Pressure point to both structure as well as support
- Height restricted
- Labor intensive, slow

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering			X		
Specialism			X		
Availability (2014-2020)				X	
Mob / Demob					X
Installing of equipment				X	
Speed of execution		X			
Demolition possibilities		X			
OVERALL IMPACT TO BUDGET				X	

Jacks come from 5-1000ton with strokes up to multiple feet

MAMMOET

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- **Considerations**:
- Pressure point to both structure as well as support
- Height restricted
- Labor intensive, slow

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering			X		
Specialism			X		
Availability (2014-2020)				X	
Mob / Demob					X
Installing of equipment				X	
Speed of execution		X			
Demolition possibilities		X			
OVERALL IMPACT TO BUDGET				X	

MAMMOET

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- **Considerations**:
- Ideal in combination with SPMT's
- Extremely stable & support friendly

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering			X		
Specialism		X			
Availability (2014-2020)				X	
Mob / Demob			X		
Installing of equipment			X		
Speed of execution		X			
Demolition possibilities			X		
OVERALL IMPACT TO BUDGET			X		

MAMMOET

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- **Considerations**:
- Above 33 ft additional bracing needed
- Stable
- Computer controlled jacking
- 500 ton per tower

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering			X		
Specialism			X		
Availability (2014-2020)				X	
Mob / Demob		X			
Installing of equipment			X		
Speed of execution		X			
Demolition possibilities			X		
OVERALL IMPACT TO BUDGET			X		

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- **Considerations**:

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering					
Specialism					
Availability (2014-2020)					
Mob / Demob					
Installing of equipment					
Speed of execution					
Demolition possibilities					
OVERALL IMPACT TO BUDGET					

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- **Considerations**:
- Ground pressure
- Extremely versatile
- Bracing between SPMT's and structure is extremely important
- Air filled tires

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering		X			
Specialism		X			
Availability (2014-2020)	X				
Mob / Demob	X				
Installing of equipment			X		
Speed of execution				X	
Demolition possibilities				X	
OVERALL IMPACT TO BUDGET		X			

25 **SPMT stands for Self Propelled Modular Trailer** (containerized cargo)

MAMMOET

ABC MOVE METHODS

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- **Considerations**:
- 30 ton per axle line!!
- 360degree steering
- Spacers available for cost savings
- Titan system combination
- Hydraulic systems can be set up for 3 or 4 point set up.

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering		X			
Specialism		X			
Availability (2014-2020)	X				
Mob / Demob	X				
Installing of equipment			X		
Speed of execution				X	
Demolition possibilities				X	
OVERALL IMPACT TO BUDGET			X		

27 **Cost & safety impact: SPMT to SPMT to structure bracing**

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26

MAMMOET

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- **MONITORING**

- **Considerations**:
- 10ft wide & thus more stable than SPMT if used as single trailer
- Less steering possibilities in most conventional trailer types
- Different loading chart for different types and brands

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering			X		
Specialism				X	
Availability (2014-2020)				X	
Mob / Demob			X		
Installing of equipment			X		
Speed of execution			X		
Demolition possibilities			X		
OVERALL IMPACT TO BUDGET			X		

28

MAMMOET

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- MONITORING

- **Considerations**:
- Great solution for value engineering

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering			X		
Specialism			X		
Availability (2014-2020)				X	
Mob / Demob					X
Installing of equipment				X	
Speed of execution		X			
Demolition possibilities			X		
OVERALL IMPACT TO BUDGET				X	

29 MAMMOET

ABC MOVE METHODS

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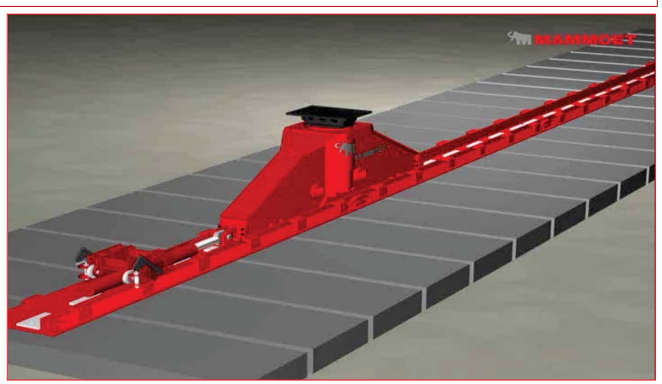

30 MAMMOET

ABC MOVE METHODS

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- **Considerations**:
- Great solution for value engineering
- Combination with jacking / installation
- Loads from 100- 750ton

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering			X		
Specialism			X		
Availability (2014-2020)				X	
Mob / Demob					X
Installing of equipment				X	
Speed of execution		X			
Demolition possibilities			X		
OVERALL IMPACT TO BUDGET				X	

31 MAMMOET

ABC MOVE METHODS

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- **Considerations**:
- Weather, water level
- Additional equipment needed: ballasting, winching, mooring, tugs
- Deck load calculations
- Can be used for spacing between other barges

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering		X			
Specialism		X			
Availability (2014-2020)		X			
Mob / Demob	X				
Installing of equipment				X	
Speed of execution	X				
Demolition possibilities		X			
OVERALL IMPACT TO BUDGET		X			

32 **Engineering is required on most additional equipment needed** MAMMOET

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- **MONITORING**

- **Considerations**:
- Load cells 5-750ton
- Lasers for measuring and / or compare distance
- Strain gauges for stress indication
- Pressure indicators for hydraulic cylinders

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering					X
Specialism			X		
Availability (2014-2020)					X
Mob / Demob					X
Installing of equipment					X
Speed of execution					X
Demolition possibilities				X	
OVERALL IMPACT TO BUDGET					X

33

ABC MOVE METHODS

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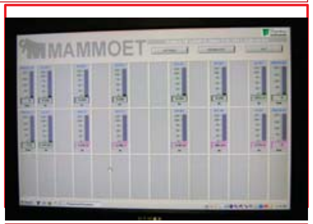


- **Considerations**:
- Software written for special projects
- Generic software is available
- Warnings based on parameters indicated by owner / engineering bureau

IMPACT TO YOUR BUDGET	$$$$$	$$$$	$$$	$$	$
Engineering					X
Specialism			X		
Availability (2014-2020)					X
Mob / Demob					X
Installing of equipment					X
Speed of execution					X
Demolition possibilities				X	
OVERALL IMPACT TO BUDGET					X

34 **S.F. Bay Bridge was vertical & horizontal monitored**

WHAT GOES UP MUST COME DOWN

Most structures can be removed by using same methods as for installation.

Keep in mind:

- Deterioration of structural members for support or lifting
- Weight prediction
- Cost savings when structure is lowered to manageable height for demolition access

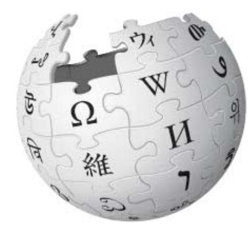
35 **Oakland Bay Bridge was lowered for demolition**

PROCURING ABC LIFTING & TRANSPORTATION SOLUTION

Procurement is the acquisition of goods, services or works from an external source.

It is favorable that the goods, services or works are **appropriate** and that they are procured at the **best possible cost** to meet the needs of the purchaser in terms of **quality** and **quantity**, **time**, and **location**.

Corporations and public bodies often define processes intended to promote **fair** and **open competition** for their business while **minimizing exposure** to fraud and collusion.



- From Wikipedia, the free encyclopedia

36 **Lifting and transportation costs can account up to 2-3%**

PROCURING AN ABC LIFTING AND TRANSPORT SOLUTION

- **Best possible cost** practices:
  - Method of lift and / or transport to be reviewed by specialized engineers
  - Support and lifting points to be designed in early stage of engineering
  - Construction of structure as low as possible but with ample space for transportation or lifting access
  - Combine removal and installation of structures with same equipment
  - Involve lifting / transportation contractor in design phase

Savings up to 20-30% of contract value can be achieved MAMMOET

PROCURING AN ABC LIFTING & TRANSPORT SOLUTION

- **Quality & Quantity practices**:
  - Education and experience should be documented for all involved in preparation and execution of project: training, testing, certification of employees.
  - Safety should not be reactive but pro-active: training, pre-employment & random drug screens, kick off, toolbox & lessons learned meetings.
  - Equipment maintenance & repairs according or surpassing guide lines of manufacturers, spare part management, documentation & certification.
  - Communication of whole project through available & clear lines.

Equipment maintenance shows when it stops working MAMMOET

PROCURING AN ABC LIFTING & TRANSPORT SOLUTION

- **Best possible cost avoidances**:

Adding extra weight	Extra equipment
False work	Transportation
Custom made rigging, towers, etc.	Fabrication
Extreme deadlines	Labor cost

MAMMOET

PROCURING AN ABC LIFTING & TRANSPORT SOLUTION

- **Quality and quantity avoidances**:

Engineering guidelines unclear	
Poor planning for mob /demob	Site congestion
On-site spectators	Liabilty

A safe employee is trained BEFORE entering your site MAMMOET


MAMMOET
THANK YOU FOR YOUR TIME

MDOT RC-1610

Accelerated Bridge Construction and Structural Move - Workshop

MARCH 2014

Department of Civil & Construction Engineering
College of Engineering and Applied Sciences
Western Michigan University

Research

Accelerated Bridge Construction and Structural Move - Workshop

Appendices

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Submitted to:

MDOT

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APPENDIX D (PART-II)

WORKSHOP PRESENTATIONS

Accelerated Bridge Construction / Structural Slide and Move Workshop

A range of proven techniques for the sliding of bridges and structures

Presented by Brent Archibald, P.Eng.

Delcan

Acknowledgement

Some of these projects were carried out by others than Delcan

Delcan

A Historical Note: Jacques Cartier Bridge - Montreal

Bridge Sliding is not a new initiative:

On October 20,1957 a 3000 ton truss was laterally rolled into position as a part of the raising of the bridge for the St. Lawrence Seaway. This is the same weight as the Dundas Street Bridge in Trenton, Ontario (presented later).

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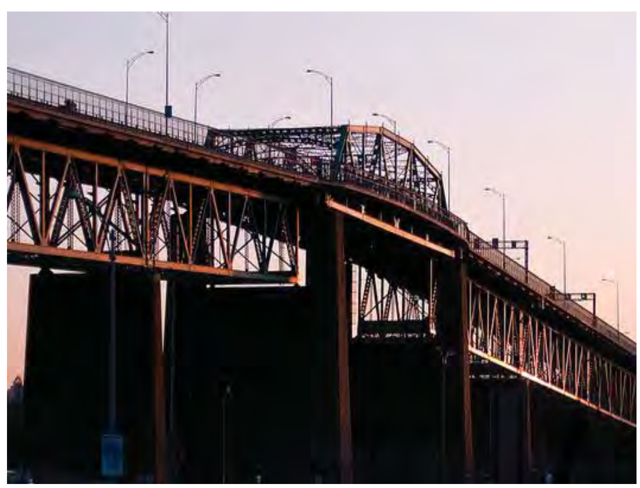

Projects for Discussion

- Dundas Street Bridge – lateral slide
- Don Valley Parkway Underpass – jacking and mining
- West Toronto Diamond – lateral slide

Common constraints which have lead to the implementation of non-traditional construction methods:

- Maintenance of traffic / operations
- Maintenance of utilities
- Maintenance of transportation structures and buildings

Delcan

Inspiration for Dundas Street Bridge

Qauibrucke Bridge, Switzerland

- River Limat at Zurich
- 7800 tonnes
- 54 hour slide performed by VSL
- Both bridges slide at once
- Flexible foundations
- 20 months saved

Inspiration for Complex Bridges

Bridge Near Landquart, Switzerland

- Arch Bridge
- 112 meter (367 ft) span
- Dual plane guiding system

Dundas Street Bridge

- 3 Span Continuous Bridge
- 3000 tonnes
- 4 hour slide
- 10 meter (33 ft) slide
- 8 day possession
- Year 1990

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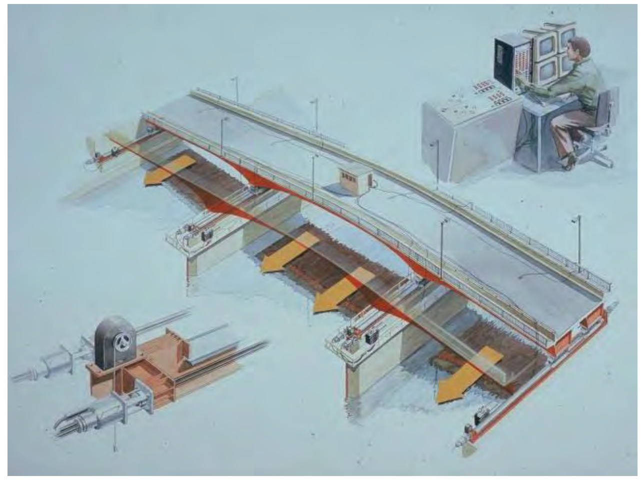
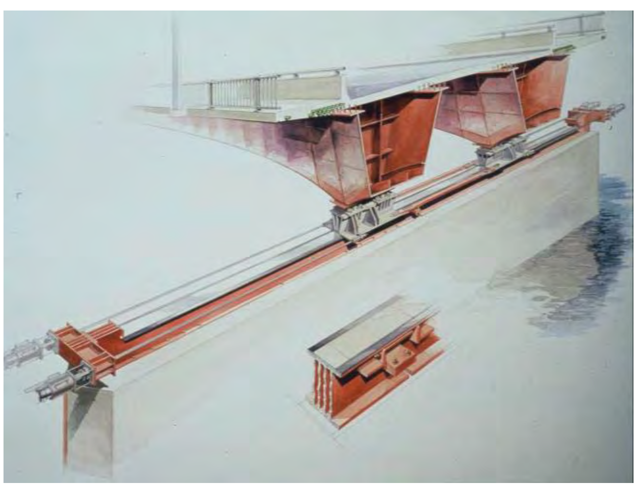




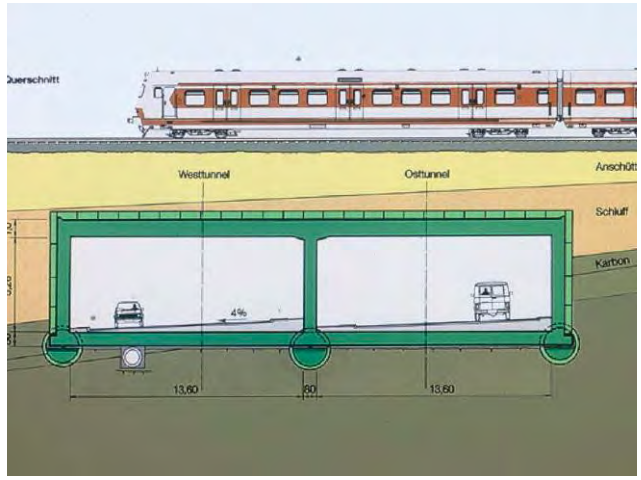

Computer Controlled Jacking System


Dundas Street Bridge
System Characteristics
Integration with overall bridge design
Communication system
Central computer control
Precision hydraulic jacking system
Safety and backup system
Maximum cost-effectiveness

Inspiration for DVP Underpass

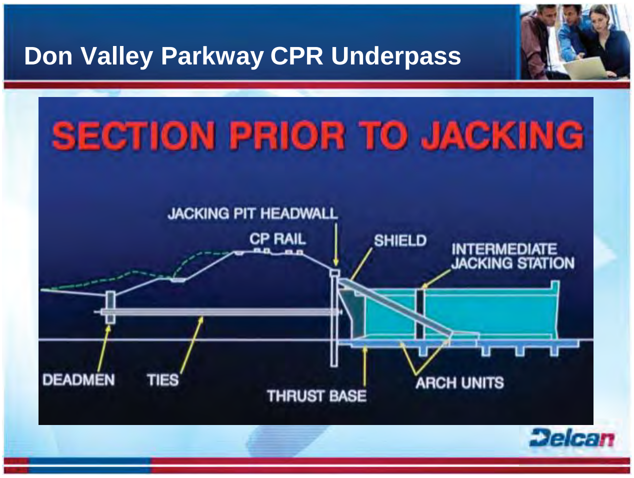
Bochum Underpass

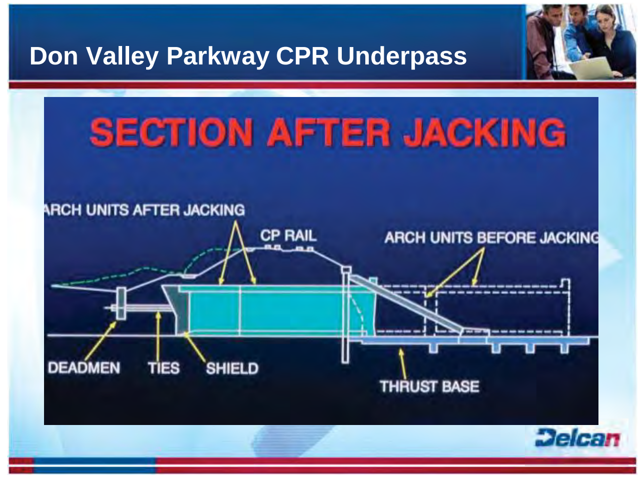
- Twin cell
- Totally shielded
- 5 electrified rail lines
- Long stroke jacks
- 3 slide paths
- Mixed face



Don Valley Parkway CPR Underpass

- Single cell
- 2000 tonnes
- 11 day jacking and mining operation
- 30 meter (98 ft) slide


Don Valley Parkway CPR Underpass
SECTION PRIOR TO JACKING
JACKING PIT HEADWALL
CP RAIL
SHIELD
INTERMEDIATE JACKING STATION
DEADMEN
TIES
THRUST BASE
ARCH UNITS
Delcan


Don Valley Parkway CPR Underpass
SECTION AFTER JACKING
ARCH UNITS AFTER JACKING
CP RAIL
ARCH UNITS BEFORE JACKING
DEADMEN
TIES
SHIELD
THRUST BASE
Delcan


JOHN DEERE 15


CP Rail
CP Rail


OFFICE LEASING
CONCORDE
863-1215

Don Valley Parkway CPR Underpass

Conclusion

- Construction completed successfully
- No damage to existing structures
- No interference with CP Rail traffic
- No effect on Don Valley Parkway traffic
- 6 months ahead of schedule
- Introduction of new technology to North America
- Potential application at major transportation corridors

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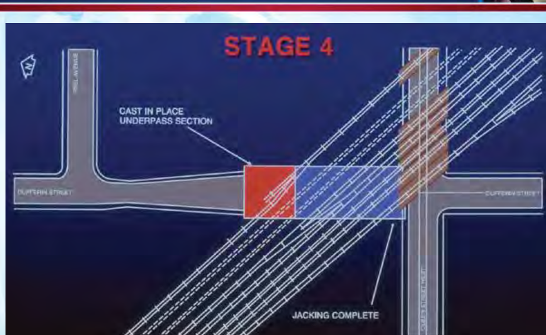
Dufferin Underpass - Toronto
Not everything gets to slide



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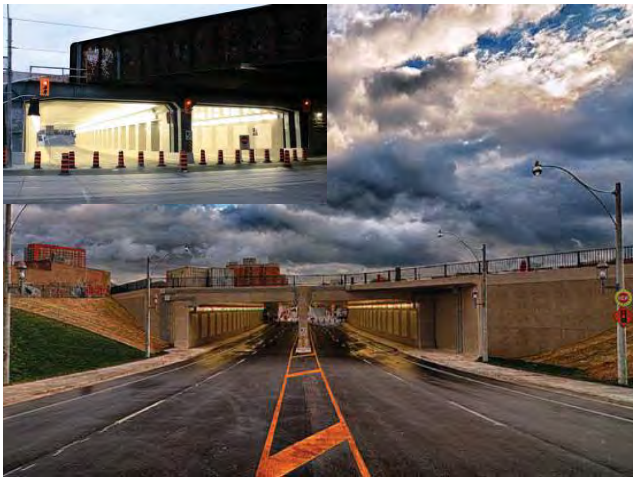

West Toronto Diamond

- 4 pre-stressed /post-tensioned slab bridges
- 5m test slides
- NOTO (2 bridges)
  - 1800 tonnes each
  - 28m (92 ft) slide in 2 hours
  - 24 hr track possession
- OWR (2 bridges)
  - 4500 tonnes each
  - 80m (262 ft) slide in 6 hours
  - 40 hour possession

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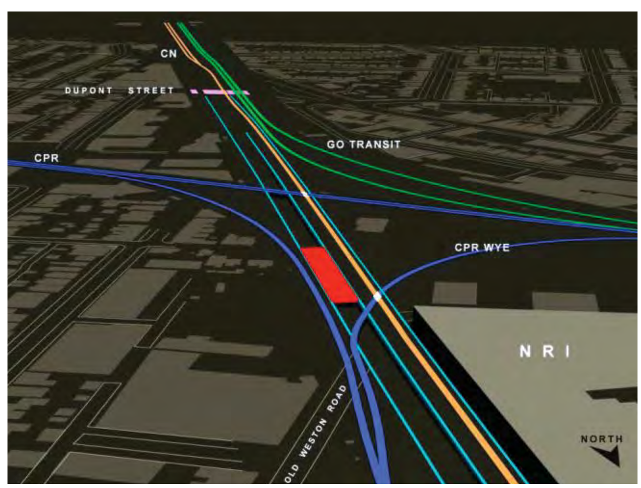

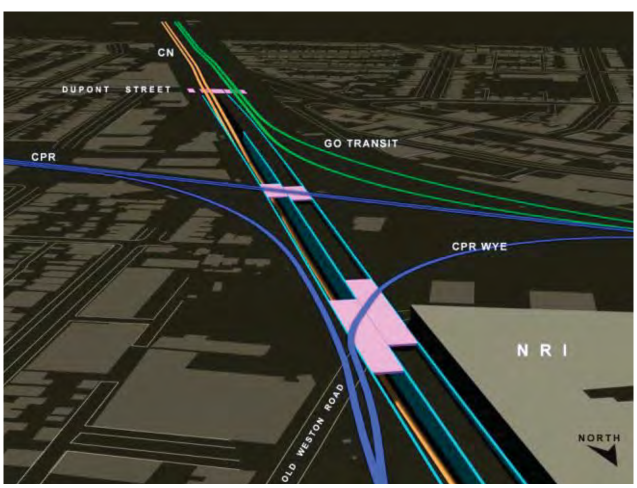

West Toronto Diamond

- Tandem jacks
  - Est. Rate = 20m/hr (65 ft/hr)
- Single jack
  - Est. Rate = 10-12m/hr (33-40 ft/hr)
- Bronze on Steel (friction)
  - 15% static
  - 8% dynamic

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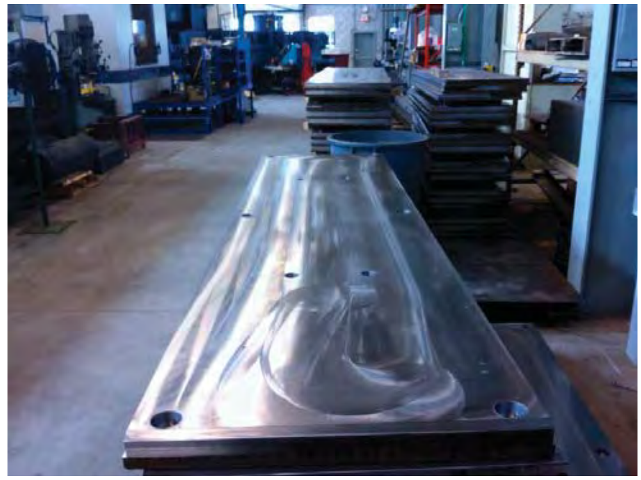
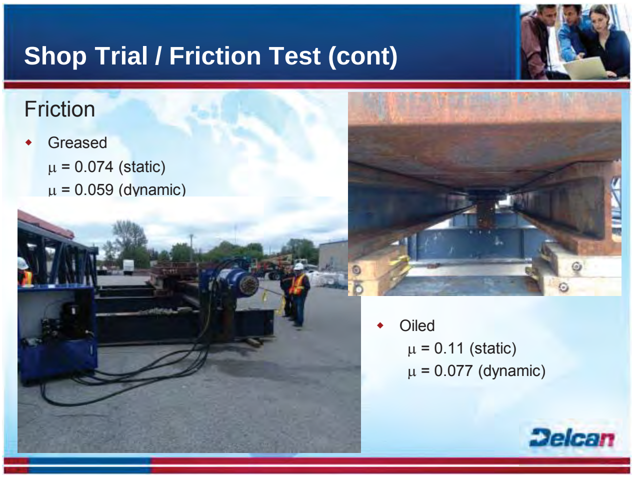
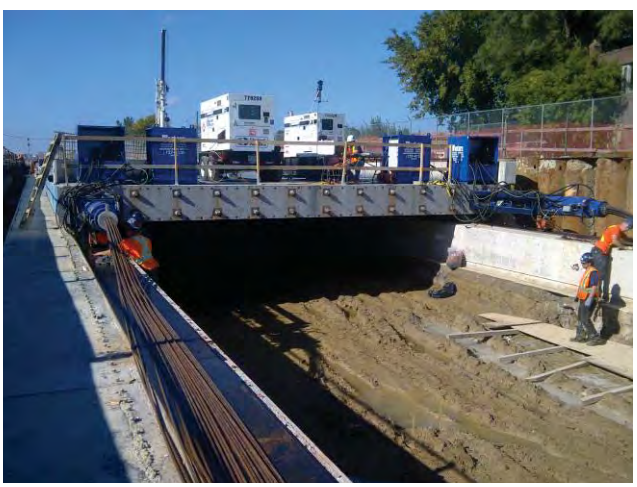



Shop Trial / Friction Test (cont)
Friction
Greased
μ = 0.074 (static)
μ = 0.059 (dynamic)
Oiled
μ = 0.11 (static)
μ = 0.077 (dynamic)
Delcan





CAT



West Toronto Diamond

<u>Conclusion</u>

- First two slides completed successfully, second two scheduled for summer 2014.
- Limited interference with CP Rail traffic
- Eliminated need for track diversion, property and relocation of railway infrastructure.

Delcan

ABC - Structural Slide and Move Workshop

Lansing, MI
December 09, 2013

HNTB

DISCUSSION

Part 1 – Sliding
Part 2 – Launching
Part 3 – Lifting and Floating

HNTB

CONSTRUCTION METHODS

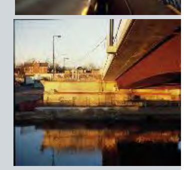
- Floating
- Launching
- Sliding
- Jacking
- Lifting
- Combination

HNTB

MDOT Workshop

Part – 1 Sliding

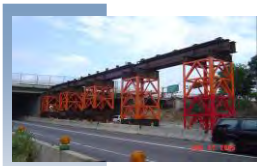
Trenton
Dingle Ridge
Jamaica – Hillside



HNTB

Reconstruction of Hillside and Jamaica Avenue Bridges - Van Wyck Expressway

Pier Bents



Jacking Down

Rolling Technology

Bearing carriage

Sliding Jacks – Manifolded and Synchronized

HNTB

MDOT Workshop

Part – 2 Launching

Iowa River
Puenta Chiapas
Schrote
Meaux

HNTB

Incremental Launching!

Segmental concrete

HNTB

OPTIMAL DIMENSIONS FOR LAUNCHING

- Spans over 80' with a steel launching nose
- Spans up to 210' with king post and stays
- Temporary piers
- Bridge length between 300' and 4500'

HNTB

GEOMETRY REQUIREMENTS

- Tangent in plan and tangent or circular in profile
- Circular in plan and horizontal in profile
- Spirals possible with wider launch bearings
- Varying-width deck slab possible

HNTB

US-20 Iowa River Bridge

HNTB

Launching Nose

HNTB

Launching Pit

HNTB

Rolling Hardware

HNTB

Replacement of Belleaire Causeway

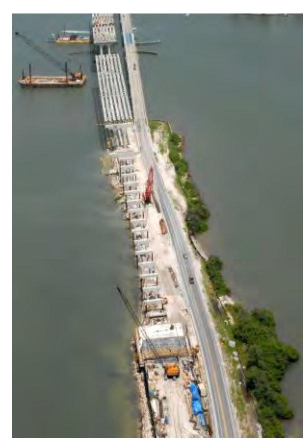
Pinellas County

HDR

Project Background

HDR

Work Space

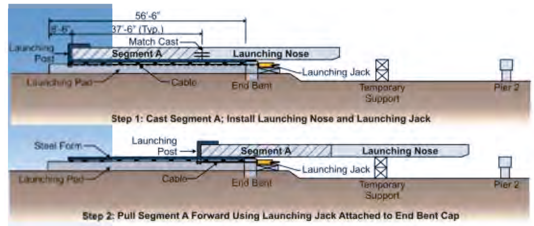


HDR

Work Space

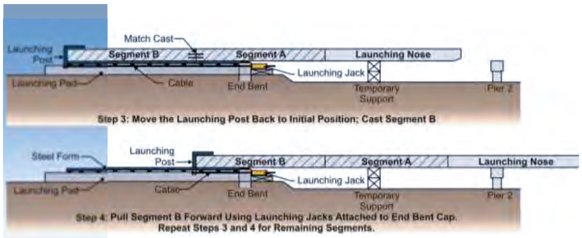
HDR

Launching Sequence



HDR

Launching Sequence



HDR

Formwork

Bulkheads and Anchors

PT and Rebar

HDR

Hydraulics

HDR

Launching Nose and Intermediate Pier

HDR

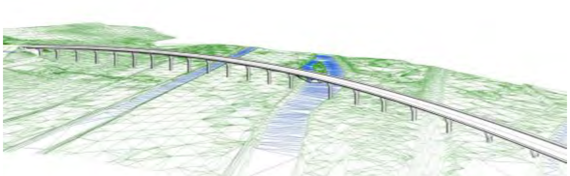
Puente Chiapas – Mexico
Long Span

HNTB

Puente Chiapas – Mexico
300 feet of water

HNTB

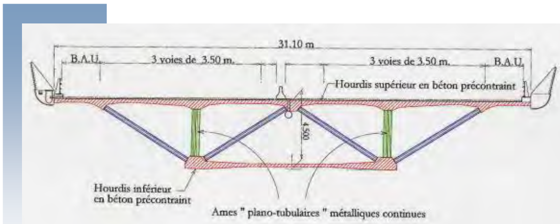
Meaux - Panorama



Total length 3,900 ft
Typical spans ±160 ft
River crossing 300ft

HNTB

Superstructure Cross Section



HNTB

General view of the precasting area

Staging Area 1 – Setting the web


Staging Area 2 –
Bottom Slab


Staging Area 3 –
Construction of top slab and struts


Staging Area 4 –
Final posttensioning and painting


Launching nose – 130ft
Jacking force 1,430 tons

Clifford Hollow - WVa

Congested Urban Environments

Small casting yard with no additional right-of-way

- compact casting yard on the footprint of approach embankment
- easy duplication of existing overpasses
- no need for heavy transportation, minimal use of ground cranes
- high quality from no form deflections

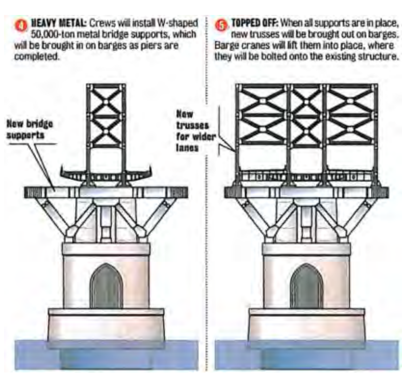
MDOT Workshop

Part – 3
Lifting, Floating and Equipment

Huey P. Long
Hastings
Chavanon
US 17

HNTB

HUEY P. LONG

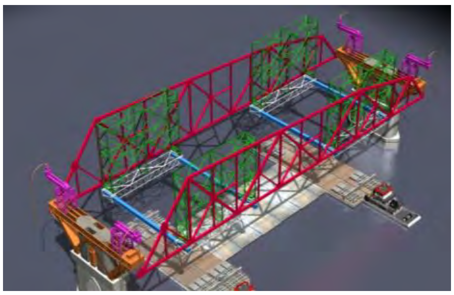


HNTB

WIDENED PIERS

HNTB

Erection Frame



HNTB

Erection Frame – Preassembly off site

Float In

HNTB

Span-By-Span Erection

Straddle Widening Trusses

Lateral Slide

HASTINGS - Foursome

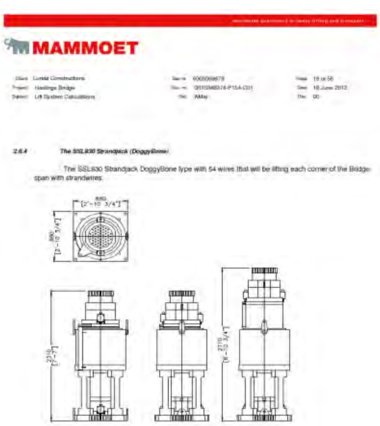
HASTINGS - Float

HNTB

Hastings – Sliding and Lifting

Skidding and Lifting

HNTB



MAMMOET

Client Lunda Constructions
Project Hastings Bridge
Subject Lift System Calculations

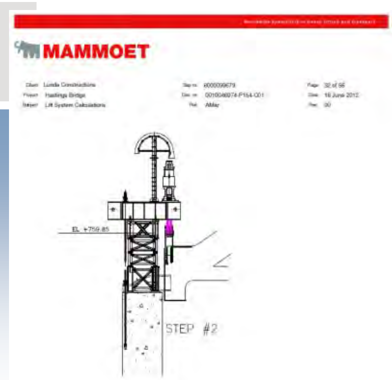
Doc no 0010046974-P154-C01
Ref AMar

Date 18 June 2012
Rev 00

2.6.4 The SSL830 Strandjack (DoggyBone)

The SSL830 Strandjack DoggyBone type with 54 wires that will be lifting each corner of the Bridge-span with strandwires.

HNTB



MAMMOET

Client Lunda Constructions
Project Hastings Bridge
Subject Lift System Calculations

Doc no 0010046974-P154-C01
Ref AMar

Page 32 of 56
Date 18 June 2012
Rev 00

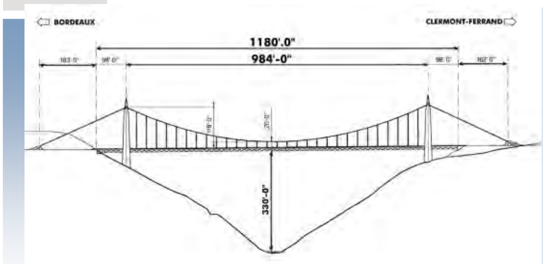
HNTB

Chavanon

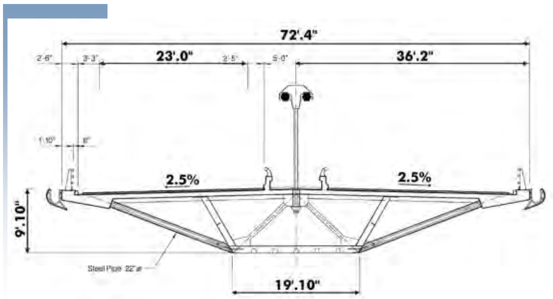
JEAN MULLER INTERNATIONAL

HNTB

Axial Suspension Bridge

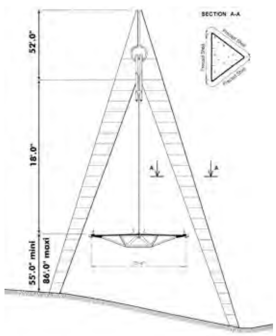


Steel Box Girder - Struts



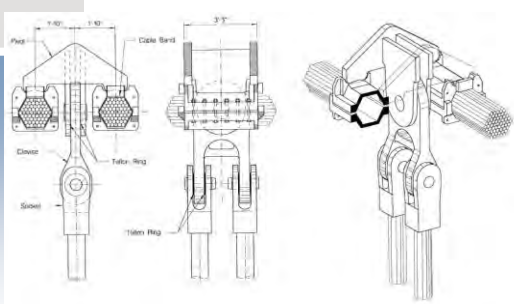
Fabrication Shed

Towers



Prepare to Launch

Permanent Hanger Assemblies



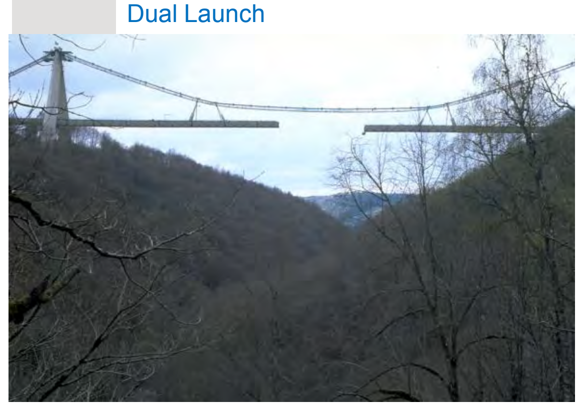
Installation of Permanent Hanger Assemblies

Temporary Hanger – Stage 1

Temporary Hangers 2– Stage

Temporary Hanger Details

Dual Launch



Approaching Closure

Exotic Equipment

US 17 Bypass – Washington, NC

HNTB

Federal Highway Administration

Every Day Counts

Innovation Initiative

National Perspective on ABC Implementation

Benjamin Beerman, P.E.
FHWA Resource Center

Michigan DOT
December 9, 2013

Overview

- EDC Initiative: ABC and PBES
- What is PBES
- Resources implementation
- What are we realizing with ABC/PBES?

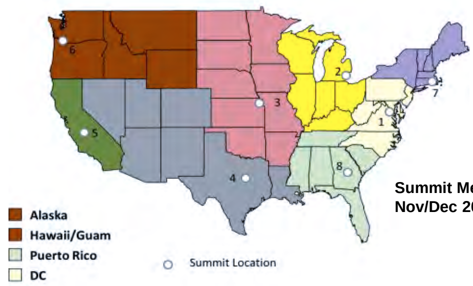
Every Day Counts Initiatives

Safety

Quality

Overall Program Delivery

Every Day Counts II 2012-14



Summit Meetings Nov/Dec 2012

www.fhwa.dot.gov/everydaycounts

EDC II – Initiatives

Shortening Project Delivery

- Programmatic Agreements II
- Locally Administered Federal Aid
- 3 Dimensional Modeling
- Intelligent compaction
- **Accelerated Bridge Construction**
- Design Build
- CMGC
- Alternative Technical Concepts (ATC)

21ST Century Solutions

- High Friction Surfaces
- Intersection and Interchange Geometrics
- Geospatial Data Collaboration
- Environmental Documentation
- First Responder Training (SHRP 2)

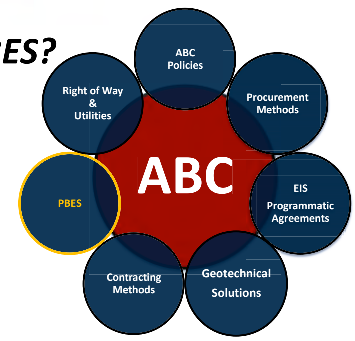
Opportunity!

"The EDC program allows bridge practitioners an opportunity to ***advance ABC innovations such as PBES into the mainstream of the bridge industry***. "

Deployment Activities

- **Workshops**
- **Webinars**
- **Scanning Tours**
- **Project Reviews**
- **Project Showcases**
- **Regional Peer Exchanges**

ABC and PBES?

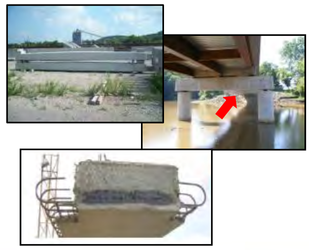


Definition of PBES

PBES are structural components of a bridge that are built offsite, or adjacent to the alignment, and includes features that reduce the ***onsite construction* time** and ***mobility impact time*** that occurs from ***conventional construction*** methods.

Element vs. System?

Elements



Systems

What are PBES?

Elements: single structural component of a bridge

- Deck Element
- Beam Elements
  - "Deck" Beam Elements
  - "Full-Width" Beam Elements
- Pier Elements
- Abutment & Wall Elements
- Miscellaneous Elements

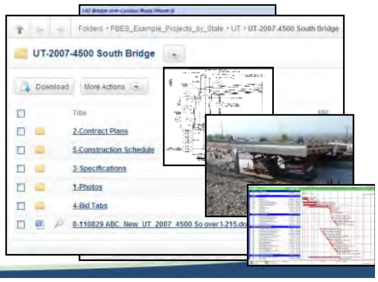
What are PBES?

Systems: - entire superstructure,
- entire superstructure & substructure,
- total bridge

National ABC/PBES Project Exchange

Project Examples use PBES/ABC

- Contract Plans
- Specifications
- Bid Tabs
- Schedule
- Pictures



- **ABC Project Exchange User's Guide**:
  Refer to the **July 25, 2013** (National ABC Project Exchange) webinar hosted by the FIU ABC Center
  http://www.abc.fiu.edu/archive-of-past-events/

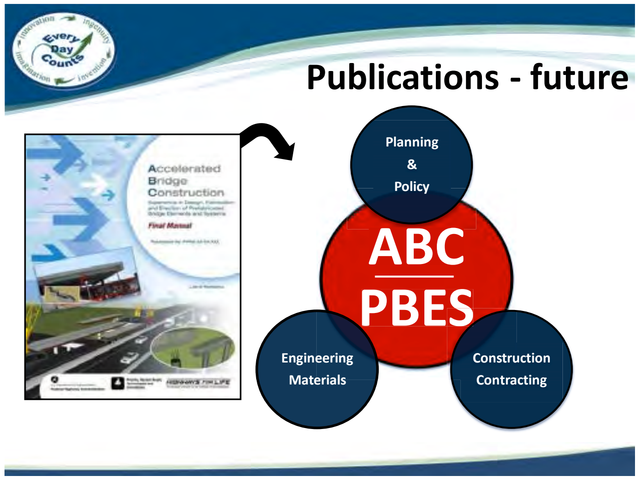
- **FHWA External Collaboration Portal**
  1) Register &
  2) Request Site Access
  https://www.transportationresearch.gov/dot/fhwa/default.aspx

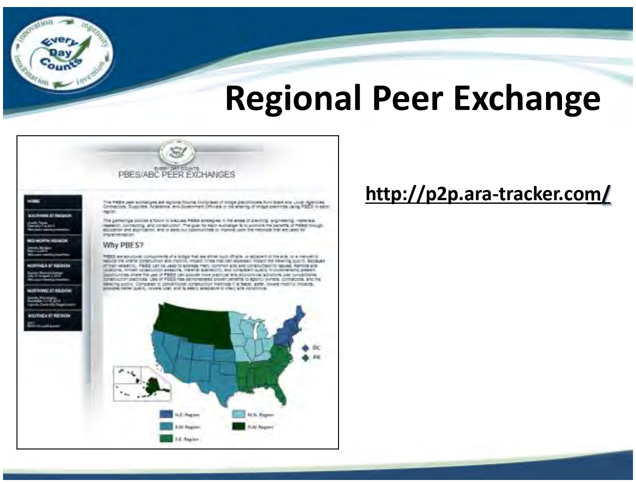
Other Resources

Webinar Training - Industry

www.fhwa.dot.gov/everydaycounts/technology/bridges/pbeswebinartraining

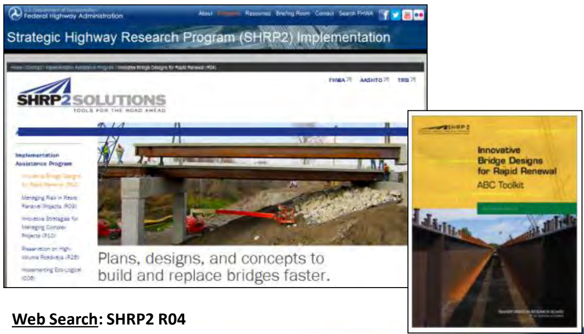

Every Day Counts
Publications
Accelerated Bridge Construction
Experience in Design, Fabrication and Erection of Prefabricated Bridge Elements and Systems
Final Manual
Manual on Use of Self Propelled Modular Transporters to Remove and Replace Bridges
www.fhwa.dot.gov/bridge/prefab/pubs.cfm


Every Day Counts
Publications - future
Accelerated Bridge Construction
Final Manual
Planning & Policy
ABC
PBES
Engineering Materials
Construction Contracting


Every Day Counts
Regional Peer Exchange
PBES/ABC PEER EXCHANGES
Why PBES?
http://p2p.ara-tracker.com/


Every Day Counts
Webinar Training - FIU
FIU Accelerated Bridge Construction (ABC) Center
Florida International University
Thursday, December 19, 2013 – 1:00 to 2:00 p.m. Eastern
New York State's I-84/Dingle Ridge Lateral Slide Project
Jerry A. DiMaggio, PE
Bala Sivakumar, PE
www.abc.fiu.edu

SHRP2 – R04



Web Search: SHRP2 R04

Other Websites

www.pcine.org/

www.udot.utah.gov/

Formation of ABC Subcommittee

AFF10 General Structures – parent committee
AFF10(3) – Subcommittee for ABC

Chair: Ben Beerman, FHWA
Vice Chair: Mary Lou Ralls

https://sites.google.com/site/trbaff103

Recent ABC NCHRP projects

- Development of an Accelerated Bridge Construction (ABC) Design and Construction Guide Specification: NCHRP 12-102

- Guidelines for Tolerances for Prefabricated Bridge Elements and Systems and Dynamic Effects in Large-Scale Bridge Moves: NCHRP 12-98

PBES/ABC and MAP-21

- **Section 1304**

  Allows Federal participation to be increased by up to 5% (not to exceed 100%) of the total project cost for projects that include innovations such as PBES technologies.

Incentive Grant Program

- Accelerated Innovation Deployment Grant

  FHWA-2013-0048
- NOFA comments due 11/22/13
- $15M/year
- Up to $1M/project

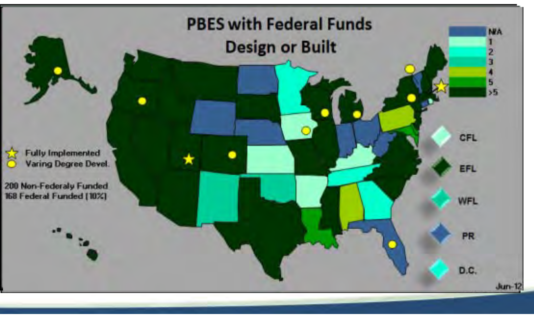
www.fhwa.dot.gov/accelerating/grants/index.cfm

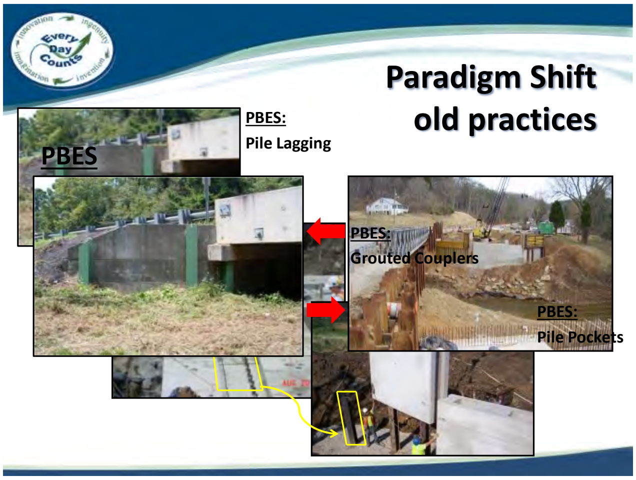
Resources - Summary

- **ABC Project Exchange:**
  - User Guide (FIU – July 25, 2013 webinar) http://www.abc.fiu.edu/event-on-07252013/
  - FHWA Collaboration Portal https://www.transportationresearch.gov/dot/fhwa/default.aspx
- **PBES Webinar Training:**
  - www.fhwa.dot.gov/everydaycounts/technology/bridges/pbeswebinartraining
- **PBES Peer Exchanges:**
  - http://p2p.ara-tracker.com/
- **ABC/PBES Publications:**
  - www.fhwa.dot.gov/bridge/prefab/pubs.cfm
- **Ongoing monthly ABC webinars via FIU:**
  - www.abc.fiu.edu
- **SHRP2 R04 Product:**
  - http://www.fhwa.dot.gov/goshrp2/
- **PCI North East:**
  - www.pcine.org/
- **Utah DOT:**
  - http://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:1991
- **TRB ABC Subcommittee AFF10(3):**
  - https://sites.google.com/site/trbaff103
- **MAP 21:**
  - http://map21.transportation.org/Pages/MAP21Bill.aspx
- **Innovative Funding Grant Program:**
  - http://www.fhwa.dot.gov/accelerating/grants/index.cfm

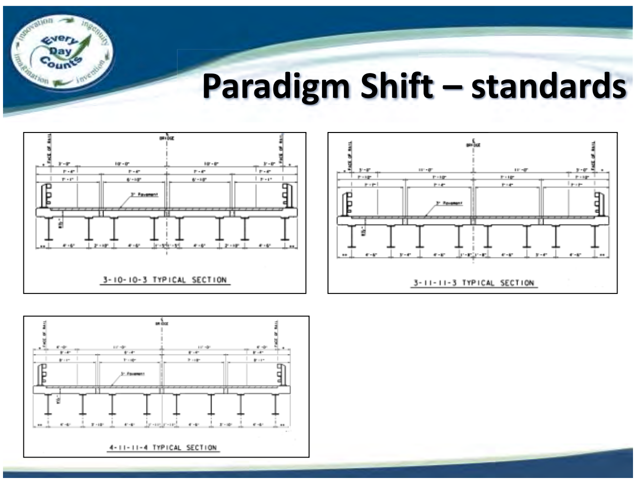
What has been done?

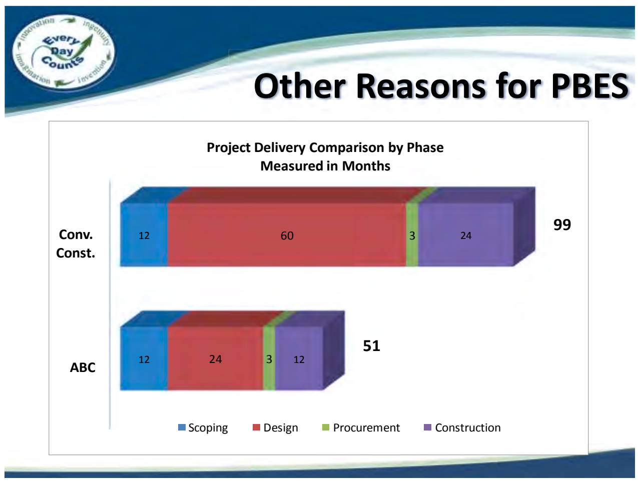
850 bridge projects




Paradigm Shift
old practices
PBES
PBES:
Pile Lagging
PBES:
Grouted Couplers
PBES:
Pile Pockets


Paradigm Shift
strategies


Paradigm Shift – standards
3-10-10-3 TYPICAL SECTION
3-11-11-3 TYPICAL SECTION
4-11-11-4 TYPICAL SECTION

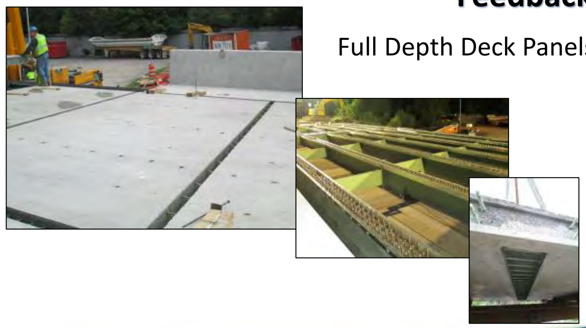

Other Reasons for PBES
Project Delivery Comparison by Phase
Measured in Months
Conv.
Const.
12
60
3
24
99
ABC
12
24
3
12
51
Scoping
Design
Procurement
Construction

Contractor's Feedback

Prefabricated Piers (columns/caps)

Contractor's Feedback

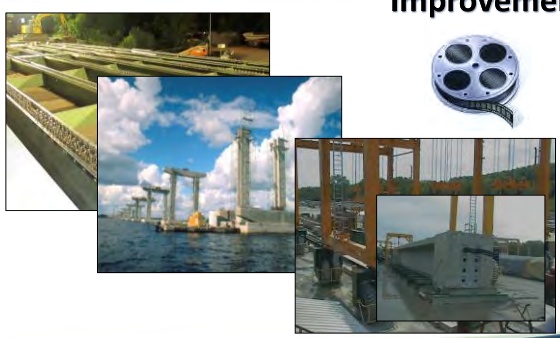
Full Depth Deck Panels



Contractor's Feedback

SPMTs

Opportunities for Improvement



Public and Political Capitol

PBES/ABC is a positive message!

"As stewards of the transportation program, we are doing due diligence to meet the needs of the traveling public."

Thank You!

FHWA

Benjamin Beerman, P.E.

Resources - Summary

- **ABC Project Exchange:**
  - User Guide (FIU – July 25, 2013 webinar) http://www.abc.fiu.edu/event-on-07252013/
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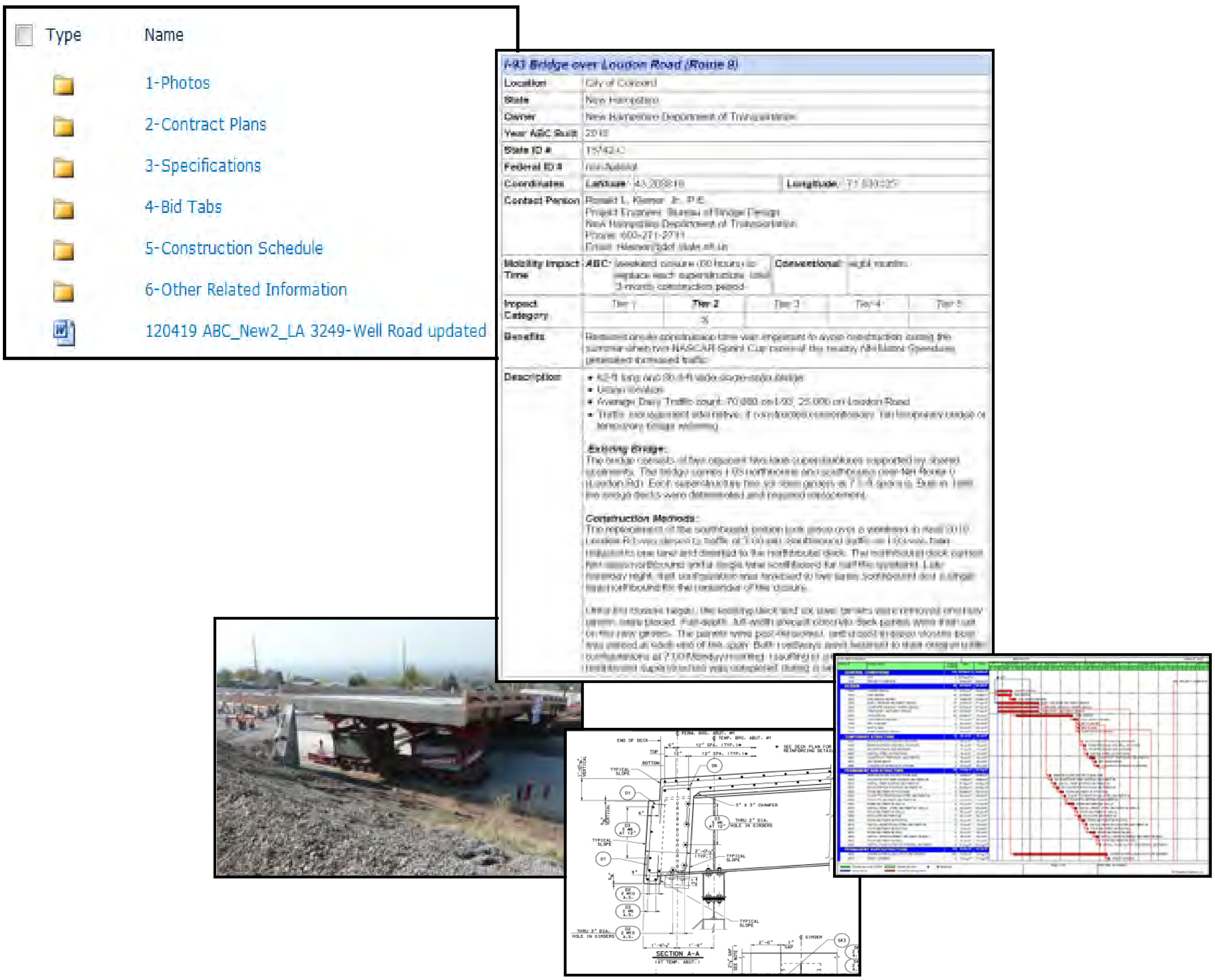
  - http://www.fhwa.dot.gov/goshrp2/
- **PCI North East:**
  - www.pcine.org/
- **Utah DOT:**
  - http://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:1991
- **TRB ABC Subcommittee AFF10(3):**
  - https://sites.google.com/site/trbaff103
- **MAP 21:**
  - http://map21.transportation.org/Pages/MAP21Bill.aspx
- **Innovative Funding Grant Program:**
  - http://www.fhwa.dot.gov/accelerating/grants/index.cfm

National ABC Project Exchange

User's Guide

July 18, 2013



U.S. Department of Transportation
Federal Highway Administration

AASHTO
SUBCOMMITTEE ON BRIDGES AND STRUCTURES

National ABC Project Exchange User's Guide

Intro

The Accelerated Bridge Construction (ABC) Project Exchange is a nationwide repository of projects that have incorporated Prefabricated Bridge Elements and Systems (PBES) with other innovative strategies to accomplish the objects of ABC. The purpose of the site is to share detailed project information and experiences among bridge practitioners located throughout the United States and abroad.

Development and management of this site is through a collaborative effort between the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO).

The posted information is made available to anyone who has registered and requested site access.

This User's Guide provides detailed information and instructions in the following areas:

- Site structure & navigation
- How to register & request site access
- Using the ABC Project Exchange
- Support

Disclaimer

The State Departments of Transportation (State DOT's) who submitted their information to help develop this site have approved the material contained in the ABC Project Exchange for posting and distribution. All attempts are made to assure the accuracy of the content posted; however, the FHWA, AASHTO, State DOT's and any person or organization that has assisted in collecting and compiling the posted information are not responsible for the accuracy of the material, or the manner in which it is interpreted or used.

Site Structure and Navigation

<u>Site Structure and Navigation</u>

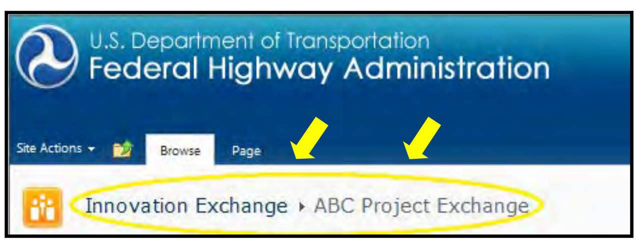
The information in the **ABC Project Exchange** is housed on the **Innovation Exchange** - which is a shared platform for discipline specific groups to exchange information as a means to advance innovations into the transportation industry.

The **Innovation Exchange** is a closed community that resides on the **FHWA's External Collaboration Portal** - which is hosted on the U.S. Department of Transportation's Research and Innovation Technology Administration site (**DOT's RITA** site).

The following demonstrates the hierarchy of the site structure…

DOT's RITA site

FHWA's External Collaboration Portal



Innovation Exchange
ABC Project Exchange

<u>Note</u>: You will be required to **Sign In** when:

- requesting site access to the **Innovation Exchange**
- accessing the **ABC Project Exchange** from the **FHWA External Collaboration Portal**

After successfully signing in, you will be sent to the **DOT's RITA** site. As shown above…

- Select the "**Federal Highways Sites**" tab to return to the **FHWA External Collaboration Portal**.
- Scroll down the page and select the **ABC Project Exchange** link to go directly to the **ABC Project Exchange** welcome page.

Banner headings similar to what is shown above are captioned in yellow throughout this User's Guide as a navigational aid.

How to Register and request Site Access

Privacy Policy

Your contact information will be required for site access to the ABC Project Exchange. Apart from your first and last name, no other contact material will be posted on the ABC portion of the Innovation Exchange. Sharing of contact information that is not approved for posting on the ABC Project Exchange is considered illegal. For more information related to the privacy policy for the ABC Project Exchange go to the following link: https://www.transportationresearch.gov/dot/fhwa/SitePages/ContactUs.aspx.

Registration & Site Access

Access to the **National ABC Project Exchange** is a sequential, two-step process. An overview of the process is shown below:

Step 1: **Register** an account on the **FHWA's External Collaboration Portal**
[**Registration** approval occurs within 24 hours]

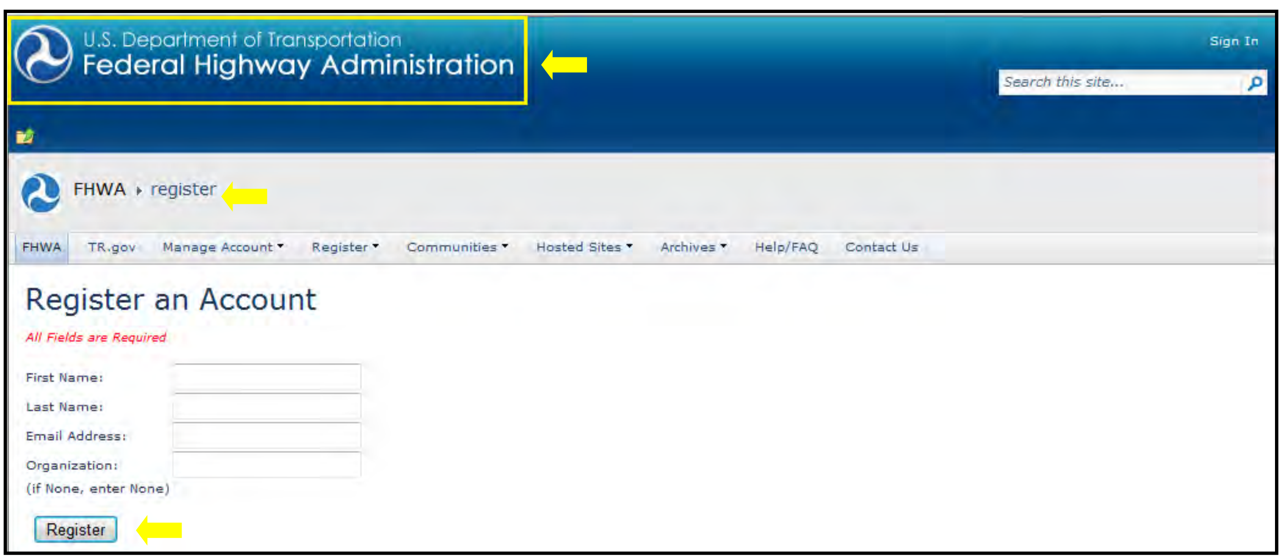
Step 2: **Request Access** to the **Innovation Exchange** – which is a closed Community on the **FHWA's External Collaboration Portal** that houses the **ABC Project Exchange**
[**Site Access** approval occurs within 24 hours]

Note: Registration approval in Step 1 must be received prior to proceeding to Step 2.

Step 1: Registration

- Go to the **FHWA's External Collaboration Portal** Registration link:
  https://www.transportationresearch.gov/dot/fhwa/SitePages/register.aspx

- Enter the information requested as shown below.



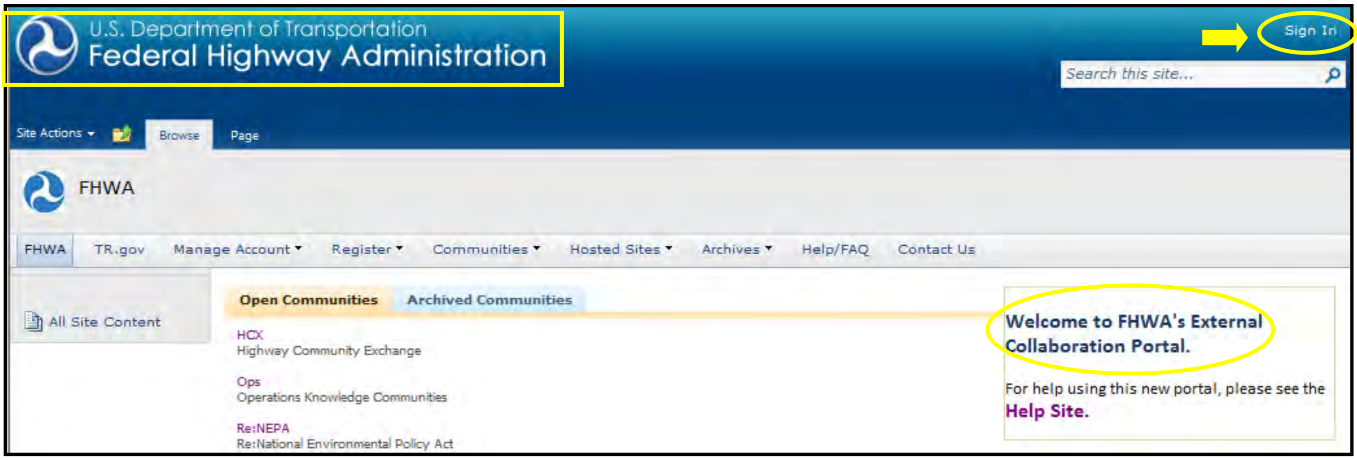
- For security purposes, two emails will be provided within ***24 business hours.*** They will include a UserID and Temporary Password required for Step 2.

- Proceed to Step 2. **Site Access** (next page)

Step 2: Site Access

- After a UserID and password is provided from Step. 1, go to the **FHWA's External Collaboration** site: **https://www.transportationresearch.gov/dot/fhwa/default.aspx**

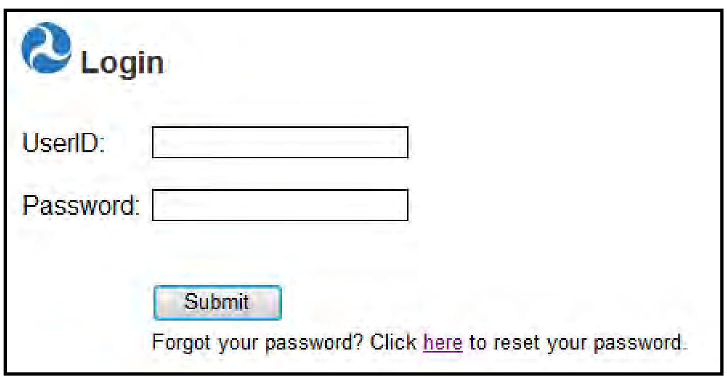
- As shown below, select the **"Sign In"** icon located in the upper right hand corner of the screen…



- and the Login Screen as shown below will appear.

- Enter the Information Requested using the UserID and Password provided in Step 1.

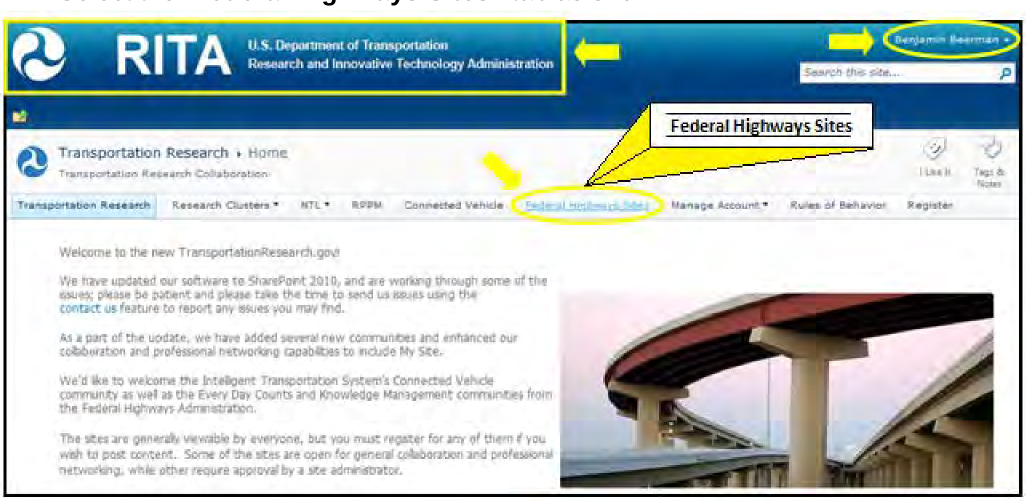
- Select the "**Submit**" icon.



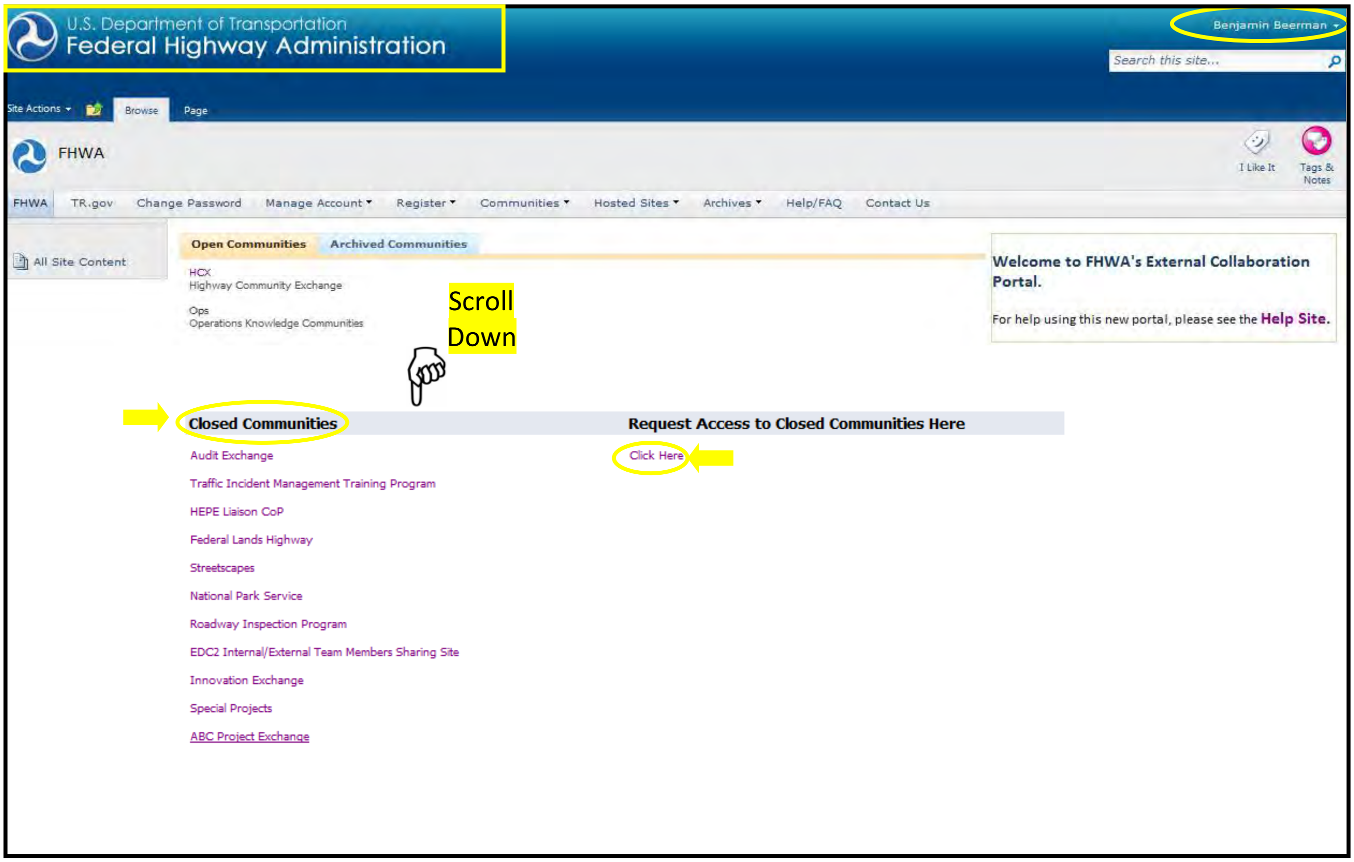
- As shown below, you will be sent to the **DOT's RITA** site.

  Note: your user name shown to the right of the screen indicates that you are **Signed In**

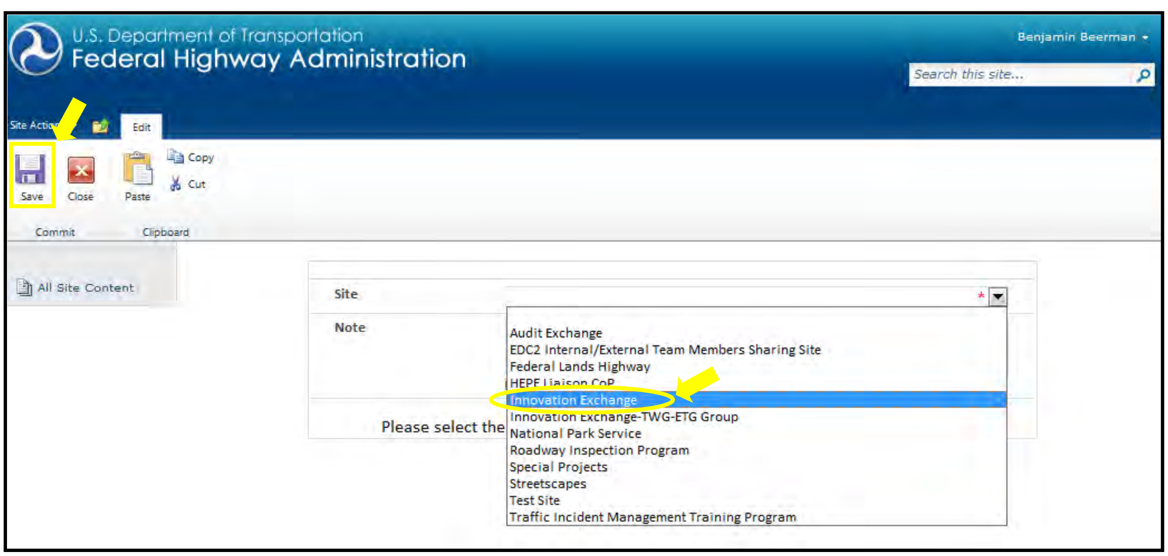
- Select the "**Federal Highways Sites"** tab as shown….



- to be sent back to the **FHWA's External Collaboration Portal** as shown below.
- Scroll down the page to the "***Closed Communities"*** heading and
- **Request Site Access** to the **Closed Communities** by selecting the "***click here***" link as shown.



- Select "**Innovation Exchange**" from the pull down menu as shown below…
- In the "**Note**" box type the following: "***Request access to the ABC Project Exchange***"
- Select the "**Save**" icon.

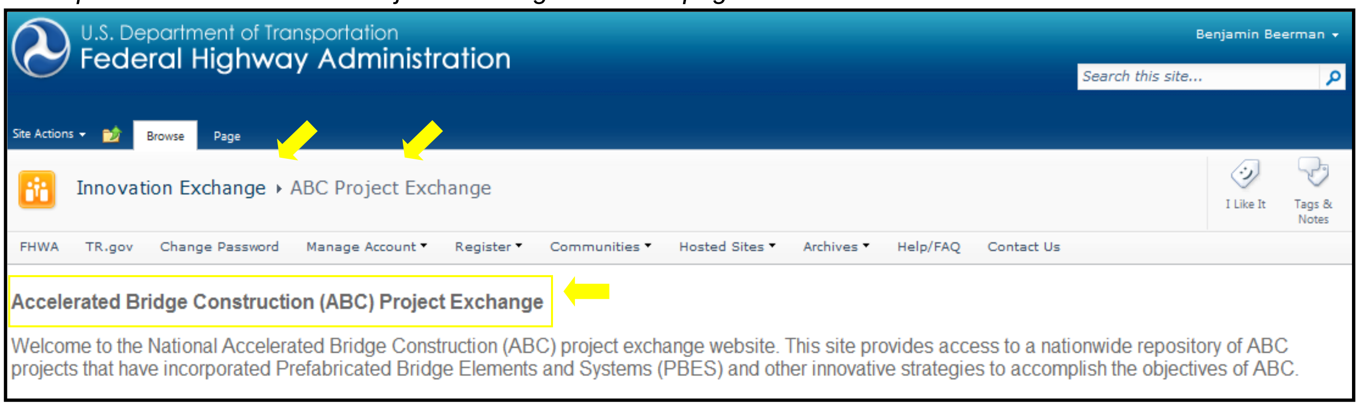


- A second email confirming **Access** to the **Innovation Exchange,** which houses the **ABC Project Exchange** will be provided within ***24 business hours***.

Registration and Site Access is now complete.

Once an email confirming you have access to the Innovation Exchange is received, you will be allowed to access to the National ABC Project Exchange.

A partial view of the ABC Project Exchange welcome page is shown below…



Using the ABC Project Exchange

- Contents and Organization
- Sign In and Navigation
- Search for project information
- Download and View documents and photos
- The Project Summary Report
- Support

Contents and Organization

The **ABC Project Exchange** contains detailed project information organized by state directory. Within each state directory are project folders that include a **Project Summary Report** (in a MS Word document) and information organized in the following subdirectories:

1. Photos
2. Contract Plans
3. Specifications
4. Bid Tabs
5. Construction Schedule
6. Other related information

Project Summary Report

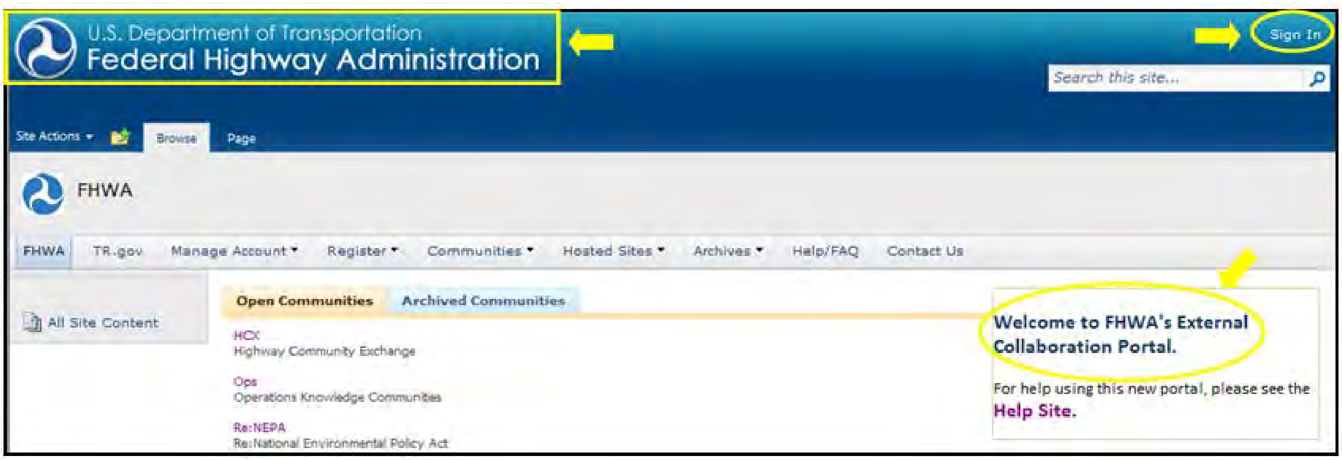
Note: If a subdirectory is not shown, the information is not available.

To access this information, you must be **Registered** and have **Site Access** to the **Innovation Exchange**.

Sign In and Navigation- after Registration and Site Access

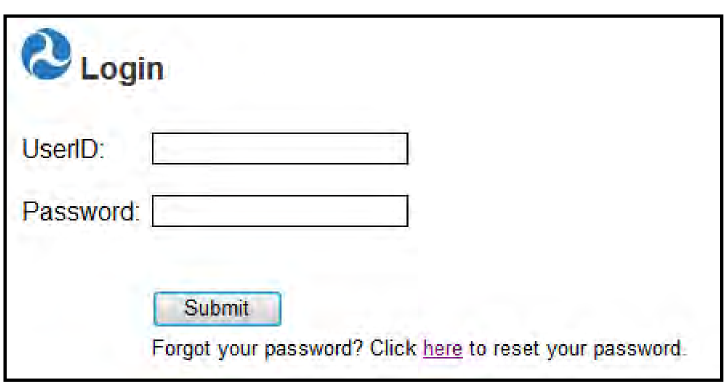
- Go to the **FHWA's External Collaboration Portal** at the following link:
  https://www.transportationresearch.gov/dot/fhwa/default.aspx

- Select the "**Sign In**" tab as shown below.



- The following Login window will appear.

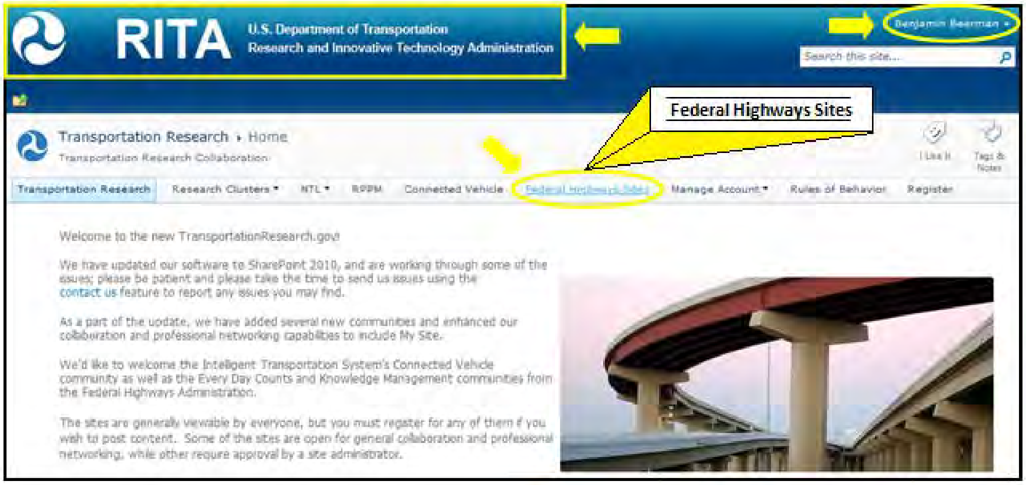
- Enter your UserID and Password and click the "**Submit**" icon.



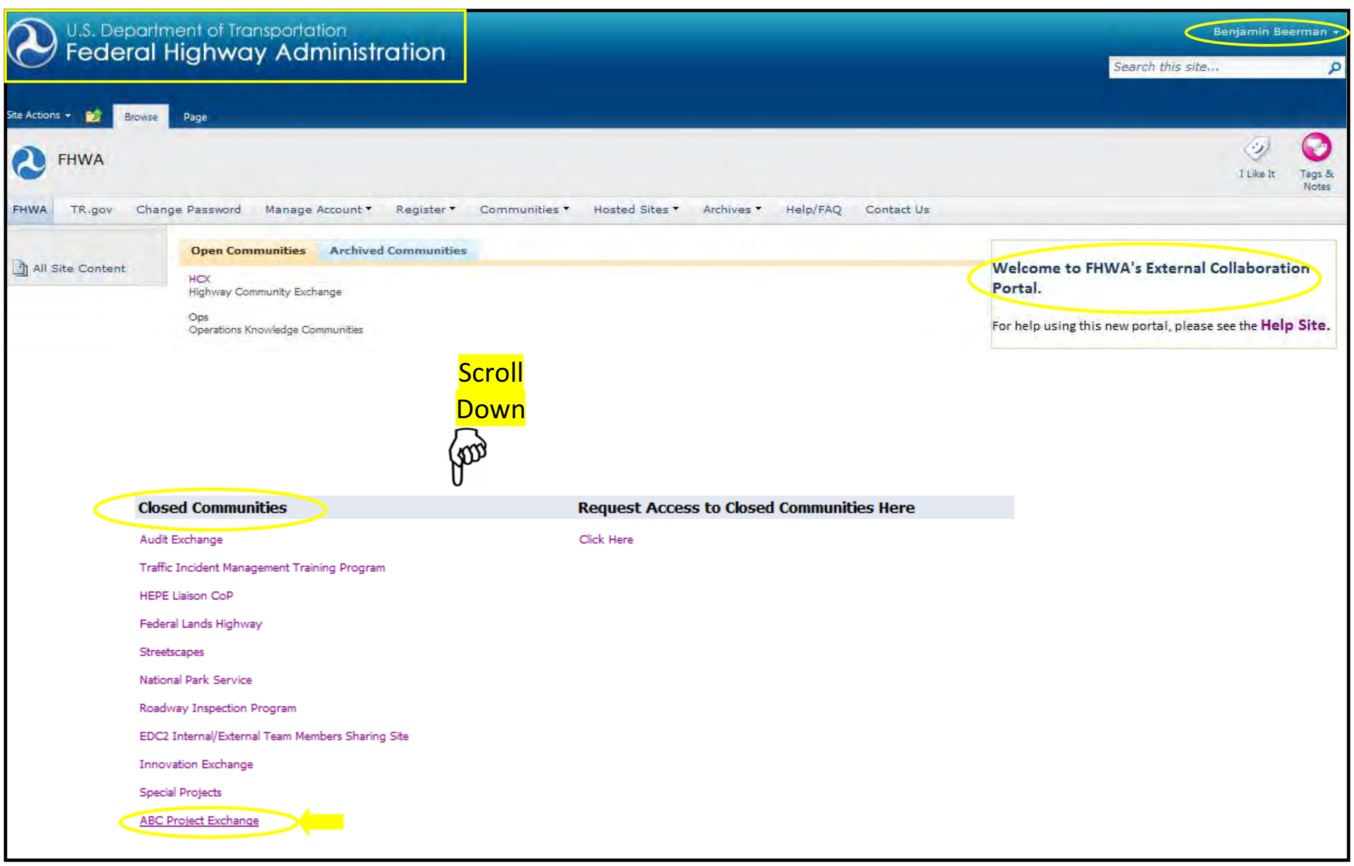
- You will be sent to the **DOT's RITA** site as shown below.

  Note: Your user name is shown in the upper right indicating that you are **Signed In**

- Select the "**Federal Highways Sites"** tab as shown.

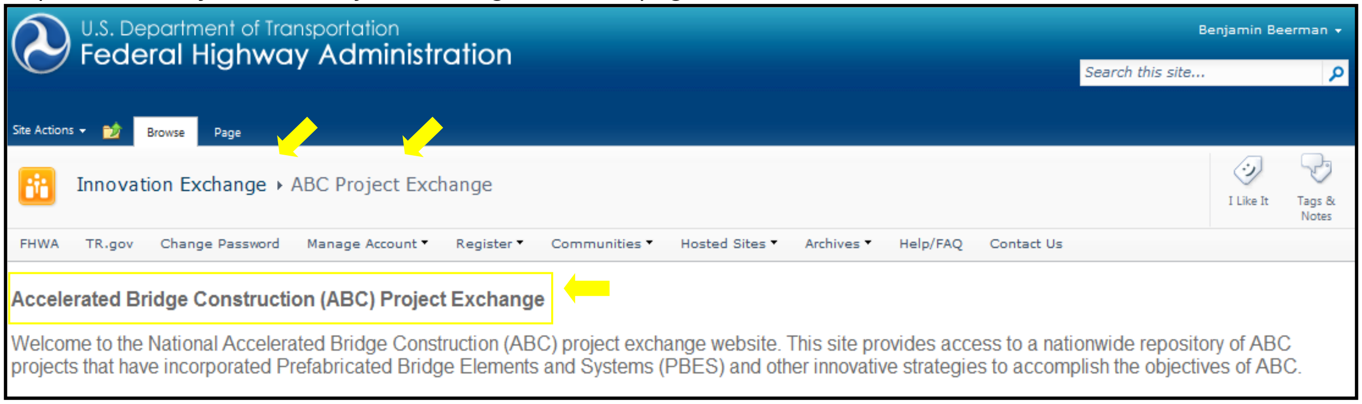


- Which will bring you back to the **FHWA's External Collaboration Portal** as shown below.
- Scroll Down to the **"*Closed Communities*"** heading and select the **ABC Project Exchange** tab as shown…



- To arrive at the **ABC Project Exchange** Welcome page

A partial view of the ABC Project Exchange welcome page is shown below…



Search for project information

There are two options to search for project information in the ABC Project Exchange. An overview, and step-by-step instructions is provided below:

Option 1: Uses a **Microsoft Excel Spreadsheet** to give you the ability to search for specific technologies using *key words* from pull down menus (direct method).

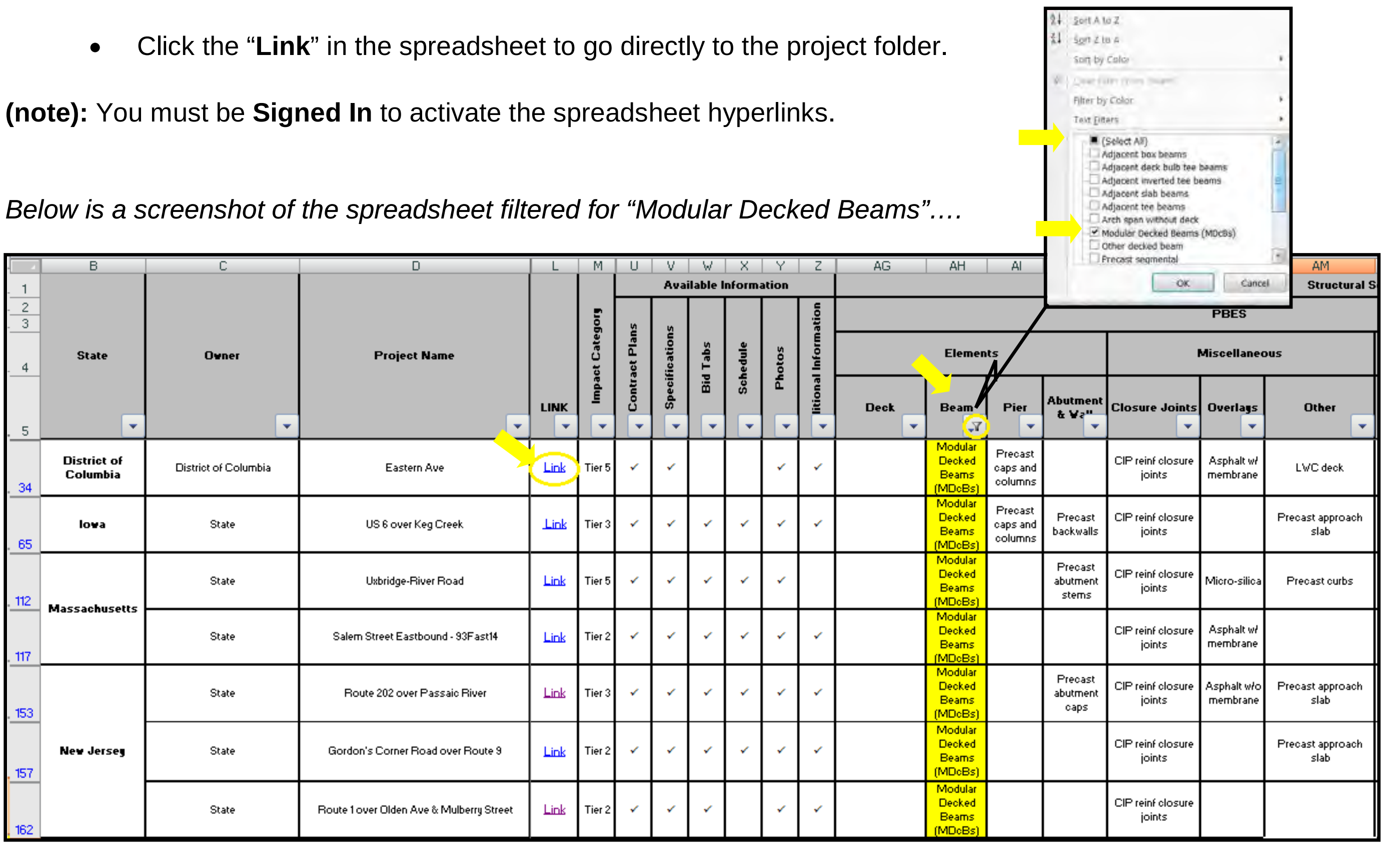
Option 2: By **State** directory – which requires you to navigate through individual project folders and subdirectories (indirect method).

Option 1: Search using the **Microsoft Excel Spreadsheet**

- On the **ABC Project Exchange** welcome page, select the **MS Excel Spreadsheet** link (picture not shown)
- The spreadsheet will open as shown below.
- Search for specific technology using the *key words* in the pull down menus available in the spreadsheet. A glossary of key terms is on the **ABC Project Exchange** welcome page.
- Click the "**Link**" in the spreadsheet to go directly to the project folder.

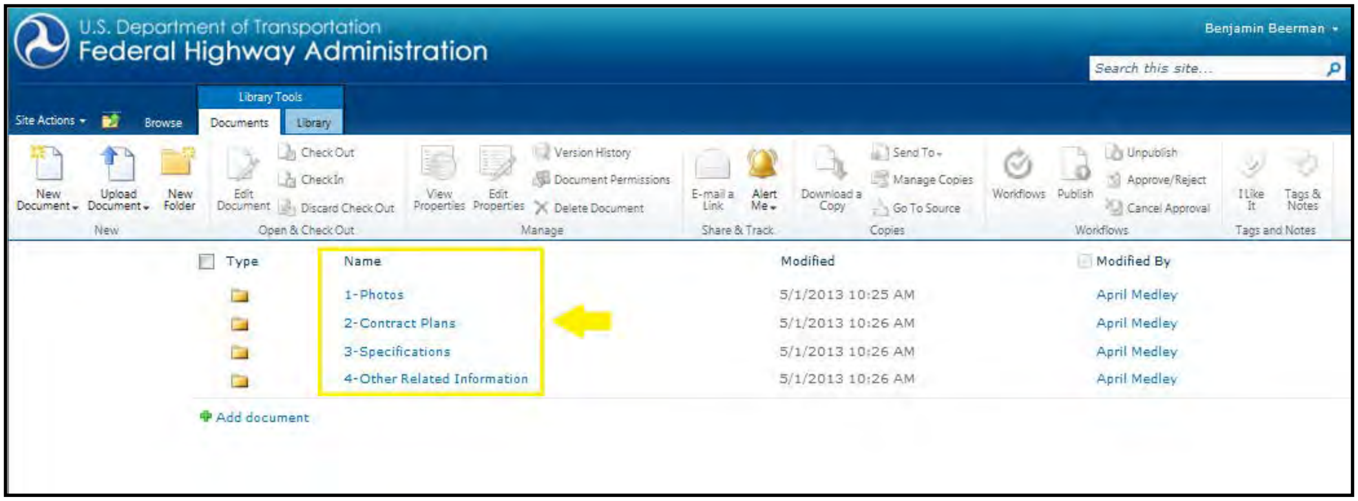
(note): You must be **Signed In** to activate the spreadsheet hyperlinks.

Below is a screenshot of the spreadsheet filtered for "Modular Decked Beams"….



	B	C	D	L	M	U	V	W	X	Y	Z	AG	AH	AI				AM
						Available Information												Structural S
												PBES						
												Elements				Miscellaneous		
	State	Owner	Project Name	LINK	Impact Category	Contract Plans	Specifications	Bid Tabs	Schedule	Photos	litional Information	Deck	Beam	Pier	Abutment & Wall	Closure Joints	Overlays	Other
34	District of Columbia	District of Columbia	Eastern Ave	Link	Tier 5	✓	✓			✓	✓		Modular Decked Beams (MDcBs)	Precast caps and columns		CIP reinf closure joints	Asphalt w/ membrane	LWC deck
65	Iowa	State	US 6 over Keg Creek	Link	Tier 3	✓	✓	✓	✓	✓	✓		Modular Decked Beams (MDcBs)	Precast caps and columns	Precast backwalls	CIP reinf closure joints		Precast approach slab
112	Massachusetts	State	Uxbridge-River Road	Link	Tier 5	✓	✓	✓	✓	✓			Modular Decked Beams (MDcBs)		Precast abutment stems	CIP reinf closure joints	Micro-silica	Precast curbs
117		State	Salem Street Eastbound - 93Fast14	Link	Tier 2	✓	✓	✓	✓	✓	✓		Modular Decked Beams (MDcBs)			CIP reinf closure joints	Asphalt w/ membrane	
153	New Jersey	State	Route 202 over Passaic River	Link	Tier 3	✓	✓	✓	✓	✓	✓		Modular Decked Beams (MDcBs)		Precast abutment caps	CIP reinf closure joints	Asphalt w/o membrane	Precast approach slab
157		State	Gordon's Corner Road over Route 9	Link	Tier 2	✓	✓	✓	✓	✓	✓		Modular Decked Beams (MDcBs)			CIP reinf closure joints		Precast approach slab
162		State	Route 1 over Olden Ave & Mulberry Street	Link	Tier 2	✓	✓	✓		✓	✓		Modular Decked Beams (MDcBs)			CIP reinf closure joints		

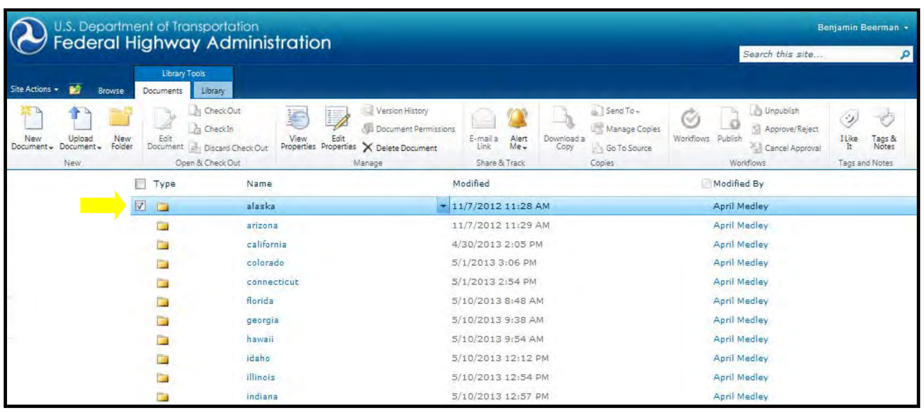
Selecting the "__Link__" in the spreadsheet will take you to the project folder that contains the available detailed information. An example is shown below…



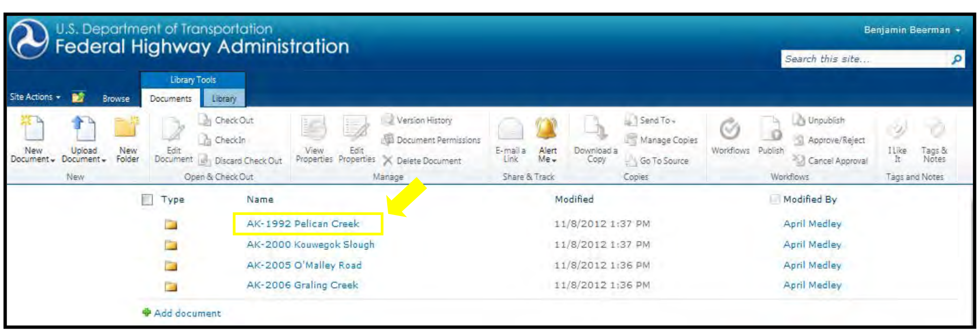
__Option 2__: Searching by **State Directory**

- On the **ABC Project Exchange** welcome page, select the **"ABC projects by state**" link

Shown below is the State directory. Selecting a State directory will take you to the posted projects folders. Within each state project folder is the Project Summary Report (MS Word document) and the subdirectories that contain the available project information. An example is shown below….



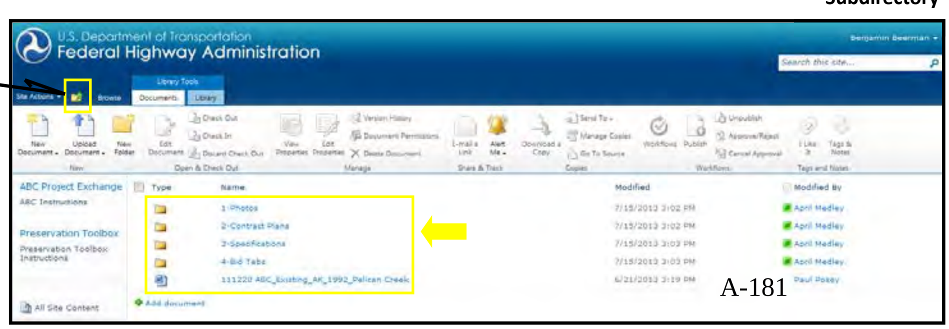
State Directory



Project Folders

Project Subdirectory

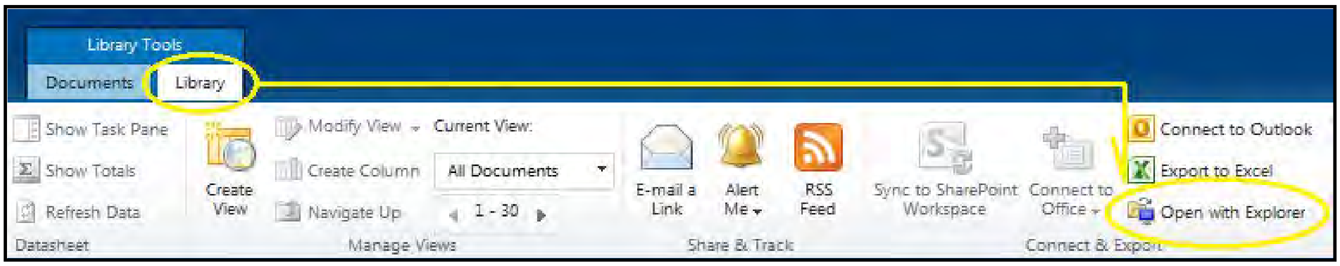
__Note:__ the "folder" icon will allow you to go back.



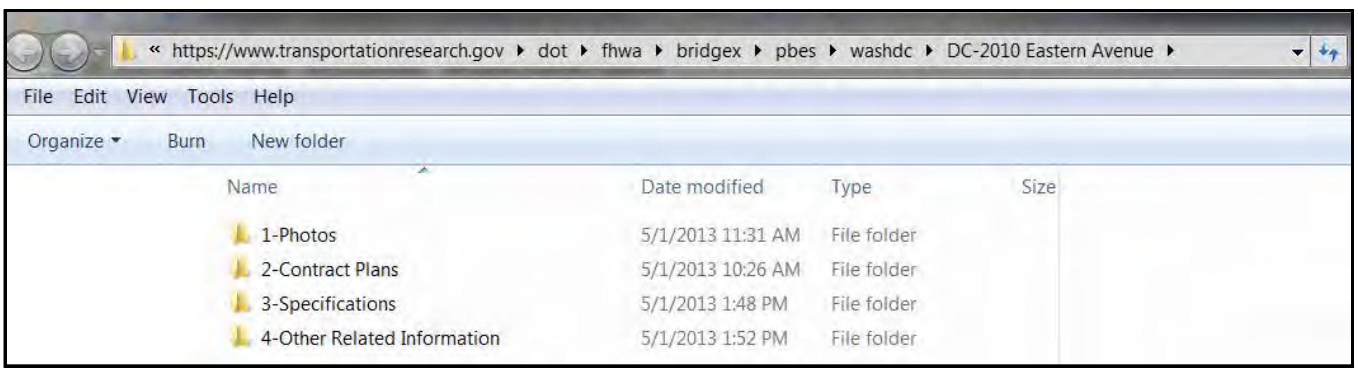
Download and view documents and photos:

All material, including documents and photos, can be viewed and downloaded to your computer.

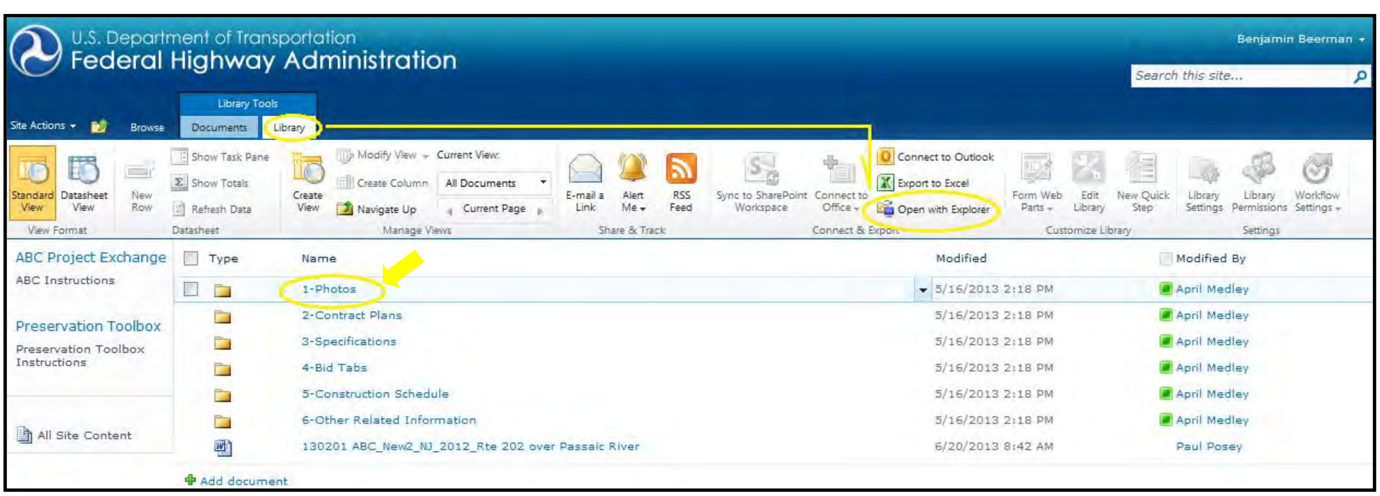
- **To download documents**: From the **Library Tool** bar shown below, click **Open with Explorer**, select the directories, files, or photos needed.
- Material can be **dragged and dropped** to your computer.



*Below is a screenshot showing the available information that can be downloaded using the **Open with Explorer** feature. Select the material needed to **drag and drop** them to a location on your computer.*

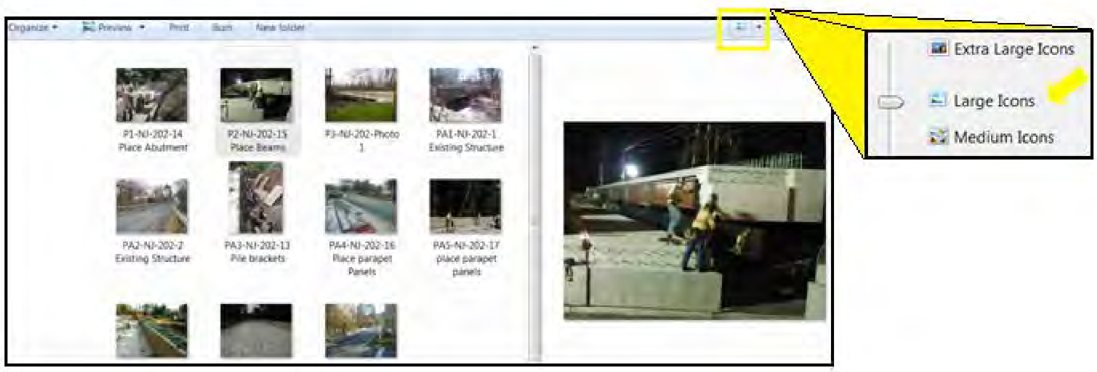


- **To View Photos**: Go to any Photo directory, select the **Open with Explorer** feature.



- Select the “**Large Icon**” option in your Windows Explorer as shown below.
- Photos can also be **dragged and dropped** to your computer.

*Below is a screenshot showing how pictures can be viewed using the **Open with Explorer** feature…*



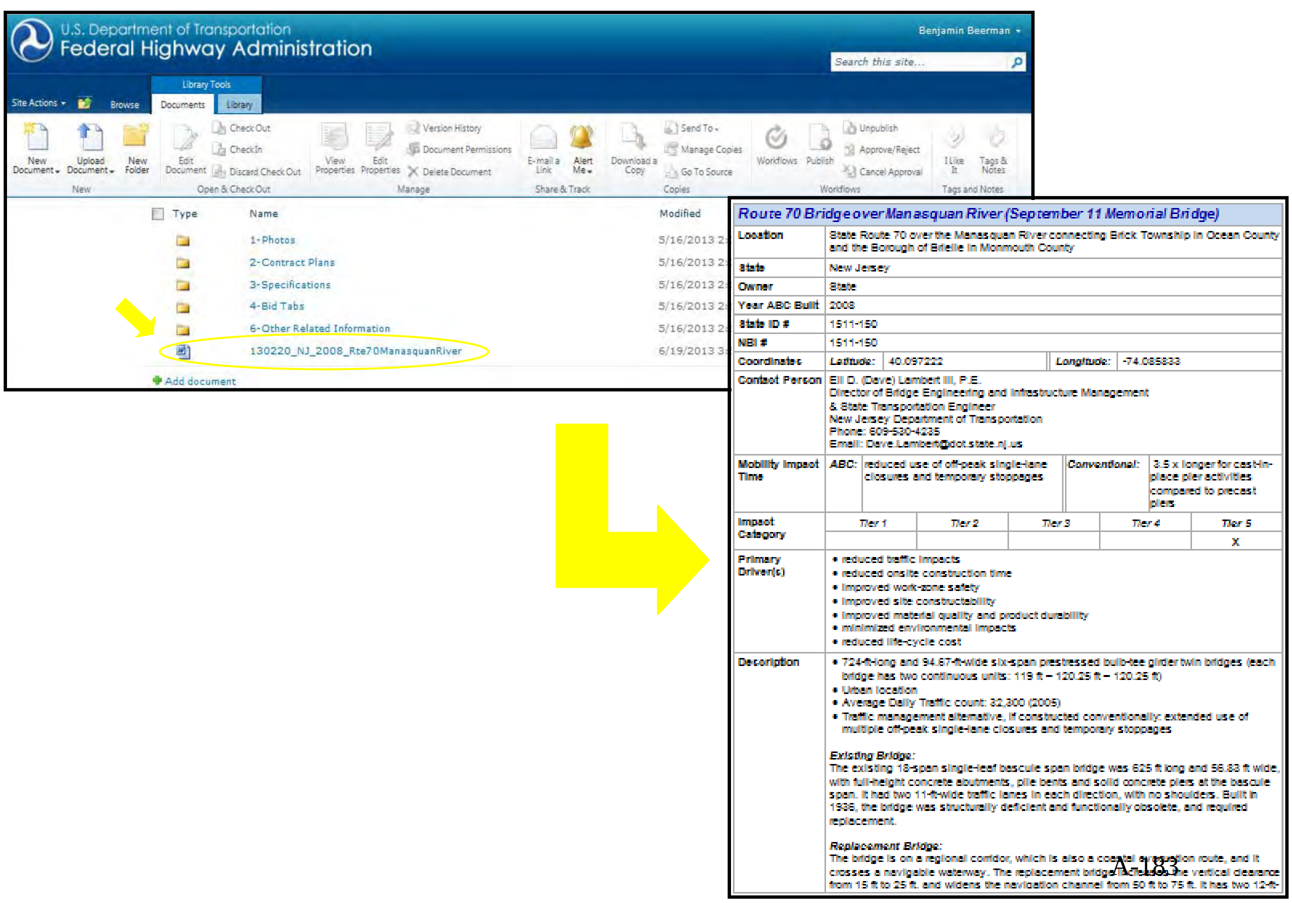
The Project Summary Report:

In every project folder resides a MS Word document. This document is the Project Summary report that includes, but is not limited to, the following information:

- Project description
- Owner contact information
- Stakeholder feedback (Owner, Engineer, Contractor, Public, etc…)
- Costs
- Links to Additional Information

You are encouraged to review the material in the Project Summary Report, including any hyperlinks to ***additional information*** that is included in the write-up.

`



Support:

- **To report issues related to the project information posted on the ABC Project Exchange**

  Please send an email to the following link: **ABC Project Exchange - comments**

- **To inquire about adding a new project to the ABC Project Exchange**

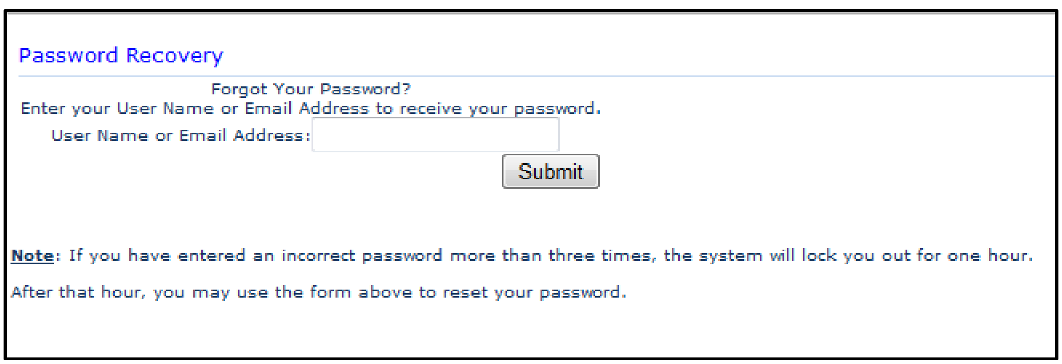
  Please send an email to the following link: **ABC Project Exchange - new project request**

- **For IT support related to site Registration, Access, and Navigation**

  Please use this form to contact the Site Administrator:
  https://www.transportationresearch.gov/dot/fhwa/SitePages/ContactUs.aspx

- **Password Reset**

  Your Password can be reset at the following link:
  https://www.transportationresearch.gov/dot/fhwa/SitePages/RecoverPW.aspx


Password Recovery

Forgot Your Password?
Enter your User Name or Email Address to receive your password.
User Name or Email Address:
Submit

Note: If you have entered an incorrect password more than three times, the system will lock you out for one hour.
After that hour, you may use the form above to reset your password.

Note: Please use the same user name or email address that was used to register the account.

- FHWA SEP-14 Active Project List:
  http://www.fhwa.dot.gov/programadmin/contracts/sep14list.cfm

- FHWA CMGC home page
  http://www.fhwa.dot.gov/construction/cqit/cm.cfm

- FHWA Design-Build home page
  http://www.fhwa.dot.gov/construction/cqit/desbuild.cfm

- June 2009, “Current Design-Build Practices for Transportation Projects,”
  http://www.fhwa.dot.gov/construction/contracts/pubs/dbpractice/

- “AASHTO Guide for Design-Build Procurement” (hard copy only -
  https://bookstore.transportation.org/item_details.aspx?ID=1181)

- Caltrans April 2008, “Alternative Procurement Guide”,
  http://www.dot.ca.gov/hq/oppd/contracting/AlternativeProcurementGuide.pdf

Alternative Analysis for Project Delivery

Accelerated Bridge Construction/ Structural Slide and Move Workshop
December 9, 2013

Haluk M. Aktan
Western Michigan University
Haluk.Aktan@wmich.edu

Project Delivery Alternatives

Conventional Construction (CC)

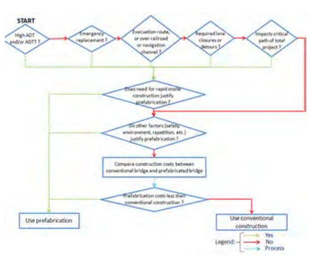
ABC – Prefabricated Bridge Elements and Systems (PBES) Assembling

ABC – Self Propelled Modular Transporter (SPMT) Moving

ABC – Bridge Sliding

Project deliver Alternative Analysis

- Decision-making process to evaluate ABC as a project delivery alternative is evolving:
  - Flowcharts
  - Structured Binary Tables
  - Scoring Models
  - Analytical Hierarchy Process

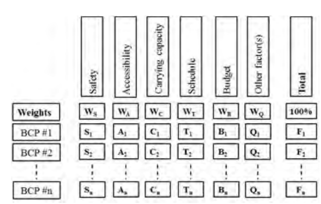


FHWA – PBES Decision-Making (2005)

Decision-Making Processes

- Bridge Construction Plan (BCP) Evaluation Process 2001
  - Decision is based on *Scoring Model*
    - Assign percentage weights (W_i) to each category
    - Rate the parameters listed under each category on an ordinal scale and summed to a total S_{ij}, A_{ij}, C_{ij}, etc.
    - Calculate the final score "F_j" for each BCP alternative

$$F_j = \sum_i \left(W_i \times S_{ij} \right)$$



BCP Comparison Objective Matrix
(Source: El-Diraby and O'Conner 2001)

Decision-Making Processes

- PBES Decision-Making Model (2005)
  - To evaluate the potential and effectiveness of using an ABC for a particular site
  - Three sections
  - Flowchart
    - Provides an overview of parameters that need to be considered in decision-making

Flowchart by Ralls (2005) for FHWA

Decision-Making Processes

- PBES Decision-Making Model (2005)

Question	Yes	Maybe	No
Does the bridge have high average daily traffic (ADT) or average daily truck traffic (ADTT) or is it over an existing high-traffic-volume highway?			
Is the bridge over a railroad or navigable waterway, or is it on an emergency evacuation route?			
Will traffic be subject to back-ups when using the bridge during construction, or be subject to excessive detours during construction of the bridge?			
Is this project an emergency bridge replacement?			
Must traffic flow be maintained on the bridge during construction?			
Can the bridge be closed during off-peak traffic periods, e.g., nights and weekends?			
Does the bridge have multiple identical spans?			
Can the bridge be grouped with other bridges for economy of scale?			
Will roadway construction activities away from the bridge be completed quickly enough to make rapid installation of prefabricated bridge a cost effective solution?			
Can adequate time be allocated from project award to site installation to allow for prefabrication of components to occur concurrently with site preparation?			
Do worker safety concerns at the site limit conventional methods e.g., adjacent power lines or over water?			
Is the site in an environmentally sensitive area requiring minimum disruption (e.g., wetlands, air quality, noise, etc.)?			
Is the bridge location subject to construction time restrictions due to adverse economic impact?			
Are there natural or endangered species at the bridge site that necessitate short construction time windows or suspension of work for a significant time period, e.g., fish passage or peregrine falcon nesting?			
If the bridge is on or eligible for the national register of historic places, is prefabrication feasible for replacement/rehabilitation per the memorandum of agreement?			
Is the bridge site accessible for delivery of prefabricated components or use of heavy lifting equipment?			

Matrix by Ralls (2005) for FHWA

Decision-Making Processes

- ABC Decision-Making (2006)
  - Decision-making parameters identified thru a survey of 25 U.S. DOTs
  - The survey also asked the share of each of 6 major-parameters in the ABC decision-making process, and the significance of the sub-parameters

Parameters and Mean Weights from Survey (2006)

Major-Parameter	Confidence interval (95%)	Mean percentage weight
Cost	16-31	25
Traffic flow	11-29	20
Safety	11-31	20
Economy	8-18	15
Social	7-16	10
Environment	7-13	10
Total		100

Decision-Making Processes

ABC Decision-Making Model (2006)

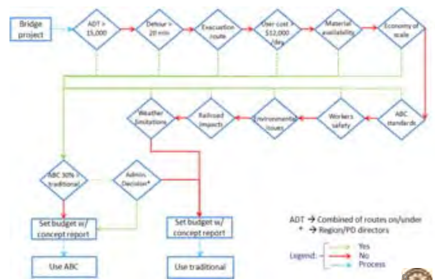
- Evaluation for a specific project
  - Each construction alternative is evaluated for its effectiveness: "e" with respect to each sub-parameter
  - The total effectiveness under each major-parameter (e_{1x} to e_{6x}) is calculated
  - The effectiveness is then multiplied with the major-parameter mean percentage weights (preset weights)
  - The resulting vector provides priority percentage of the construction alternatives for that specific project

$$\begin{bmatrix} Alternative\ X \\ Alternative\ Y \\ Alternative\ Z \end{bmatrix} = \begin{bmatrix} e_{1x} & e_{2x} & e_{3x} & e_{4x} & e_{5x} & e_{6x} \\ e_{1y} & e_{2y} & e_{3y} & e_{4y} & e_{5y} & e_{6y} \\ e_{1z} & e_{2z} & e_{3z} & e_{4z} & e_{5z} & e_{6z} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \\ w_6 \end{bmatrix}$$

Evaluation of Construction Alternatives (2006) for Ohio DOT

Decision-Making Processes

- UDOT ABC Decision-Making (2008)
  - Extended version of “FHWA – PBES Decision-Making Model”
  - The *Yes/No* option selection was retained; triggering of one *Yes* on a critical parameter may lead to ABC implementation decision



ABC Decision Chart by Ralls (2008) for Utah DOT

Decision-Making Processes

- UDOT ABC Decision-Making Scoring Model (2010)
  - A scoring table and associated flowchart
  - One set of parameters utilized rather than grouping under major-parameters and sub-parameters
  - *Scoring model* was utilized
  - For a specific site, the values are assigned based on site characteristics (field observation)

ABC rating procedure: Enter values for each aspect of the project. Attach back-up data if applicable

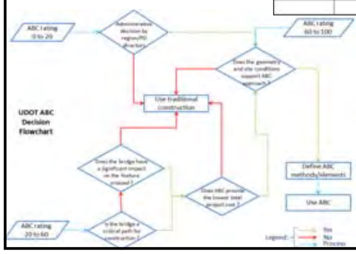
Average Daily Traffic	3	0	No traffic impacts
Combined on and under		1	Less than 5000
Enter 1 for Interstate Highways		2	5000 to 10000
		3	10000 to 15000
		4	15000 to 20000
		5	More than 20000
Delay Time	2	0	No delays
		1	Less than 5 minutes
		2	5-10 minutes
		3	10-15 minutes
		4	15-20 minutes
		5	More than 20 minutes
Bridge Classification	1	1	Normal Bridge
		3	Essential Bridge
		5	Critical Bridge
User Costs	4	0	No user costs
		1	Less than $10,000
		2	$10,000 to $50,000
		3	$50,000 to $75,000
		4	$75,000 to $100,000

UDOT ABC Scoring Table (2010)

UDOT ABC Scoring Model (2010)

- Predefined weights were assigned to each parameter (preset weights)
- The values from field observation are multiplied with preset weights and summed to obtain a *total score*
- The *ABC rating* is used in the flowchart to provide the decision

ABC rating	Score	Weight factor	Adjusted score	Maximum score	Adjusted score
Average daily traffic	X1	10	X1 * 10	5	50
Delay time	X2	10	X2 * 10	5	50
Bridge classification	X3	4	X3*4	5	20
User costs	X4	10	X4*10	5	50
Economy of scale	X5	3	X5*3	3	9
Use of typical details	X6	3	X6*3	5	15
Safety	X7	8	X7*8	5	40
Railroad impacts	X8	5	X8*5	5	25
Weather limitations	X9	3	X9*3	5	15
		Total score	Σ	Max. score	274

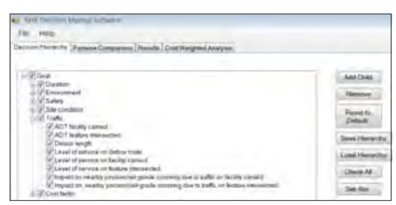


$$\text{ABC rating} = \frac{\text{Total score}}{\text{Maximum score}} \times 100$$

UDOT – ABC Decision Flowchart (2010)

Decision-Making Processes

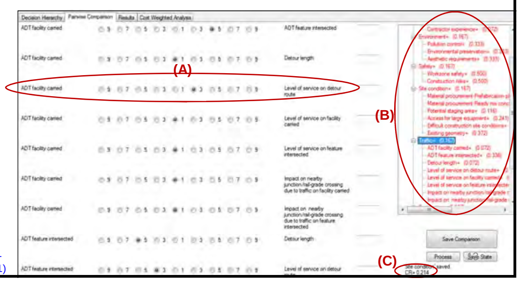
- AHP Decision-Making Software (2011)
  - Developed by Oregon State University under a FHWA pooled fund study
  - Based on Analytical Hierarchy Process (AHP)
  - A *Microsoft Visual Studio.NET* application to evaluate between conventional and ABC alternatives
  - The user can: i) edit/view the decision hierarchy, ii) perform pair-wise comparisons, iii) view results, and iv) perform cost weighted analysis



OSU – AHP Decision-Making Software (2011)

AHP for Decision-Making (2011)

- Pair-wise comparisons of unrelated parameters **(A)**
- Repeated pair-wise comparison steps **(B)**
- The pair-wise comparison process need to be repeated until AHP consistency ratio (CR) < 0.10 is achieved **(C)**
- The cost weighted analysis requires neglecting the cost related parameters in the pair-wise comparisons and entering the total project cost instead



OSU – AHP Decision-Making Software (2011)

Decision-Making Model

- Requirements for a useful and robust tool
  - Incorporation of project-specific quantitative data
  - Incorporation of life-cycle (LCC) cost data and user cost (UC) models
  - Input from multiple experts for collaborative decision making
  - Automation to improve usability and efficiency of the decision-making process along with addressing the sensitivity of results
  - Decision making method with mathematical validity

LCC Analysis Models

Parameters \ LCA models		FHWA Model & NIST Model	Finnish Transport Agency Model	Remaining Life Prediction Models	LCA based on Ecological Parameters	Lifetime Assessment through Reliability Concept
Net Present Value (NPV) of Life-Cycle Cost		☑	☑			
Probabilistic Approach		☑				
Construction Cost, R&R Cost, Demolition Cost		☑	☑		☑	☑
User Cost		☑	☑	☑		
Deterioration Mechanisms				☑		☑
Monitoring, NDT & Visual Inspection				☑		☑
Material, Type of Design & Load bearing capacity				☑		☑
Resource Production Cost					☑	
Discount factors		☑	☑			
Society Cost	Environmental (Noise, Vibration, Pollution)		☑	☑	☑	
	Global stressors (CO_2 Equivalents)		☑		☑	
Risks	Agency		☑			☑
	Users		☑			☑
	Society		☑		☑	

15

LCC Parameters for ABC

Parameters \ LCA models		FHWA Model & NIST Model	Finnish Transport Agency Model	Remaining Life Prediction Models	LCA based on Ecological Parameters	Lifetime Assessment through Reliability Concept
Net Present Value (NPV) of Life-Cycle Cost		☑	☑			
Probabilistic Approach		☑				
Construction Cost, R&R Cost, Demolition Cost		☑	☑		☑	☑
User Cost		☑	☑	☑		
Deterioration Mechanisms				☑		☑
Monitoring, NDT & Visual Inspection				☑		☑
Material, Type of Design & Load bearing capacity				☑		☑
Resource Production Cost					☑	
Discount factors		☑	☑			
Society Cost	Environmental (Noise, Vibration, Pollution)		☑	☑	☑	
	Global stressors (CO_2 Equivalents)		☑		☑	
Risks	Agency		☑			☑
	Users		☑			☑
	Society		☑		☑	

16

USER COST ANALYSIS MODELS

User cost models / Parameters	FHWA Model	NIST Model	Quickzone	CA4PRS (UCB)	CO^3 (UofM & MDOT)
Traveler delay cost	☑	☑	☑	☑	☑
Vehicle operating cost	☑	☑	☑	☑	☑
Accident cost	☑	☑			
Decrease in demand cost					☑
Detour travel cost	☑	☑	☑	☑	☑
Contemporary economic parameters (e.g., wage rate, etc.)	☑	☑	☑	☑	☑
User cost breakdown per hour			☑	☑	☑
User cost due to backups	☑				☑
User cost w.r.t different work zone times/strategies				☑	☑
Traffic simulation				☑	
Network of roadways considered (to select low user cost incurring route)			☑		

17

USER COST PARAMETERS FOR ABC

User cost models / Parameters	FHWA Model	NIST Model	Quickzone	CA4PRS (UCB)	CO^3 (UofM & MDOT)
Traveler delay cost	☑	☑	☑	☑	☑
Vehicle operating cost	☑	☑	☑	☑	☑
Accident cost	☑	☑			
Decrease in demand cost					☑
Detour travel cost	☑	☑	☑	☑	☑
Contemporary economic parameters (e.g., wage rate, etc.)	☑	☑	☑	☑	☑
User cost breakdown per hour			☑	☑	☑
User cost due to backups	☑				☑
User cost w.r.t different work zone times/strategies				☑	☑
Traffic simulation				☑	
Network of roadways considered (to select low user cost incurring route)			☑		

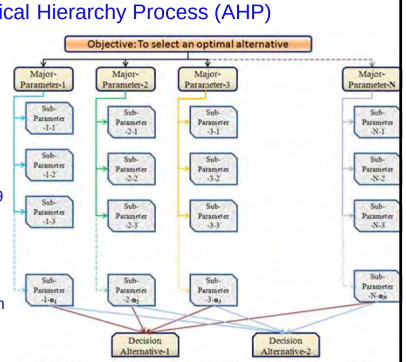
18

OUTLINE

- Michigan Accelerated Bridge Construction Decision-Making [Mi-ABCD] Model
- Mi-ABCD Guided Software
- Mi-ABCD Implementation
- Conclusions

Mi-ABCD MODEL

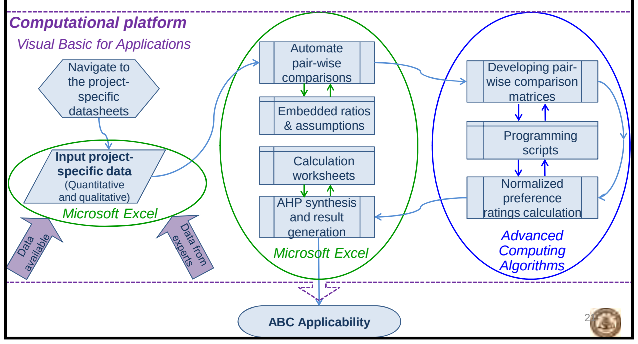
- Implementing Analytical Hierarchy Process (AHP)
  - Define major-parameters and sub-parameters
  - Perform Pair-wise comparison of parameters on an ordinal scale of 1 to 9
  - Develop AHP matrices
  - Calculate priority vectors
  - Calculate preference probabilities for the decision alternatives



→Multiple decision alternatives existing for a project are rated against each sub-parameter.

Mi-ABCD Model

- Graphical User Interface (GUI) to acquire user data



Mi-ABCD Model

- Major-parameters and sub-parameters

Major-Parameters	Site and Structure Considerations (S&ST)	Cost	Work Zone Mobility (WZM)	Technical Feasibility and Risk (TF&R)	Environmental Considerations (EC)	Seasonal Constraints and Project Schedule (SC&PS)
Sub-Parameters	Precaster/Ready-mix supplier proximity	Initial Construction cost	Significance of maintenance of traffic on facility carried	Contractor experience	Environmental protection (e.g., wet land)	Seasonal limitations
	Availability of staging area	Life-cycle cost	Significance of maintenance of traffic on feature intersected	Manufacturer/ Precast plant experience	Aesthetic requirements	Construction duration
	Existing structure type and foundations	User cost	Length of detour	Work zone traffic risk		Stakeholder(s') limitations
	Terrain to traverse	Economic impact on surrounding businesses	Significance of level of service on detour route	Construction risks		
	Access and mobility of construction equipment	Economic impact on surrounding communities	Impact on nearby major intersection/highway-rail grade crossing due to traffic on facility carried**			
	Number of similar spans		Impact on nearby major intersection/highway-rail grade crossing due to traffic on feature intersected**			

Blue text → Quantitative parameters   Red text → Qualitative parameters

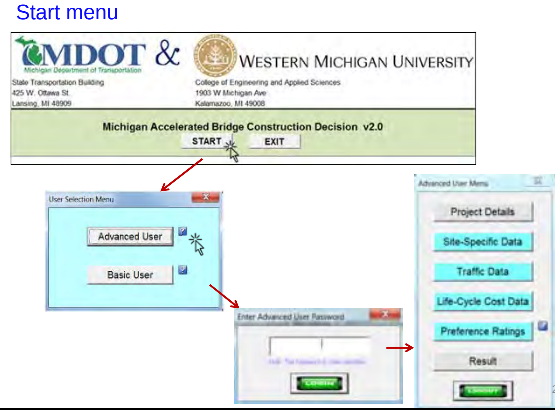
** Number of nearby major intersections/highway-rail grade crossing affected may vary

Mi-ABCD Guided Software

- The software is developed using Microsoft Excel and Visual Basic for Applications (VBA) scripts
- The VBA's GUI → interact with the user
  - Pop-up menus
  - Datasheets
  - VBA scripts
  - Embedded worksheets

Mi-ABCD Guided Software

- Start menu



Mi-ABCD Guided Software

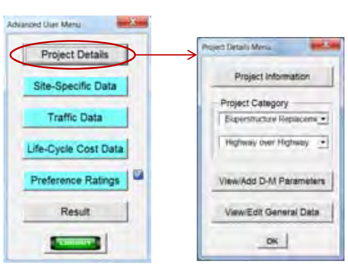
- Key steps
  - Project Specific Data input by Advanced User
  - Preference Data input by multiple Basic Users
  - Data analysis
  - Interpretation of results

Mi-ABCD Guided Software

- Advanced User
  - Project manager with access to site-specific data, cost estimates, and traffic data.
  - Enter and edit Project Details, Site-Specific Data, Traffic Data, Life-Cycle Cost Data, and Preference Ratings
  - Execute data analysis and review Results
- Basic User(s)
  - Project team members enter preference ratings based on their experiences on recent bridge projects
  - View Project Information, enter Preference Ratings, execute data analysis, and review Results

Mi-ABCD Guided Software

- Project Details Menu
  - Accessed by Project Details button on the Advanced User Menu to enter project information, select project category, view/add decision-making parameters, and view/edit the general data



Mi-ABCD Guided Software

- View/Add decision-making parameters

Decision-Making Parameters for Highway over Highway Project

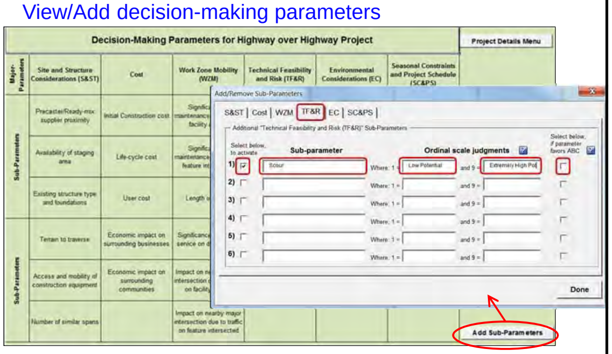
Major-Parameters	Site and Structure Considerations (S&ST)	Cost	Work Zone Mobility (WZM)	Technical Feasibility and Risk (TF&R)	Environmental Considerations (EC)	Seasonal Constraints and Project Schedule (SC&PS)
Sub-Parameters	Precaster/Ready-mix supplier proximity	Initial Construction cost	Significance of maintenance of traffic on facility carried	Contractor experience	Environmental protection (e.g., wet land)	Seasonal limitations
	Availability of staging area	Life-cycle cost	Significance of maintenance of traffic on feature intersected	Manufacturer/ Precast plant experience	Aesthetic requirements	Construction duration
	Existing structure type and foundations	User cost	Length of detour	Work zone traffic risk		Stakeholder(s') limitations
Sub-Parameters	Terrain to traverse	Economic impact on surrounding businesses	Significance of level of service on detour route	Construction risks		
	Access and mobility of construction equipment	Economic impact on surrounding communities	Impact on nearby major intersection due to traffic on facility carried			
	Number of similar spans		Impact on nearby major intersection due to traffic on feature intersected			

Project Details Menu

Add Sub-Parameters

Mi-ABCD GUIDED SOFTWARE

- View/Add decision-making parameters



Mi-ABCD GUIDED SOFTWARE

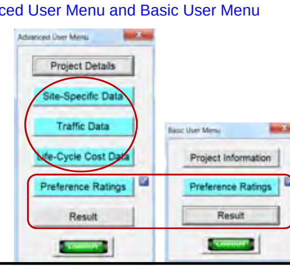
- General data
  - The average wage rate of the drivers,
  - County job multipliers that give significance of a particular county on surrounding counties,
  - Ready-mix concrete plants/prefabrication plants/staging area distances,
  - ADT limits,
  - Significance of maintenance of traffic based on LOS change,
  - Detour length ranges,
  - Range for the number of similar spans,
  - Peak hour factors for roadways, and
  - Predefined tables based on site/state specific criteria.

Mi-ABCD GUIDED SOFTWARE

- Preference ratings

Mi-ABCD GUIDED SOFTWARE

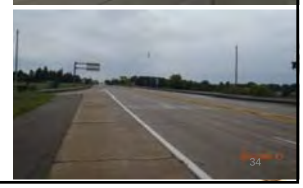
- Access datasheets and Results sheet
  - o Command buttons on the Advanced User Menu
    - Site-specific data
    - Traffic data
    - Life-cycle cost data
  - o Command buttons on Advanced User Menu and Basic User Menu
    - Preference ratings
    - Results



IMPLEMENTATION

33

- Stadium Drive (I-94 BR) over US 131 in Kalamazoo County, Michigan
  - Single structure
  - Year built = 1963
  - Length = 236.91 ft
  - Width = 85.30 ft
  - Skew = 5°
  - No. of main spans = 4
  - Max. span length = 81.99 ft
  - Underclearance = 14.83 ft
  - ADT = 29,643 (2007 data)
  - Future ADT = 41,774 (2018 estimate)



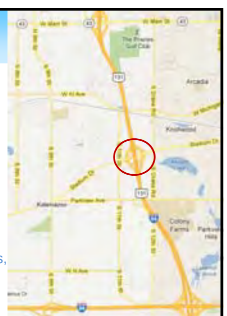
34

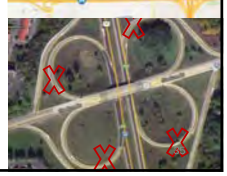
IMPLEMENTATION

- Full bridge replacement
- Project delivery alternatives → ABC Vs. CC

Bridge replacement considerations

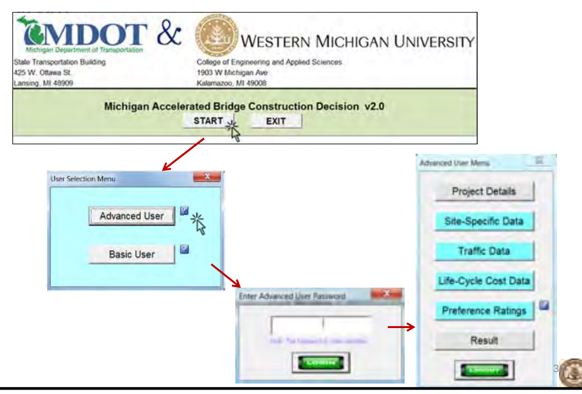
- Underclearance ≥ 16.25 ft
- Alignment change
  (Requires changing the elevation of the approach, abutments, bent cap(s), and girders)
- Two-exit and two-entrance ramps
  (Need to be closed for either staged construction or full closure)
- Project planning
  (Recommend *full closure* to resolve project complexities and to improve safety (FHWA 2003))
- Ramps closure & construction duration impact
  (Significant impact to the stakeholders including the WMU)

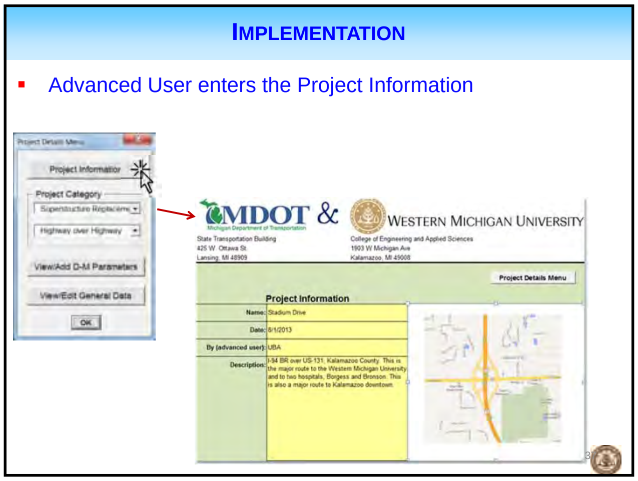


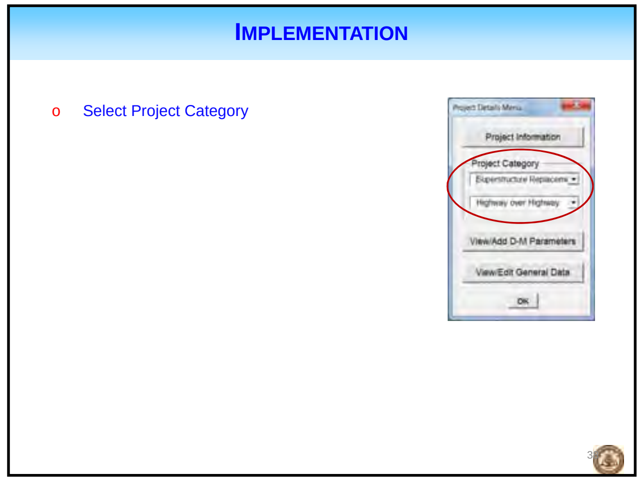


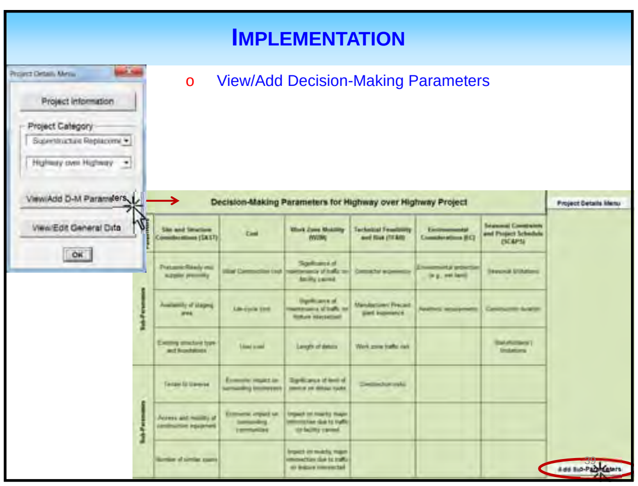
IMPLEMENTATION

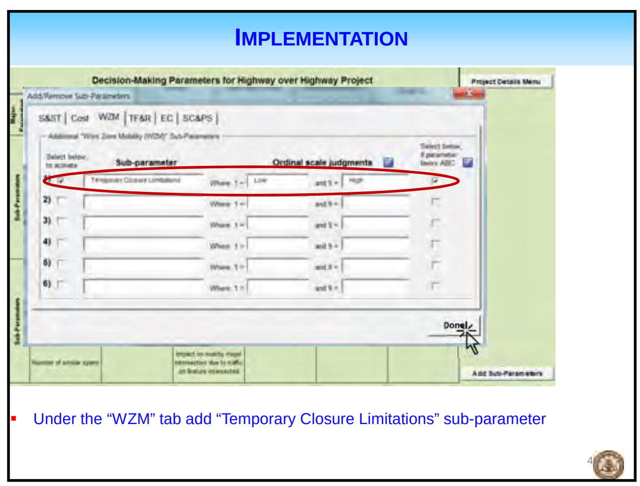
- Execute the software and access the *Advanced User Menu*



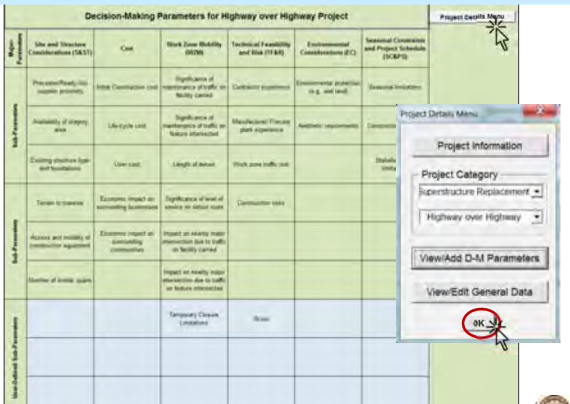

IMPLEMENTATION
Advanced User enters the Project Information
Project Details Menu
Project Information
Project Category
View/Add D-M Parameters
View/Edit General Data
OK
MDOT & WESTERN MICHIGAN UNIVERSITY
Project Information
Project Details Menu


IMPLEMENTATION
Select Project Category
Project Details Menu
Project Information
Project Category
Highway over Highway
View/Add D-M Parameters
View/Edit General Data
OK


IMPLEMENTATION
View/Add Decision-Making Parameters
Project Information
Project Category
View/Add D-M Parameters
View/Edit General Data
OK
Decision-Making Parameters for Highway over Highway Project
Project Details Menu

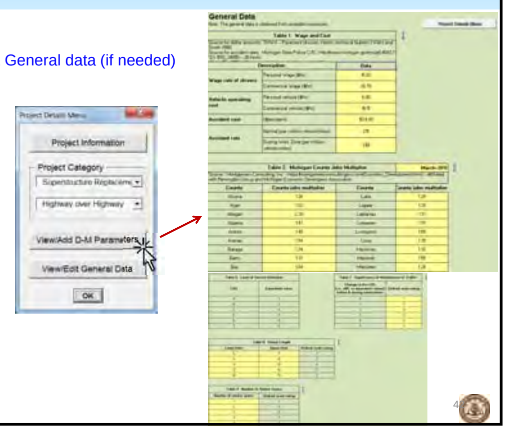

IMPLEMENTATION
Decision-Making Parameters for Highway over Highway Project
Project Details Menu
Add/Remove Sub-Parameters
Sub-parameter
Ordinal scale judgments
Done
Add Sub-Parameters
Under the “WZM” tab add “Temporary Closure Limitations” sub-parameter

IMPLEMENTATION



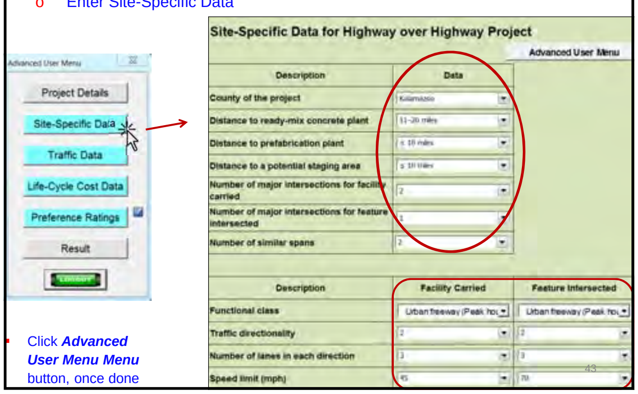
IMPLEMENTATION

- View/Edit General data (if needed)



IMPLEMENTATION

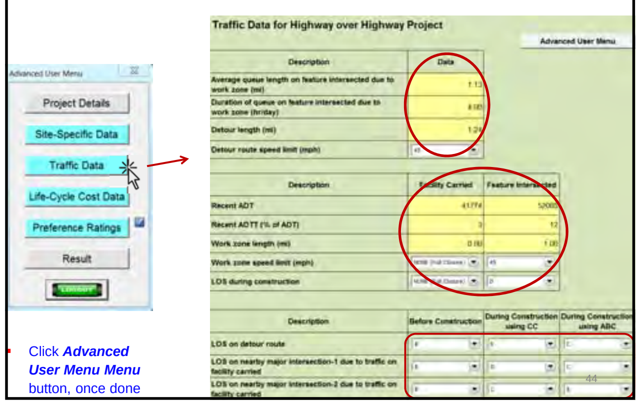
- Enter Site-Specific Data



- Click ***Advanced User Menu*** button, once done

IMPLEMENTATION

- Enter Traffic Data



- Click ***Advanced User Menu*** button, once done

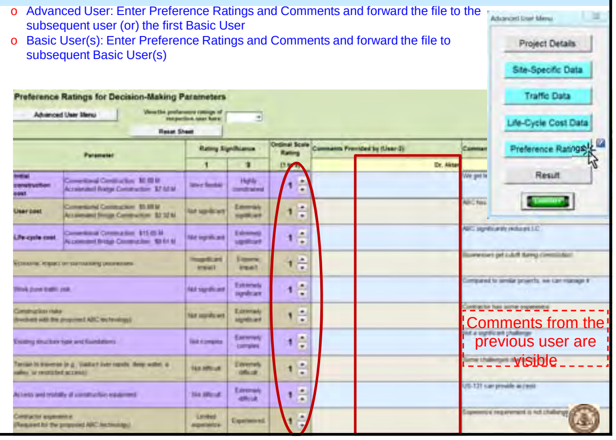
Implementation

- Enter Life-Cycle Cost Data

- Click ***Advanced User Menu Menu*** button, once done

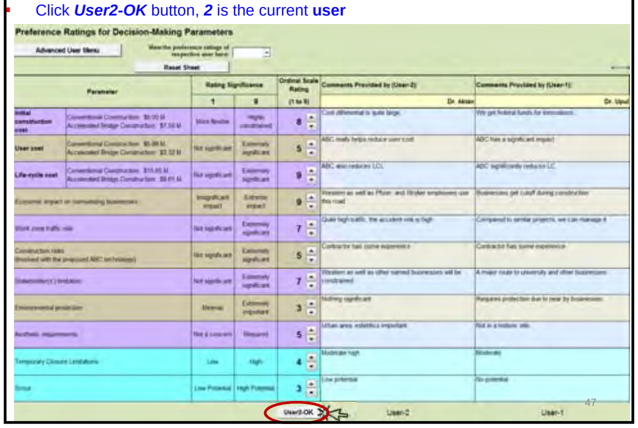
Implementation

- Advanced User: Enter Preference Ratings and Comments and forward the file to the subsequent user (or) the first Basic User
- Basic User(s): Enter Preference Ratings and Comments and forward the file to subsequent Basic User(s)



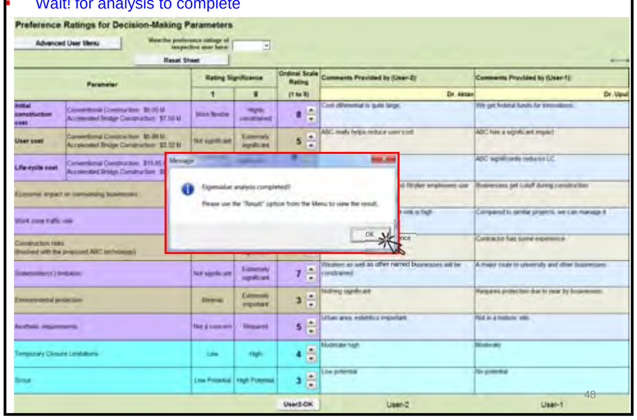
Implementation

- Click ***User2-OK*** button, ***2*** is the current **user**



Implementation

- Wait! for analysis to complete



IMPLEMENTATION

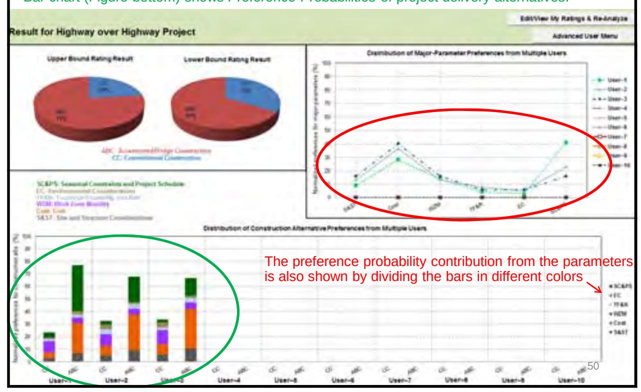
- Click on the ***Result*** command button

This button will be inactive until the current user clicks ***LOGOUT*** and the subsequent user logs in.

Note: This is programmed so that all the user ratings and respective comments are preserved under corresponding user numbers.

IMPLEMENTATION

- Pie charts (Figure-top left) show the upper and lower bound of user data.
- Line chart (Figure-top right) shows the distribution of major-parameter user preferences.
- Bar chart (Figure-bottom) shows *Preference Probabilities* of project delivery alternatives.



IMPLEMENTATION

- Tabular format of Preference Probabilities Bar Chart

Users or Decision Makers	Construction Alternatives	Site and Structure Considerations (SASTI) (%)	Cost (%)	Work Zone Mobility (WZM) (%)	Technical Feasibility and Risk (TFNR) (%)	Environmental Considerations (EC) (%)	Seasonal Constraints and Project Schedule (SCAPS) (%)	Overall Preference (%)
User-1	CC	[illegible]	4	5	[illegible]	1	4	23
	ABC	7	[illegible]	4	[illegible]	2	[illegible]	77
User-2	CC	5	8	9	4	4	3	32
	ABC	3	[illegible]	4	4	2	[illegible]	68
User-3	CC	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]
	ABC	[illegible]	[illegible]	5	4	[illegible]	[illegible]	67
User-4	CC	0	0	0	0	0	0	0
	ABC	0	0	0	0	0	0	0
User-5	CC	0	0	0	0	0	0	0
	ABC	0	0	0	0	0	0	0
User-6	CC	0	0	0	0	0	0	0
	ABC	0	0	0	0	0	0	0
User-7	CC	0	0	0	0	0	0	0
	ABC	0	0	0	0	0	0	0
User-8	CC	0	0	0	0	0	0	0
	ABC	0	0	0	0	0	0	0
User-9	CC	0	0	0	0	0	0	0
	ABC	0	0	0	0	0	0	0
User-10	CC	0	0	0	0	0	0	0
	ABC	0	0	0	0	0	0	0

IMPLEMENTATION

- Exit and forward the file to subsequent Basic User.

Logout button takes user back to ***Start Menu***

- ***EXIT*** button closes the program

FINAL NOTES

- The decision-making process is based on site-specific data.
- Methodology integrates quantitative data to assist user in qualitative decisions.
- Experts opinions are based on their experiences on “recent projects” and NOT on pair-wise comparisons.
- The AHP consistency of results are assured by Eigenvalue analysis.
- The decision-making model is limited to typical bridges of short and medium span and less than 30° skew.
- The model is being extended to incorporate all ABC alternatives.

5