Federal Highway Administration

Every Day Counts

Innovation Initiative

Accelerating Innovation & Technology Deployment: Prefabricated Bridge Elements & Systems (PBES)

Participant Workbook

U.S.Department of Transportation
Federal Highway Administration

Participant Workbook

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- M3: Examples of Decision-Making Frameworks – UTAH DOT
- M4: *PBES Cost Study: Accelerated Bridge Construction Success Stories* (FHWA, 2006), http://www.fhwa.dot.gov/bridge/prefab/successstories/091104/
- M5: FHWA Prefabricated Bridges Web Link, http://www.fhwa.dot.gov/bridge/prefab/
- M5: FHWA Highways for LIFE Demonstration Projects Web Link, http://www.fhwa.dot.gov/hfl/projects.cfm
- M5: FHWA Accelerated Bridge Construction Technologies Web Link, http://www.fhwa.dot.gov/bridge/accelerated/
- M5: FHWA Accelerated Construction Technology Transfer Web Link, http://www.fhwa.dot.gov/construction/accelerated/
- M5: National Cooperative Highway Research Program Web Link http://www.trb.org/NCHRP/Public/NCHRP.aspx
- M5: Strategic Highway Research Program 2 (SHRP 2) Web Link, http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Blank2.aspx
- M5: FHWA *Manual on Use of Self-Propelled Modular Transporters to Remove and Replace Bridges*, June 2007, http://www.fhwa.dot.gov/bridge/pubs/07022/
- M5: *Accelerated Bridge Construction: SPMT Process Manual and Design Guide*, November 2009, Utah DOT at www.udot.utah.gov
- M5: *Best Practices in Accelerated Construction Techniques*, March 2009, NCHRP, http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-68A_07-02.pdf
- M6: *Connection Details for Prefabricated Bridge Elements and Systems* (Introduction) http://www.fhwa.dot.gov/bridge/prefab/if09010/

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- M6: *Guidelines for Accelerated Bridge Construction: Using Precast/Prestressed Concrete Components*, PCI Northeast Bridge Technical Committee, www.pcine.org
- M7: *Manual on Use of Self-Propelled Modular Transporters to Remove and Replace Bridges*, June 2007
- EDC Brochure
- PBES Orientation Brochure
- PBES Table Top Exhibit
- Online Outreach Resources:
    - *Public Roads Magazine* (TFHRC) *http://www.fhwa.dot.gov/publications/publicroads/index.cfm*
    - *Public Roads -- A*uthor Instructions (TFHRC)
    - *http://www.fhwa.dot.gov/publications/publicroads/author.cfm*
    - FOCUS Magazine (Office of Infrastructure) *http://www.fhwa.dot.gov/publications/focus/*
    - *Centered on Service* newsletter (FHWA Resource Center) *http://www.fhwa.dot.gov/resourcecenter/success/cos.cfm*

I. EXECUTIVE SUMMARY

Accelerated Bridge Construction (ABC) employs structural and geotechnical engineering technologies to help agencies and the traveling public saves time and money, when bridge rehabilitation or reconstruction projects are implemented. The five broad categories of those technologies are Foundation & Wall Elements, Rapid Embankment Construction, Prefabricated Bridge Elements & Systems, Structural Placement Methods, and Fast Track Contracting.

This PBES Participant Workbook will highlight **Prefabricated Bridge Elements & Systems (PBES),** which is one of many ABC innovations available to bridge owners. PBES consists of bridge structural elements and systems that are constructed off the bridge alignment to accelerate onsite construction time relative to conventional bridge construction. Others innovations include, but are not limited to, the use of Geosynthetic Reinforced Soil (GRS), Integrated Bridge Systems, Expanded Polystyrene (EPS) Geofoam, and Continuous Flight Auger (CFA) piles. As always, bridge owners should select the ABC option that best fits their project situations.

Foundation & Wall Elements	*Rapid Embankment Construction*	*Prefabricated Bridge Elements & Systems (PBES)*	*Structural Placement Methods*	*Innovative Contracting*
Continuous Flight Auger Piles **Geosynthetic Reinforced Soil Integrated Bridge System**	**Expanded Polystyrene Geofoam**	**Prefabricated Elements** **Prefabricated Systems** • **Superstructures** • **Substructures** • **Total Bridge**	**Self-Propelled Modular Transporters (SPMTs)** **Longitudinal launching** **Horizontal sliding or skidding** **Other heavy lifting equipment and methods**	**Innovative Contracting:** • **Best Value** • **CMGC** • **Design Build** • **A+B** • **A+B+C** • **Warranties**

Approximately one-fourth of the Nation's 600,000 bridges require rehabilitation or replacement. Bridge repair, rehabilitation, and replacement activities, however, can significantly impact bridge users. For example, full-lane closures in large urban centers or on highways due to bridge projects can have a significant economic impact on commercial and industrial activities. In many cases, the direct and indirect costs of traffic detours, the loss of the use of the bridge during construction, and the disruption to the local economy caused by a bridge project can exceed the actual cost of the bridge structure. Lane closures and other bridge activities also can lead to safety issues. Because of these potential economic impacts and safety concerns, minimizing traffic disruptions during bridge rehabilitations and repairs is a critical issue that should be considered as important as maintaining construction quality and reducing the life cycle costs and environmental impacts of the bridge.

The ABC Technology Deployment Implementation Team identified the following Vision and Mission statements as they relate to ABC technologies:

Why use this ABC Technology?

Prefabricated bridge elements and systems in construction can help minimize traffic delays and community disruptions by reducing onsite construction time and improving quality, traffic control, and safety. Consequently, using PBES means that time-consuming formwork construction, concrete placements, curing, and other tasks associated with fabrication can be done offsite in a controlled environment without affecting traffic.

The ABC technologies discussed in this course offer solutions to many of the bridge construction challenges highway agencies are facing. The *PBES Implementation & Marketing Plan* describes the current status of the bridge system, the elements that support ABC, and outlines a comprehensive approach for encouraging State bridge engineers to consider, learn about, and ultimately try ABC technologies when situations are appropriate for use.

The *PBES Implementation & Marketing Plan* establishes an aggressive, stakeholder-engaged program to rapidly accelerate the deployment of four identified and proven ABC Technologies. On March 15-16, and March 24-25, 2010, the PBES Technology Deployment Implementation Team held training and a retreat, in Baltimore, MD, to establish a clear vision for the program, identify the target audience, develop the mission statement and overall goals for the program, and to establish the performance measures and strategies needed to accelerate implementation.

II. INTRODUCTION

When the Interstate Highway System in the United States was first conceived and promoted, it was with the vision that one day Americans would be able to drive from coast-to-coast without stopping for a traffic signal. In the over 50 years since President Dwight D. Eisenhower launched the system with the signing of the Federal Aid Highway Act of 1956, drivers in this country have seen that vision realized. Achieving the goal required the construction of a complex system of highways, bridges, interchanges, drainage systems, traffic controls, landscaping, and signaling systems.

Today, the National Highway System (NHS) encompasses some 160,000 miles of roadway. Although the NHS makes up only 4 percent of America's roads, it carries more than 40 percent of all highway traffic, 75 percent of all heavy truck traffic, and 90 percent of tourist traffic. It has become the very backbone of the American economy, serving as the primary means of moving goods throughout the country. The NHS serves 198 ports, 207 airports, 67 Amtrak train stations, 190 rail/truck terminals, 82 intercity bus terminals, 307 public transit stations, 37 ferry terminals, 58 pipeline terminals, and 20 multipurpose\passenger terminals. It is literally what holds the Nation's entire transportation system together.

Unfortunately, the NHS is not without its problems.

First, it's overcrowded. By the year 2020, ninety percent of all urban Interstate highways will be at or exceeding capacity. Three years ago, the Texas Transportation Institute (TTI 2007 Urban Mobility Report (437 urban communities) put the cost of congestion in the Nation's 437 urban areas at $78.2 billion. Total congestion cost for the 437 urban areas came to almost $78.2 billion. The TTI report indicated that there are 4 billion hours/year in time delay and 2.9 billion gallons of wasted gas/year.

Second, NHS pavements are not lasting as long as they should. Highways built to last 25 years take such a pounding from the amount and the weight of traffic that they rarely stay in optimum condition that long. Today, more than 11,000 miles of pavement on the NHS are in poor condition. Almost a quarter of all bridges in the country—some 146,000—are either structurally deficient or functionally obsolete. Yet, many highway engineers agree that 50-year pavements and 100-year bridges should be attainable using current technology.

Third, our NHS is not safe enough. Every year for the past decade, some 33,000 people die on America's highways. Over half of these fatalities have occurred on two-lane roads that carry only 25 percent of the total NHS traffic. Some 15,000 fatalities are ascribed directly to substandard road conditions, obsolete designs, or roadside hazards. The National Highway Traffic Safety Administration indicated that there were 11,674 fatalities in 2008 at a cost of $40.4 billion. The list goes on and on. Truly, America's highway system needs help. But how do we bring the system up to the level of quality the traveling public deserves? That's the challenge the Nation faces at the beginning of a new century. To be sure, many leaders have thought long and hard about solutions. For some, the automatic response to such a challenge is simply to throw money at the problem. Certainly, having the funds to complete necessary road and bridge projects has long been an issue with highway agencies at all governmental levels. But according to organizations such as The Road Information Program (TRIP) and the American Public Transportation Association (APTA), not only is the idea of funding such a massive reconstruction effort unrealistic, the very future of highway funding is in jeopardy.

The average car now gets nearly a third more miles per gallon than it did 23 years ago. Thirteen years ago, a report from the National Cooperative Highway Research Program (NCHRP) warned that with increasing fuel efficiency (and an expected move toward electric and hybrid vehicles), drivers would be buying less gas in the future, and that would reduce the amount of tax money available for improving roadways. In 2003, a report from the Brookings Institution confirmed those projections and indicated that States are already seeing declines in their tax revenues. Indeed, as gasoline prices have risen, the public has focused more on conservation, vehicles with higher fuel economy, and vehicles powered with alternative fuels.

This has meant less money paid into gasoline taxes. The result is a deep concern that both States and the Federal Government will have to find alternative means for funding highway projects. Toll roads are becoming more and more prevalent, and concepts such as equipping vehicles with on-board computers which calculate mileage and automatically bill the vehicle owner a tax-per-mile fee are getting serious consideration. Several times, Congressional leaders have introduced bills which would provide drivers with a "temporary gas tax holiday," a move which, while appealing to some, would result in severely decreased funds for maintaining the highway system. Yet, even if the funds were available, a massive effort to rebuild the entire highway system using current practices would be inconceivable today. The public would not stand for the congestion it would bring with it. In 2001, a study analyzing three national surveys of the driving public showed clearly that the public already equates highway construction—*any* highway construction—with congestion. Increasing construction levels, even if it is intended to ultimately cut congestion levels by adding lanes, only exacerbates the public's perception that "the shortest distance between two points is always under construction."

FILLING THE NEED

How do we bring the existing highway system up to the level of quality the public wants, yet do so without the congestion headache that such construction invariably causes? The solution is to find ways to do as much of the work as possible at times and in locations that minimize interference with the driving public, and for that portion of the work that *does* require such interference, to do it as quickly and safely as possible. These innovative approaches should also result in facilities that are safer, last longer, and are of better quality overall than what was there previously.

Currently, there are numerous innovations that, if implemented nationwide, would have just such a dramatic impact on the driving experience of the motorist. Congestion levels would be reduced, especially in construction work zones. In addition, because construction schedules would be shortened, overall congestion would decrease. Safety levels would be heightened, both in work zones and, because of enhanced designs, on the everyday sections of highway. Highways and bridges would last longer, and as a result, there would be less frequent road closures for construction. In addition, roadways would cost less, both in initial cost, and in the entire life cycle of the highway or bridge.

MARKET ANALYSIS

Bridge projects are one of the most notorious culprits for traffic delay. In many cases, a bridge provides the only passage across a geographic barrier. Taking such facilities out of service for any length of time can mean alternatives that cause great delay and that take drivers many miles out of their way. Also, because of the limited construction work space on bridge projects, safety hazard levels for construction workers and motorists are much higher than those of roadway projects. An analysis of urban reconstruction project usually shows bridges to be a critical path element for impacting construction schedules. In order to shorten construction times, and reduce the impact on users, bridge construction techniques must be changed.

THE CURRENT BRIDGE INVENTORY

Today there are more than 600,000 bridge structures over 20-feet in length in the National Bridge Inventory. These include bridges made of steel, concrete, wood, aluminum, fiber reinforced polymers, and masonry. Current thinking is that bridges should be able to last at least 75-100 years. The average age of our nation's bridge population is approximately 42 years. While functioning bridges still exist that were built more than 100 years ago, the design life of those bridges was 50 years.

III. EVERY DAY COUNTS (EDC) PERSPECTIVE

The overarching purpose of the Every Day Counts (EDC) initiative is to focus on advocating and recommending practices/technologies that meet the States' needs, develop an internal network of individuals trained to deploy new, national, initiatives at the state and local level, focus on EDC priority initiatives, and ensure that all staff incorporate the new business model perspective into day to day activities.

With that in mind, the following Division goals have been identified:

- Adopting a "Leaning Forward Approach" by explaining the nuance of how the EDC PBES initiative will actually change how FHWA does business
- Emphasizing consistency throughout the Agency
- Promoting the use of tools that are being developed for PBES
- Identifying deployment obstacles
- Developing Division staff as extremely creditable resources for State and Local partners
- Ensuring Division staff can identify what condition is best suited for using PBES (What is the benefit at that condition? What is the diminished benefit for that condition? When is it no longer suitable to use the technology/practice?)
- Enabling Division staff to motivate opponents (Developing soft-skills/leveraging strong relationships)
- Identifying best practices/experiences that FHWA endorses for PBES
- Goal is to achieve positive deployment results and not just meet the performance measures
- The desire is to streamline PBES innovations into everyday activities
- Identifying project and program triggers (opportunities) within our regular processes/business practices to market/sell an EDC initiative (An example of a project trigger is the Value Engineering process)

IV. TARGET AUDIENCE

The target audiences for this training are bridge and construction engineering staff from local, regional, and state transportation agencies as well as consultants and the consulting industry. The training includes 12 individual topic modules scheduled for the convenience of audiences in the east, central/mountain, and west coast time zones. Participants will be able to down load a workbook that includes the presentations and presenter notes for each of the 12 modules, and also two additional modules not covered in the web training.

V. PBES Online Seminars

Prefabricated Bridge elements and Systems (PBES) is a tried and true technology that is advancing bridge construction to the next level. To further support the FHWA's Every Day Counts initiative of PBES implementation, a series of webinar modules have been scheduled to provide continued awareness for local, regional, and state transportation agencies. These modules will be hosted online and offered at no cost via the FHWA webinar training platform.

Representatives from the concrete, steel, compsits, and construction industries will highlight how their industry efforts and capabilities support the EDC PBES deployment for accelerated bridge construction. The training includes project-specific examples and case studies to highlight the benefits of PBES and accelerated bridge construction.

A total of 4 Sessions (3 modules per Session) will be held over a two-day period.

SCHEDULE and REGISTRATION

A total of 4 Sessions (3 modules per Session) will be held over a two-day period. **Registration must be completed separately for each Session at the links shown below.**

DAY 1 MORNING
SESSION 1 – Modules 1 thru 3
AUGUST 16, 2011
11:00 AM - 12:30 PM EST

Session 1 Registration Link

Training Summary:

- What are Prefabricated Bridge Elements and Systems for Accelerated Bridge Construction (ABC)?
- Owner Perspective on Lessons Learned in Implementing ABC
- Decision-Making Frameworks for using PBES

DAY 1 AFTERNOON
SESSION 2 – Modules 4 thru 6
AUGUST 16, 2011
3:00 PM - 4:30 PM EST

Session 2 Registration Link

Training Summary:

- ABC/PBES Costs
- ABC/PBES Specifications, Plans and Details
- Connection Details and PBES Design Example

DAY 2 MORNING
SESSION 3 – Modules 7 thru 9
AUGUST 17, 2011
11:00 AM - 12:30 PM EST

Session 3 Registration Link

Training Summary:

- Efforts and Capabilities to Support PBES Deployment
- Concrete Industry
- Steel Industry
- FRP Industry

DAY 2 AFTERNOON
SESSION 4 - Modules 10 thru 12
AUGUST 17, 2011
3:00 PM - 4:30 PM EST

Session 4 Registration Link

Training Summary:

- Lightweight Concrete Benefits for PBES Deployment
- Construction Industry Efforts and Capabilities to Support PBES Deployment
- ABC Decision Making and Economic Modeling Tool

About Our Webinar System

The NHI webinar room is a web-based conferencing tool used for live online committee meetings, sharing documents, training and team collaboration among staff members and partners. To participate, you will need a touch-tone phone and an internet connection.

If you have never attended an Adobe Connect meeting before:

- Test your connection: **Test Link**
- Get a quick overview: **Overview Link**
- Questions? Contact Corey Martin at (703)235-0540

V. COURSE MATERIALS

Module 1: What are Prefabricated Bridge Elements & Systems (PBES) for Accelerated Bridge Construction (ABC)?

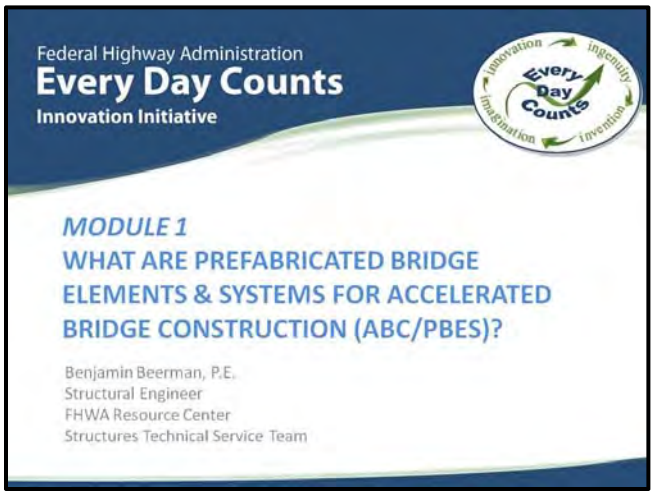
MODULE LEARNING OUTCOMES

By the end of this Module, you will be able to:

- EDC Program: the vision, mission and deployment goals for PBES
- the reasons for using ABC/PBES
- definition of PBES
- case studies of PBES
- benefits of PBES
- the status of EDC deployment goals for PBES

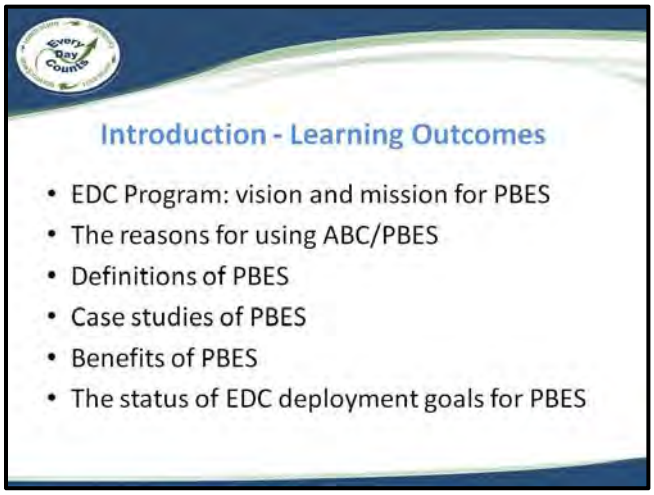
MODULE SLIDES & NOTES

Slide 1: What are Prefabricated Bridge Elements & Systems for Accelerated Bridge Construction (ABC/PBES)?



Slide 2: By the end of Module 1, you will have knowledge and understanding of:

- EDC Program: the vision, mission and deployment goals for PBES
- the reasons for using ABC/PBES
- definition of PBES
- case studies of PBES
- benefits of PBES
- the status of EDC deployment goals for PBES



Slide 3: As many of you all know, there has been an **increased** and **focused** awareness on the benefits of using PBES by State and Local Transportation agencies throughout the U.S. as a result of the Every Day Counts program that was launched by our FHWA executive leadership in November of 2009.

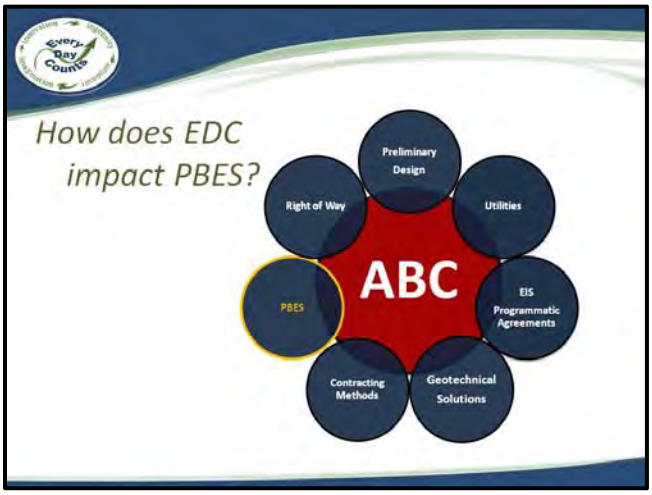
Slide 4: To meet the ***objectives*** *of the EDC program*, there are 15 initiatives, of which 10 are focused on **shortening project delivery** and 5 are focused on ***technologies*** that **improve safety**, **reduce congestion**, and **keep America moving and competitive in the world market**.

The EDC program is about taking ***effective, proven, and market-ready*** technologies that are ***ready for Agency implementation*** and putting them into ***widespread use***.

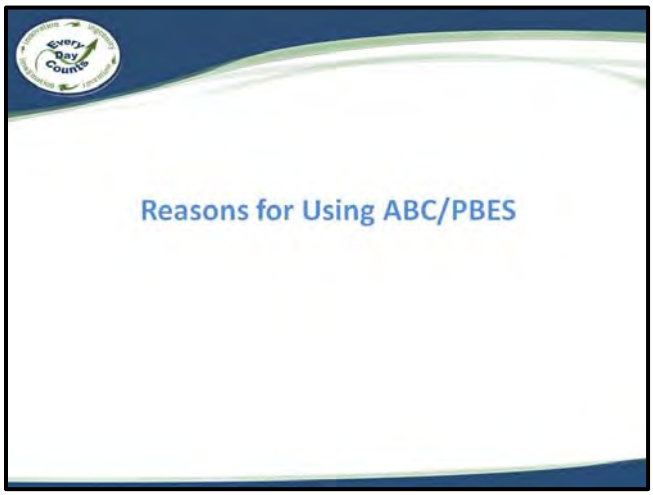
Slide 5: So how does the EDC program impact the use of PBES, or from a broader perspective, Accelerated Bridge Projects?

Over half of the EDC initiatives which fall under the "Shortening Project Delivery" category are planning strategies that are often used in conjunction with PBES to Accelerate onsite bridge construction– either for a single, group, or entire program of bridge projects.

And because every one of the 15 initiatives from the EDC program has defined deployment goal that your leadership is committed to - the methods in which you and your Agency are procuring bridge construction projects in the future may be changing.



Slide 6: Why is there a need to Accelerate on-site construction?



Slide 7:

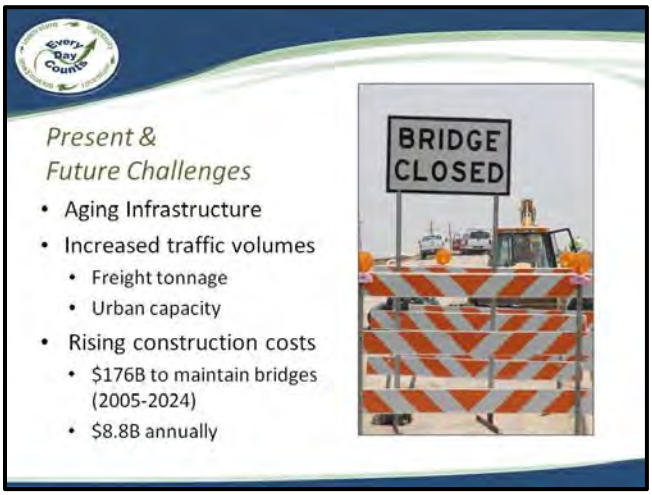
As you already know, we are challenged by:

- Aging Infrastructure – 1/3 of the Nation's Bridge Inventory is in Poor Condition
- Our transpiration network experiences increased Traffic volumes every year

Between 1998 & 2020 we can expect to see a 70% Increase in Freight Tonnage
and by the year 2020, 90% of Urban Interstates are Expected to exceed/approach their capacity

- Highway Construction costs for bridges are extensive

Cost to Maintain our Bridges is expected to amounted to over - $176.0 Billion over the next 20 years (2005 to 2024) - or $8.8B annually.

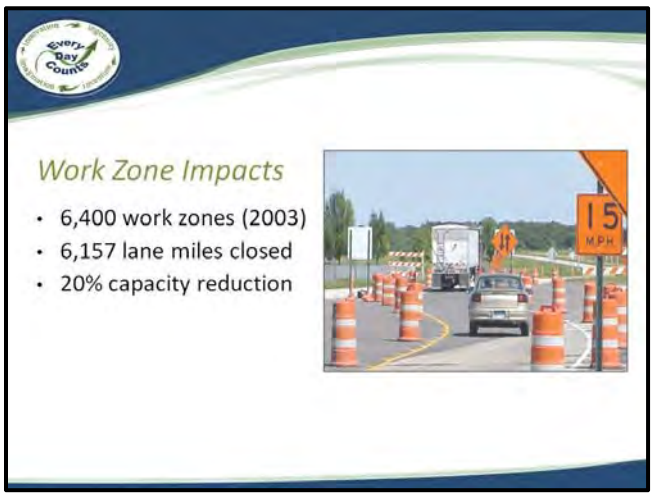


Slide 8:

In the transportation infrastructure renewal program, impacts from increasing work zones is almost certain.

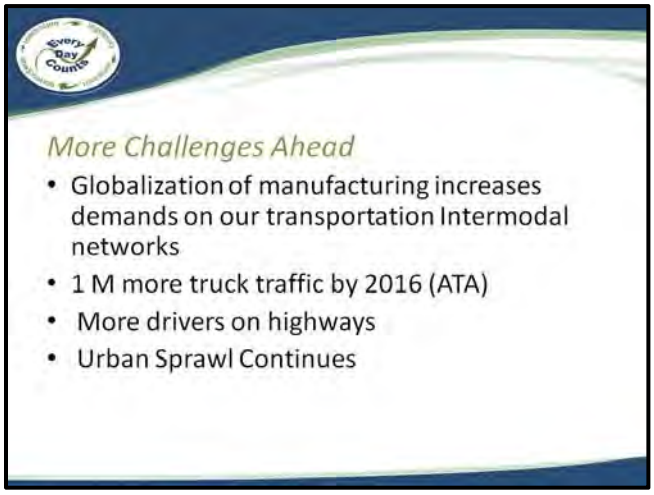
A study in 2003 reported the total number of highway work zones in the summer was estimated to be
more than 6,400 – which corresponded to over 6,000 lane miles closed.

That amounts to 20% of the capacity reduction on our national highway network!



Slide 9: The American Truckers Association reports that by 2016 our highways will carry 1 million more trucks. This is caused by trucker's hours-of-service regulations – which prevents haulers from operating their rigs for more than 11 hours/day and for more than 70 hours per eight-day period.

As quoted by B.J. Gorman, president of Tango Transport Inc. of Shreveport, LA. (ref. AASHTO Journal, September 15, 2006), "One reason for trucks' popularity is that they become de facto warehouses as the result of our modern inventory-control systems. This is a service other forms of transport can't supply."

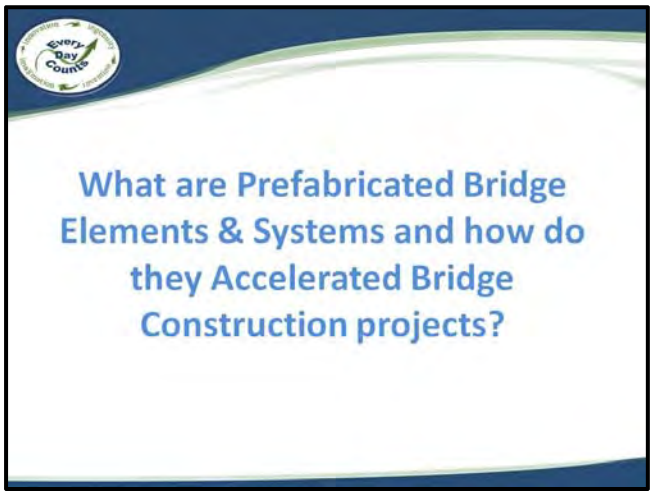


ATA's Chief economist Bob Castello reported that there are 2.7 million big rigs on U.S. Highways as of 2006.

Slide 10: One business at a time, and one commuter at a time - congestion robs our nation of productivity and quality of life.
Based on TTI 2007 Urban Mobility Report (437 urban communities) congestion translates to:

- 4 billion hours/year in time delays
- 2.9 billion gallons of wasted gas/year
- $78.2 Billion cost to travelers (Based on gas price in 2005.)
- Total congestion cost for the 437 urban areas came to almost $78.2 billion per year.

Slide 11: What are Prefabricated Bridge Elements & Systems how do they Accelerated Bridge Construction projects?



Slide 12: Before we discuss the definition of PBES, lets first discuss how ABC differs from conventional bridge construction (CBC).

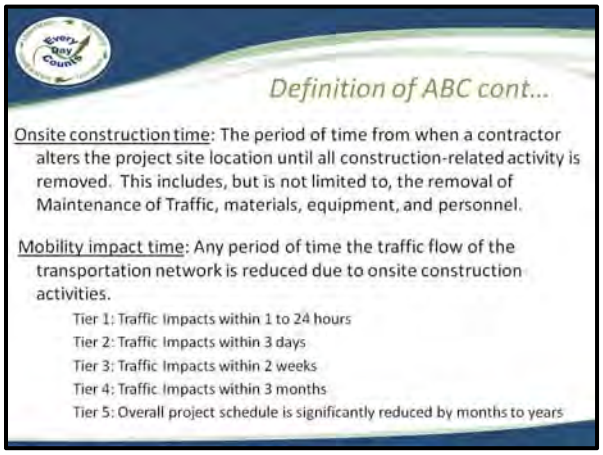
We define Conventional Bridge Construction as construction methods that do not significantly **seek out** methods to reduce the onsite construction time that is needed to build, replace, or rehabilitate a single, or group of bridge projects.

Conventional construction methods require time consuming onsite activities which are typically weather dependent, impact the flow of traffic which may present driver distractions that can reduce the safety of the traveling public and the safety of contractor personnel.

An example of conventional construction includes onsite installation of substructure and superstructure forms, followed by reinforcing steel placement, concrete placement, and concrete curing, all typically occurring in a liner manner, oftentimes alongside - or adjacent to ongoing traffic.

Slide 13: Alternatively - we define Accelerated Bridge Construction as bridge construction which use ***innovative*** planning, design, materials, and construction methods in a manner to ***specifically*** reduce the onsite construction time and mobility impacts that occur when building new bridges or replacing and rehabilitating existing bridges.

Slide 14: To gauge the effectiveness of ABC, two time metrics is included in the definition of ABC:
The first is….
Onsite construction time: **Which is:** The period of time from when a contractor alters the project site location until all construction-related activity is removed. This includes, but is not limited to, the removal of Maintenance of Traffic, materials, equipment, and personnel.

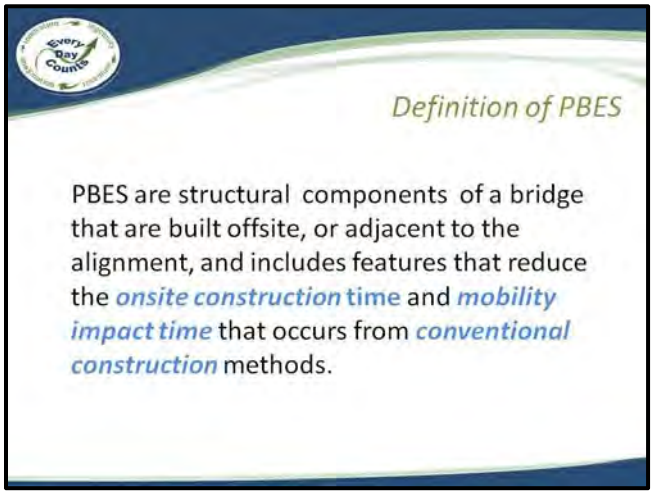


The second time metric is the….
Mobility impact time: **This is** Any period of time the traffic flow of the transportation network is reduced due to onsite construction activities. **There are 5 mobility impact time categories as shown below…**

Tier 1: Traffic Impacts within 1 to 24 hours
Tier 2: Traffic Impacts within 3 days
Tier 3: Traffic Impacts within 2 weeks
Tier 4: Traffic Impacts within 3 months
Tier 5: Overall project schedule is significantly reduced by months to years

A common reason to use **ABC** is to reduce the traffic impacts because the flow of the transportation network can be directly impacted by the disruptions caused by onsite construction related activities.

Slide 15: Use of Prefabricated Bridge Elements and Systems (PBES) is one strategy that can meet the objectives of accelerated bridge construction.



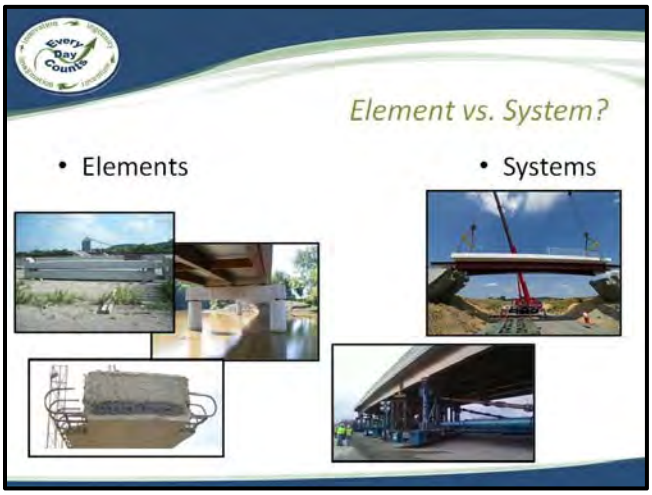
PBES are structural components of a bridge that are built offsite, or adjacent to the alignment - and includes features that reduce the ***onsite construction time*** and ***mobility impact time*** that occurs if ***conventional construction*** methods were used.

By building the structural elements, or the entire bridge offline, the onsite construction period can be condensed and the mobility impacts to the transportation network can be reduced – like in hours or in a weekend!

However, there are other common and equally viable reasons to use PBES which deal with site constructability issues. Oftentimes remote site locations, limited construction seasons, material availability, and consistent quality in workmanship present opportunities where the use of PBES can provide more practical and economical solutions over conventional construction methods.

Regardless of the reason(s) to choose PBES, On-site construction time and Mobility impact time are typically reduced in some manner relative to conventional construction methods.

Slide 16: Is there a difference between a prefabricated element and a prefabricated system?



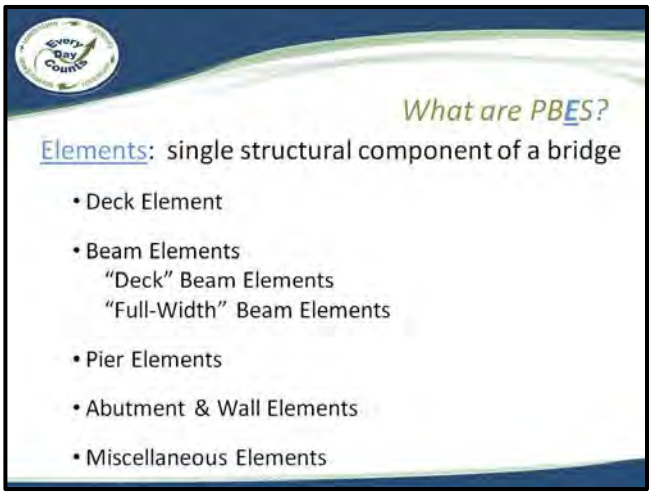
Due to the influx of information received from our EDC quarterly surveys, we are finding that it would be useful to build upon the definitions that we have used in the past so that we can relate key words and terms to common technologies.

In addition, the ability to track what types of elements and systems are being used (and which was aren't) would be useful so that we can easily identify trends and have the ability to get information such as plans, specifications, bid-tabs, and schedules for projects that have are been built using PBES.

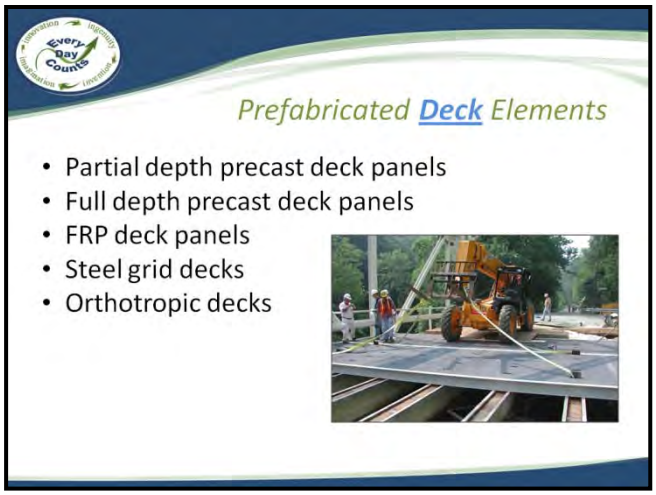
Internally, the FHWA is developing a tracking tool to provide such information, so that Transportation Agencies can easily share and exchange information from one another.

Slide 17: Given the need to categorize our information better, we are defining single structural components of a bridge that are prefabricated in a manner and eliminates or reduces the onsite construction time that is needed to build a similar structural component using conventional construction methods as a **Prefabricated Element**.

Elements are typically built in a repeatable manner to offset costs thru the economies of scale. Because the elements are built under controlled environmental conditions, the influence of weather related impacts can be eliminated and improvements in product quality and long-term durability can be better achieved. There are 5 ***categories*** of Prefabricated Bridge Elements which we will define in more detail and provide key words and examples, starting with the deck elements.



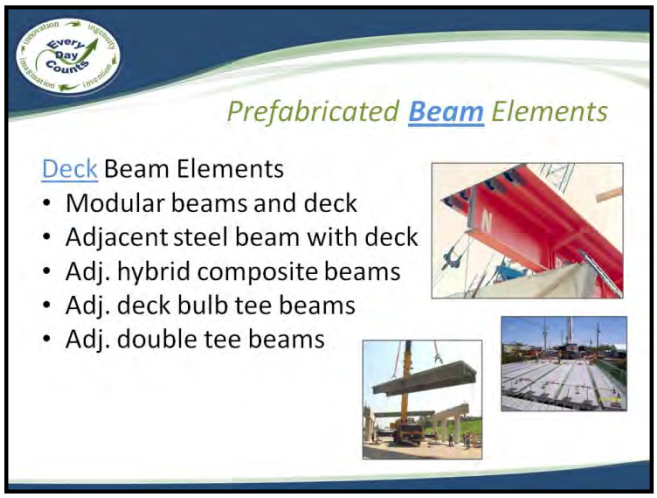
Slide 18: Prefabricated **deck** elements **eliminate** activities that are associated with conventional deck construction - which typically includes onsite installation of deck forms, overhang bracket and formwork installation, reinforcing steel placement, bid-well set up, concrete placement, and concrete curing.



Key words and examples of Prefabricated Deck Elements include:

- partial-depth precast deck panels
- full-depth precast deck panels with and without longitudinal post-tensioning
- lightweight precast deck panels
- FRP deck panels
- steel grid (open or filled with concrete)
- orthotropic deck
- other prefabricated deck panels made with different materials or processes

Slide 19: Prefabricated beam elements are classified into two "sub" categories: "deck" beam elements" and "full-width" beam elements.



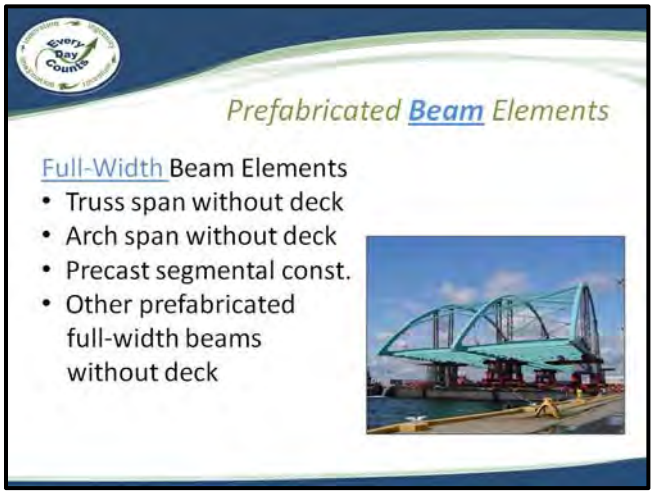
Deck beam elements eliminate conventional onsite deck forming activities, but do so in a different manner than the "deck" elements previously discussed. To reduce onsite deck forming operations, "deck" beam elements are typically placed in an abutting manner.

Key words and Examples of Deck Beam Elements include:

- adjacent deck bulb tee beams
- adjacent double tee beams
- adjacent inverted tee beams
- adjacent box beams

- modular beams with decks
- post-tensioned concrete thru beams
- other prefabricated adjacent beam elements

Slide 20: The second sub category is **"Full-width"** beam elements which eliminate conventional onsite beam placement activities **and substructure** construction by reducing the number of spans and pier units. Once placed, they make up the full-width cross section of the bridge and are typically rolled, slid, or lifted into place.

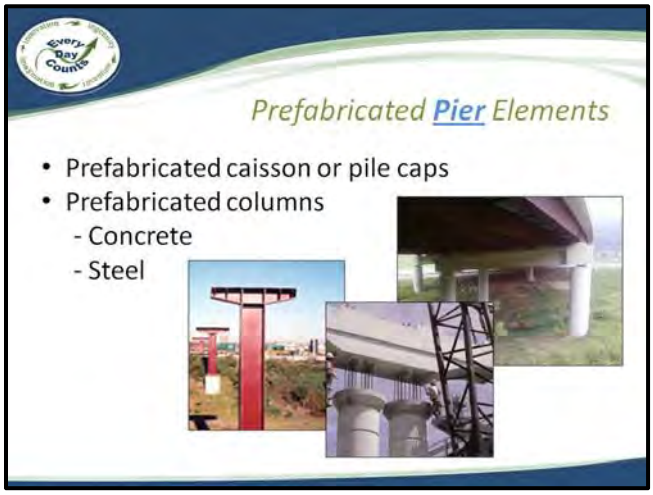


Examples of Full-Width Beam Elements include:

- full width truss and arch spans without decks
- full width, pre-cast segmental construction
- other prefabricated full-width beam element without deck

Given their size and weight, the entire deck is ***sometimes*** not included.

Slide 21: Moving down into the substructure, we have Prefabricated ***pier*** elements which eliminate activities that are associated with conventional CIP pier construction.

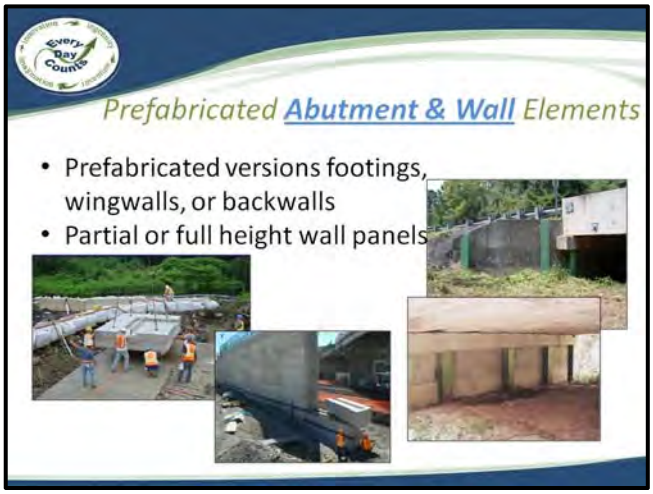


Examples of Pier Elements include:

- prefabricated caps for caisson or pile foundations
- precast spread footings
- prefabricated columns
- prefabricated column caps
- prefabricated combined caps and columns

Slide 22: We also have versions of Prefabricated abutments and wall elements. Which include:

- Prefabricated versions of wing-wall and back-walls
- Partial or full height wall panels
- And other prefabricated systems that eliminate onsite CIP activities



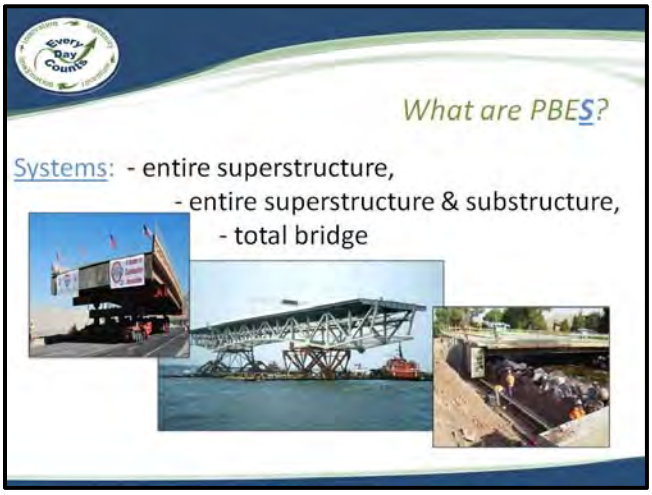
Slide 23: In our last category, we have a "miscellaneous" prefabricated element group that consists of secondary structural components that are often used in conjunction with the major structural components previously discussed.

Examples of Miscellaneous Elements include:

- precast approach slabs and
- prefabricated parapets (flexible and hard systems)

Because of the ongoing evolvement of innovations, we also include "deck closure" methods and
"overlay systems" in this category.

Slide 24:



We discussed the various versions of prefabricated elements, so how do they differ from prefabricated systems?

Prefabricated Systems are defined as a category of PBES that consists of an **entire superstructure**, an **entire superstructure and substructure**, or a **total bridge** that is procured in a modular manner such that traffic operations ***can be*** allowed to resume after placement.

Prefabricated systems are typically rolled, launched, slid, lifted, or otherwise transported into place, and have the deck - and preferably the parapets in place.

Due to the manner in which they are installed, prefabricated systems often require innovations in planning, engineering design, high-performance materials, and unique Structural Placement Methods.

The benefits of using prefabricated systems include:

- Minimal utility relocation and right-of-way take (if any at all)
- No- to- minimal traffic detouring over an extended period of time
- Preservation of existing alignment
- No use of temporary alignments
- No temporary bridge structures
- No- to- minimal traffic phasing or staging

THE BENEFITS OF USING PBES

Prefabricated bridge elements and systems offer bridge designers and contractors significant advantages in terms of onsite construction time, safety, environmental impact, constructability, and cost.

- **Minimizes Traffic Impacts of Bridge Construction Projects**
  Using prefabricated bridge elements and systems means that time-consuming formwork, concrete curing, and other tasks associated with fabrication can be done offsite in a controlled environment without affecting traffic.
- **Improves Construction Work Zone Safety, and worker safety.**

The benefits to the traveling public are obvious. Because PBES diminishes the time that the traveling public is interrupted, it obviously decreases the risk and exposure to the traveling public, resulting in safer work zones. A secondary benefit of PBES is that because prefabrication moves so much of the preparation work for bridge construction offsite, the amount of time that workers are required to operate onsite, frequently in or near traffic or at high elevations or over water, is greatly diminished. Job site hazards and constraints such as nearby power lines are minimized when workers can complete most of their construction off-site. This secondary benefit amounts to less risk for workers.

- **Makes Construction Less Disruptive for the Environment**
  Bringing prefabricated superstructures and substructures to the site ready for installation reduces disturbance to the land surface at the site, and it reduces the amount of time required onsite for heavy equipment. Keeping equipment out of sensitive environments is less disruptive for those environments.
- **Improves Constructability**
  Many job sites impose difficult constraints on the constructability of bridge designs—heavy traffic on an Interstate highway that runs under the bridge being constructed, difficult elevations, long stretches over water, or restricted work areas due to adjacent properties, to name a few. Using prefabricated bridge elements and systems relieves such constructability pressures.
- **Increases Quality and Lower Life Cycle Costs**
  Prefabricating bridge elements and systems takes them out of the critical path of the project schedule: work can be done ahead of time, using as much time as necessary, in a controlled environment. This reduces dependence on weather and increases quality control of the resulting bridge elements and systems. In addition we can bring to bear the quality control processes and material handling techniques inherent to manufacturing processes to bear on PBES elements. All projects that use prefabricated bridge elements and systems increase the quality of their components; most also lower life cycle costs.

Slide 25: So what do successful projects that use PBES look like?

We can start with the Graves Avenue project which is an example of a Prefabricated **superstructure** "**system**".

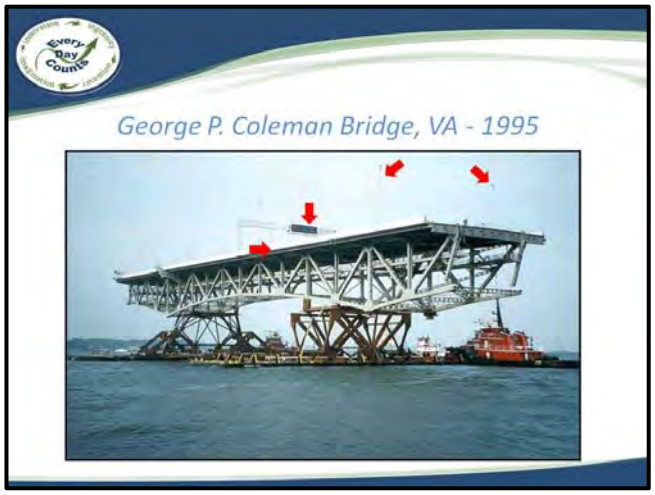
A 143' long, 59-ft wide structure was built in an adjacent staging area on Self Propelled Modular Transporters (or SPMTs).

Once complete, the existing spans over I-4 were removed using SPMTS (different set) using ½ hour rolling roadblocks.

Slide 26: Once the existing bridge was removed, the new structures were transported and installed during night time operations in just a few hours.

Slide 27: Another example of a Prefabricated Superstructure "system" is the Coleman Bridge, in which the entire deck and superstructure was constructed on barges and "floated" in place.

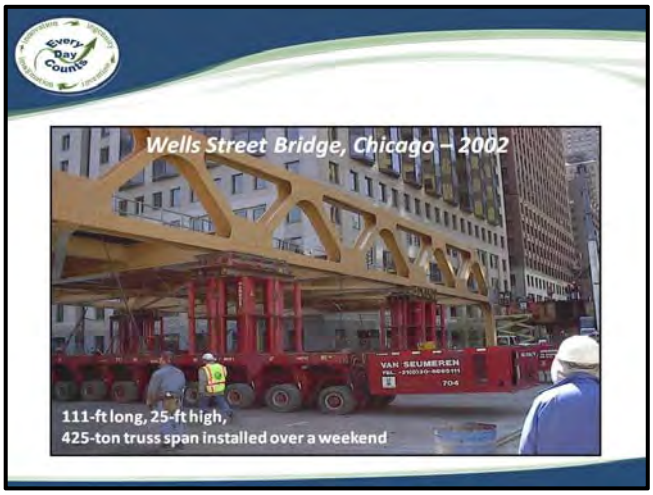
Note that it has the parapet already in place, as well as the overhead lights and signs!



Slide 28:

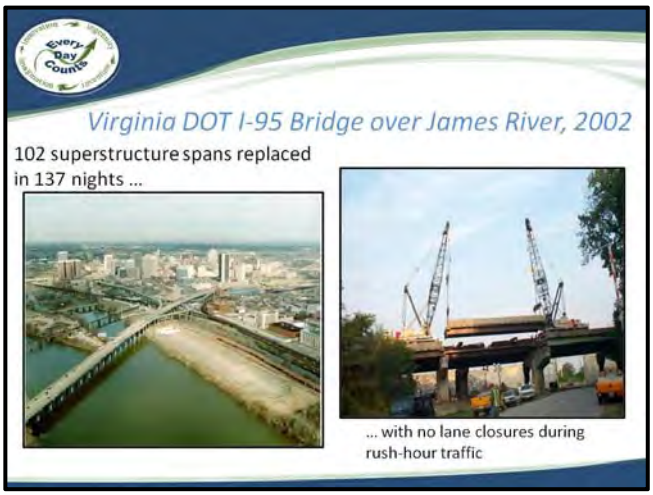
Shown here in the congested area of downtown Chicago, a 111-ft long, 425-ton truss span owned by the Chicago Transit Authority was fabricated near site and installed over a weekend timeframe.

This was done to avoid the loss in revenue impacts from transit riders using alternative modes of transportation while the bridge was out of service.

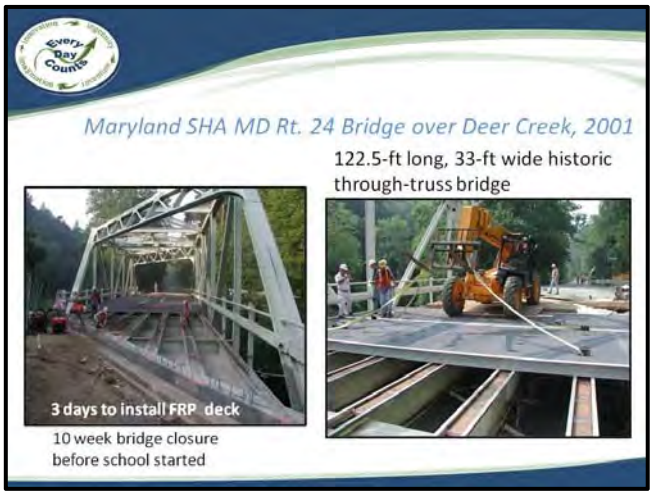


Slide 29:

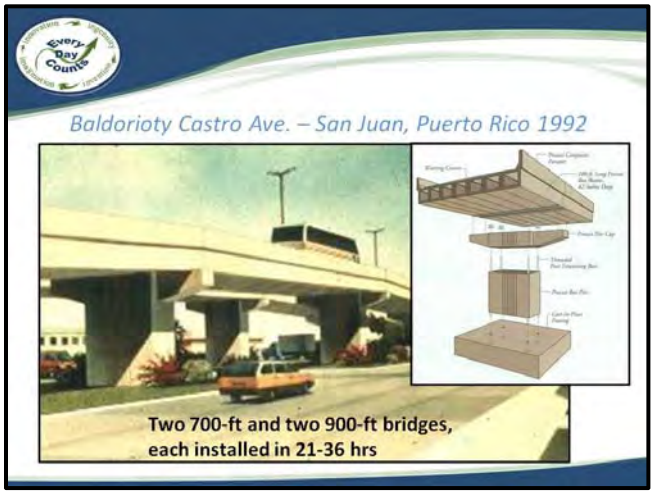
In these photos here, **prefabricated versions of "beam deck" elements** were used to replace 102 superstructure spans in 137 nights with no lane closures during rush hour traffic.



Slide 30: **Full Width prefabricated FRP "deck" elements** were used to accelerate the onsite construction time needed to rehabilitate this thru truss located Maryland.



Slide 31: And in Puerto Rico, two bridges - 700 ft and 900 ft long, were installed in just 21 to 36 hours each using totally prefabricated bridge elements!



Slide 32: Europe has been installing bridges in hours for years, even multi-span bridges as shown here.

In this case, the bridge was placed in two hours, and the entire length of closure of the highway was limited to one weekend.

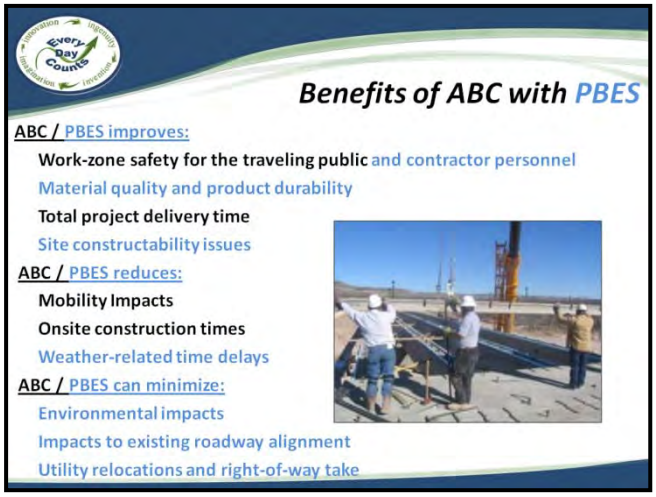
Slide 33: To date, a "total" bridge system has not been moved in the United States. However, in Normandy, this multiple-span railroad bridge was built adjacent to the existing railroad tracks on the concrete slab where the truck is sitting .

The existing railroad tracks were closed for a short duration (usually several days) and the existing embankment was removed to accommodate the wider bridge opening.

Once ready, the prefabricated bridge (including the entire superstructure and substructure) was picked up and moved into place using SPMTs. The railroad tracks were connected and trains began using the new bridge soon afterwards.

The concrete struts used for lifting the bridge were latter removed in their entirety.

Slide 34: ABC offers benefits to the traveling public.

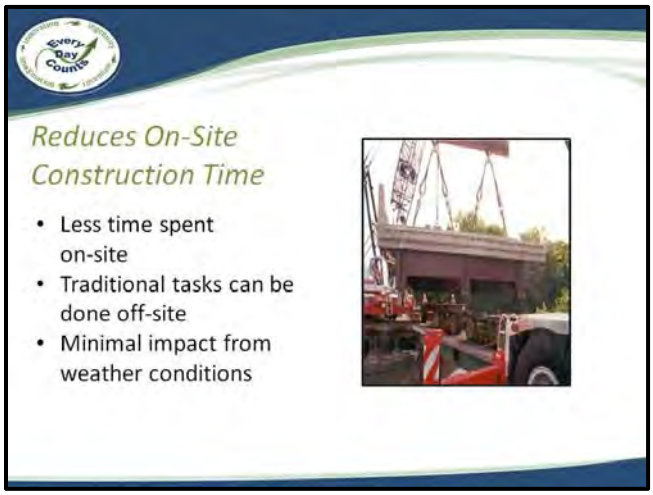


However, ABC by itself can simply be a matter of providing more onsite labor, equipment, and contracting mechanisms (like I/D clauses) to meet the need to "get in/get out/stay out".

But when we use PBES to accelerate bridge construction - we not only meet the objectives of ABC, we do so in a more efficient manner and realize additional benefits as well. By replacing conventional on-site construction activities with prefabricated elements and systems, the benefits of ABC **expand** and **compound**.

For example, the safety of the traveling public **in addition** to the safety of the contractor's personnel improves. Improvements in product quality and long term durability can be better achieved, the opportunity for weather related time delays become less, and the on-site project disruptions which can directly influence the existing roadway alignment, environmental impacts, ROW, and Utility disruptions **can be** minimized even further.

Slide 35: Using prefabricated bridge elements and systems means that time consuming onsite construction activities such as formwork construction, re-bar and concrete placement, concrete curing, formwork removal and other related tasks including the planning, coordination, and scheduling efforts for the on-site labor, material, and equipment can be done off-site and off the critical path.

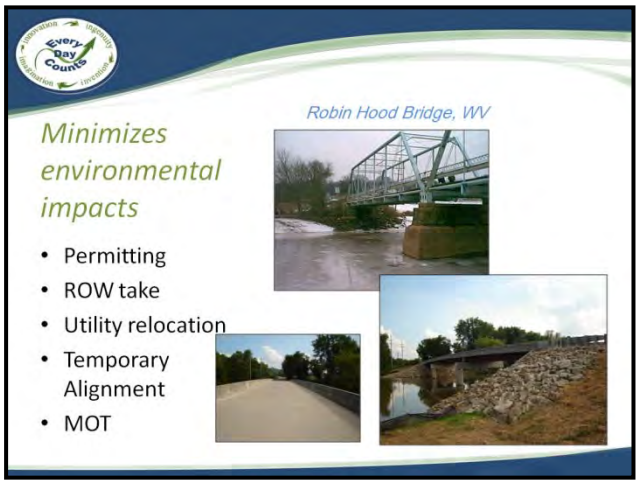


Slide 36: Prefabricated bridges minimize traffic impacts by reducing the amount of on-site construction time.

This reduces lane closures, detours, and traffic delays which results in improved safety for the traveling public.

Slide 37: Here is a project example where the use of PBES greatly reduced the permitting, utility, right-of-way, and maintenance of traffic involvement that is commonly associated with most transportation improvement projects during the Environmental process.

In this particular site location, if a temporary alignment was placed to the right of the structure to maintain traffic, ROW impacts and the removal of a hillside would be needed. If placed to the left, Utility Relocations would be required, and a longer temporary bridge and longer temporary road alignment would have been an equally extensive activity to construct.

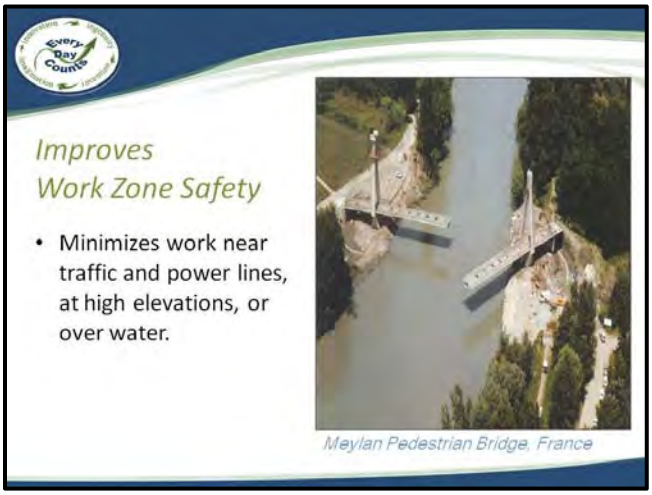


As an Owner, these impacts not only add costs to the project, but they also require time consuming resources to coordinate with the land owners, outside permitting agencies, and private utility companies – that oftentimes have conflicting priorities and agendas.

To circumvent the site constraints, public feedback was sought out during a “public meeting” to see if closing the bridge in its entirety - but for a limited timeframe, was an option. During the limited closure period, the public agreed to use an alternate detour, and coordination for emergency services and bus routes for the residences on either side of the structure was made.

To meet the time constraints established by the public, the substructure was built around the existing structure using drilled shafts while traffic operations resumed. Once the shafts were complete, the bridge was shut down entirely and the remaining structure was replaced in an accelerated manner using prefabricated bridge elements to minimize the closure period (prefabricated saddle cap is just a p/s box beam).

Slide 38: Because on-site construction times are reduced when PBES are used, work zone safety can be greatly improved upon. Construction workers spend less time near high traffic volumes, power lines, and over elevated work areas. The durations of exposure to extreme weather conditions which influence worker fatigue also becomes less.



As shown in this slide, the bridge was totally prefabricated over land then rotated into place. The workers did not have to work over the water, and **there were no impacts to navigational clearances during construction.**

Other challenges could have been realized when we look at how this bridge could have been constructed:

For example, using prefabricated sections lifted from barges as a method of construction would require permitting and a biological impact assessment by multiple approving agencies – which is a time and resource consuming activity.

As an alternative method of construction, form travelers could be used; however, encroaching into the vertical clearance envelope of the navigational channel from above and assuring concrete delivery over the water way would be two issues that would have to be dealt with. Raising the vertical profile could be an option to address this issue, but to do so unnecessarily would introduce additional material costs to the project for the additional approach work and taller towers (or lower profile cable stays).

Slide 39: When we discuss the need to improve On-site Constructability, we speak of the project sites that impose constraints to the constructability of bridges. Examples include heavy traffic on an interstate highways, difficult elevations, long stretches over water, restricted work areas due to adjacent facilities such as utilities and buildings, and detour routes that aren’t feasible nor practical.

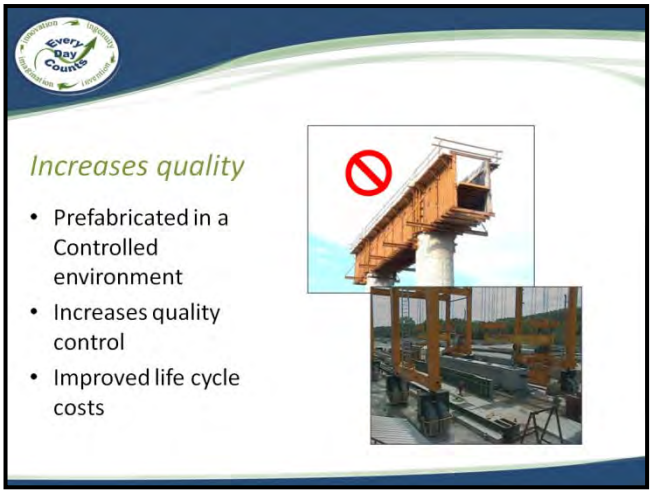
Areas that experience high traffic volumes, either with or without congestion in terms of ROW and utility impacts are common in urban and major metropolitan areas.
However, rural areas also experience their share of difficult site conditions.

For example, as shown in this picture we can see that the need to deliver material, equipment, and labor could be a challenge due to the site being in a remote location. (Dealing with remote site locations is actually a very common site issue throughout the U.S.)
In some parts of the country the Construction Season can be limited. Alaska for example, has only a 2-3 month construction season due to the long winters.

Another site that introduces 2 common constructability constraints is shown here. There is no feasible detour route to use if the existing bridge is taken out of service. In this case, the road wraps around a mountainside and there is there is only one way in and one way out. A temporary bridge would also be costly given that the existing bridge spans over a gore area with over a 150 foot vertical drop.

Construction using prefabricated bridge elements could be used to help address the site constraints in any of these examples.

Slide 40: Prefabricating **the** structural components of a bridge takes them off **the** critical path of the project schedule: work can be done ahead of time, using as much time as necessary, and it can be done so in controlled environmental conditions.



This reduces the dependence on weather, and can improve the control of quality of the resulting elements and systems.

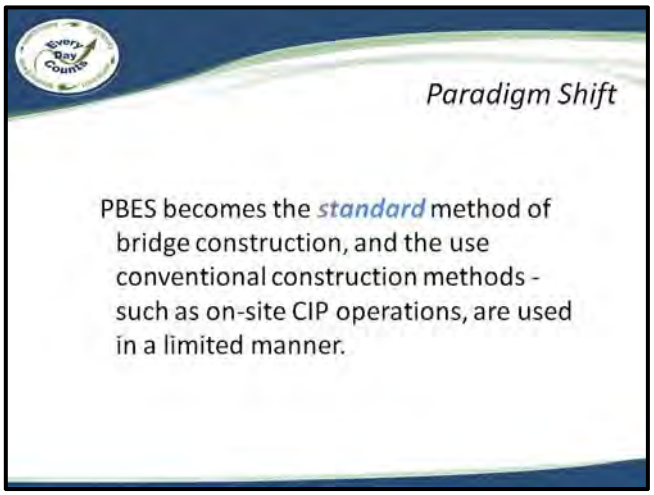
Here, we see the form work that is used set 30 feet in the air to conventionally construct this pier cap.

Whereas in this picture, we see a substructure pier cap being constructed off the critical path, where consistency in material and concrete curing is easily achieved.

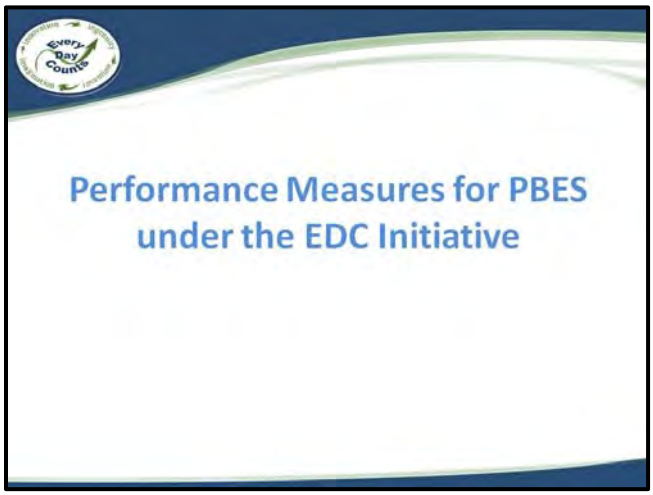
As a result of the improved quality that can be expected from using prefabrication, we should also expect to see the additional benefits of lower life-cycle costs.

Slide 41

Because **the** use of PBES offers so many benefits **and** it's use is so versatile for many site situations, the FHWA's goal is to shift the paradigm of our industry so that the use of PBES becomes **the standard method of construction** and the use of conventional construction methods, such as on-site CIP operations are used in a limited manner.



Slide 42: So let's discuss the performance measures for PBES under the EDC initiative to see where we **were** and where we **are** headed.



Slide 43: Prior to the EDC program, a state survey on PBES implementation was conducted in 2003 thru NCHRP report 324.

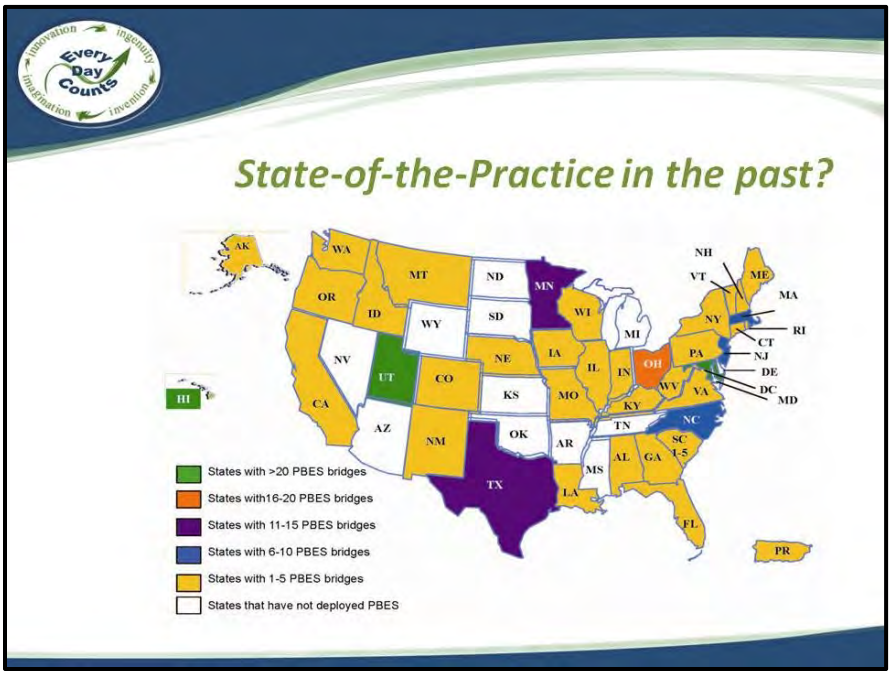
The response at that time indicated that 40 states used PBES in 1 or more projects, while 3 have used PBES **in 20 or more projects**.

Also, during that timeframe, 11 states were actively pursuing the use of PBES as their standard practice.

Slide 44: This national map shows a breakdown of the implementation of PBES at that time.

These are projects that have been designed or built using PBES in increments of 5, over the past several years ***prior*** to the implementation of the EDC deployment goals.

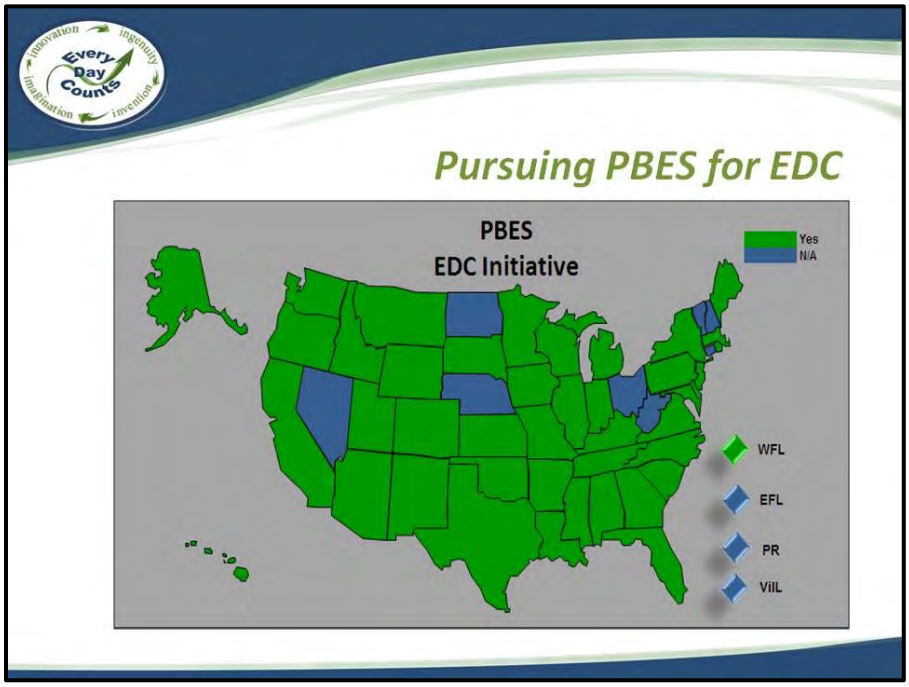
These projects don't count!



Slide 45: This is a map showing how many Agencies that reported a commitment to using PBES as part of their EDC deployment goals.

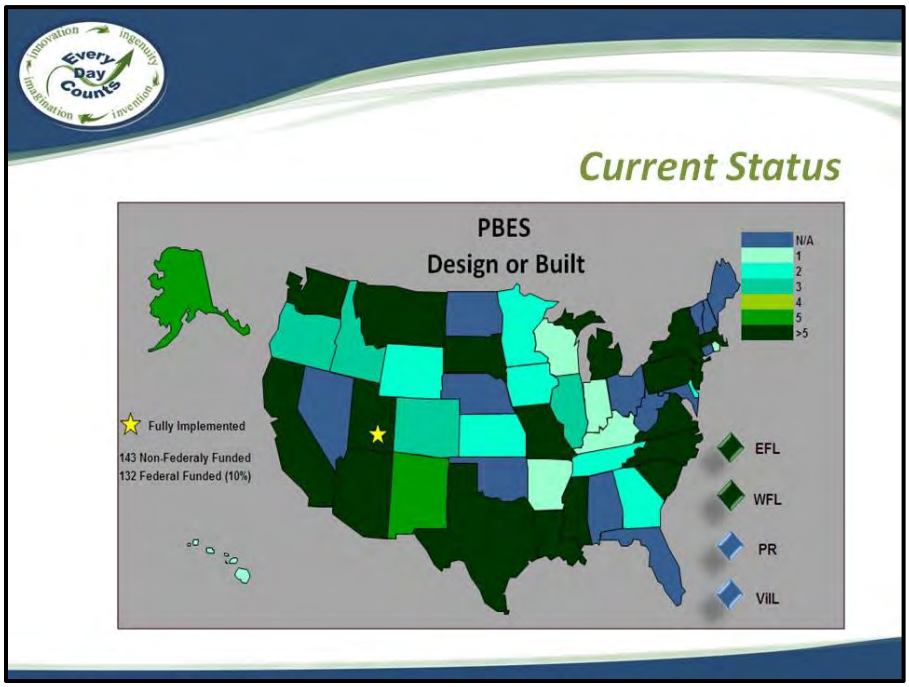
44 out of 55 Agencies

Note: Data validation may be further required.

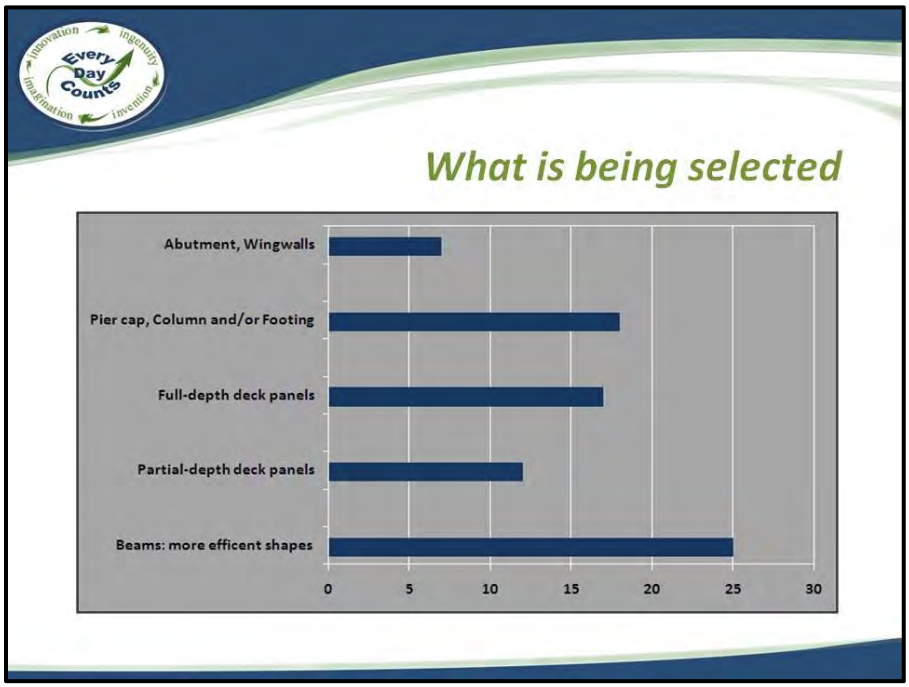


Slide 46: These are the results of the ***1st Quarterly EDC survey*** showing the number of PBES projects that are either designed or have been built using PBES.

The survey results represents the time period between October 2010 to about March/April 2011.



Slide 47: This graph shows what the Agencies are selecting. For example, 25 Agencies reported that they are using versions of prefabricated beams, 12 are using partial depth deck panels, and 16 are using full depth deck panels.



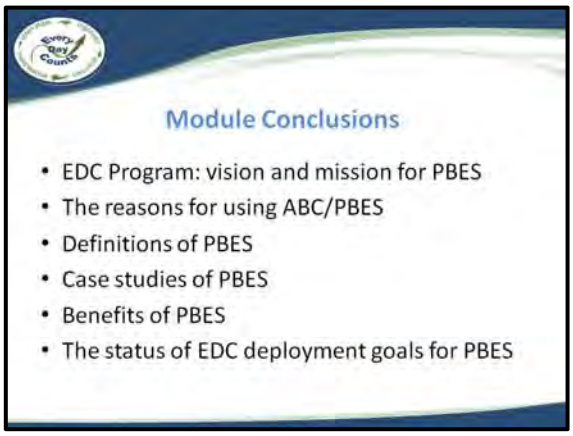
Slide 48: **These are the deployment goals for PBES under the EDC initiative:**

- **By December 2012, 100 cumulative bridges have been** designed and/or constructed rapidly using PBES.
- **By December 2012, 25 percent of single- or multi-span replacement bridges** authorized using Federal-aid have at least one major prefabricated bridge element that shortens onsite construction time relative to conventional construction

Slide 49: Although not an EDC initiative, Agencies that have more than **20 bridges** designed and/or constructed using PBES in the past 3 years and a **decision-making framework that considers the use of PBES** in the design process is considered fully implemented.

Slide 50: This concludes Training Module 1
To summarize, we discussed the…

- EDC Program: vision and mission for PBES implementation
- The reasons for using ABC/PBES
- Definitions of PBES
- Case studies of PBES
- Benefits of PBES
- The status of EDC deployment goals for PBES

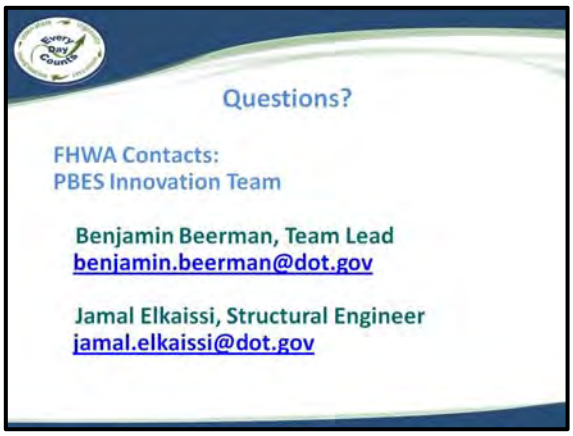


Slide 51: Why are we championing the use of PBES technologies? It offers significant advantages.

- Faster (offsite & off critical path)
- Safer (for the public and contactor personnel)
- Can provide Better Quality (controlled environment)
- Can provide Lower Cost (from a total project and/or life cycle costs)
- Is easily adaptable to address many site constraints

Slide 52: **Why Use PBES Technologies?** ***Bottom Line: The traveling public deserves a new driving experience with reduced user costs due to reduced work zones and congestion.***

Slide 53:



Module 2: An Owner's Perspective on Lessons Learned in Implementing ABC

MODULE LEARNING OUTCOMES

By the end of this Module, you will be able to:

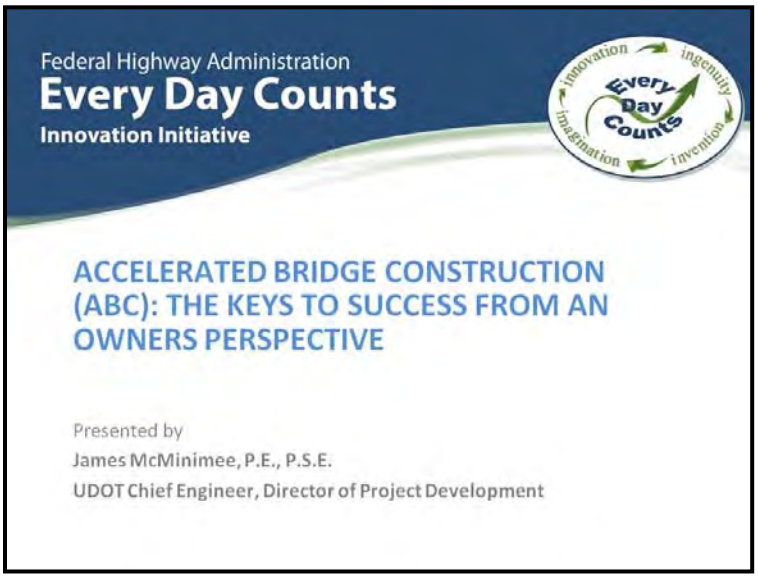
- identify customer needs from a Utah perspective
- recall the benefits of using PBES
- recall the concept of user costs
- identify associated risks from Utah's perspective
- identify lessons learned

MODULE SLIDES & NOTES

Slide 1:.

Greetings.

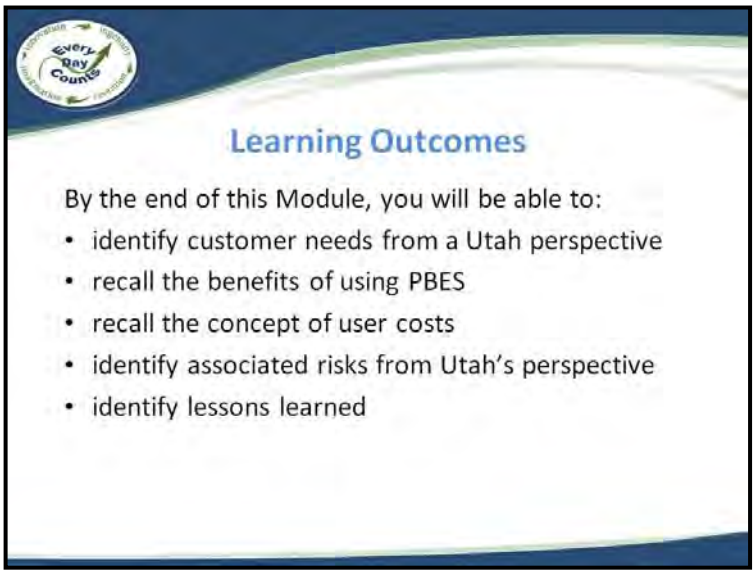
My name is James McMinimee.
I retired from the Utah Department of Transportation in January of 2010. I am happy to be here to talk to you about prefabricated bridge elements and systems.



Slide 2:

By the end of this Module, you will be able to:

- identify customer needs from a Utah perspective
- recall the benefits of using PBES
- recall the concept of user costs
- identify associated risks from Utah's perspective
- identify lessons learned



Slide 3:

First, I would like to talk to you about Utah. In order to understand how Utah implemented prefabricated bridge elements and systems it is important that you have a little background on the State itself.

Utah is a small state, not geographically, but demographically. Utah has about 2.5 million people, and a federal gas tax program of $350 million. The Utah Department of Transportation is a relatively small organization with only 1650 employees statewide. Interestingly, Utah has a relatively big transportation program. Utah's current program includes over 250 jobs, and over $2 billion projects under construction.

Slide 4:

The Utah Department of Transportation is also differs culturally from many DOTs. UDOT has a very customer driven culture. They are willing to take risks, and in the past, have also been willing to embrace new technologies.

Utah has tried accelerated bridge construction, accelerated pavement construction, a new technology called diverging diamond interchanges, and other innovative highway construction techniques. With all of that, they also increased their partnerships, with industry, local governments, and resource agencies.

Slide 5:

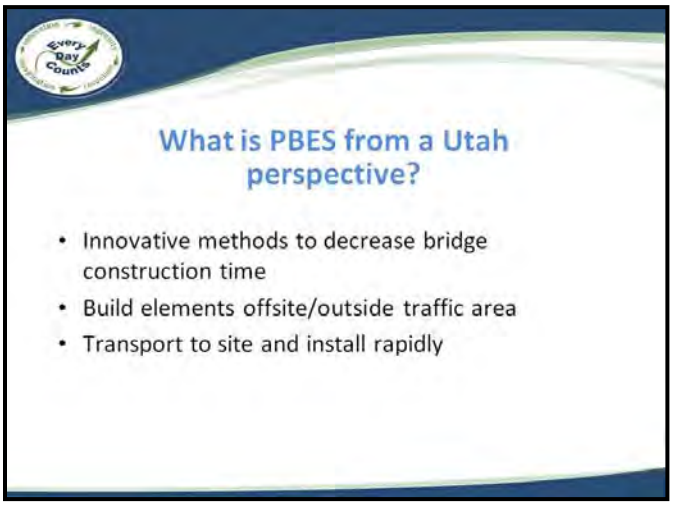
UDOT has a set of department themes. Every project that Utah does considers these department themes in the project effort and scope. The four themes are: to accelerate delivery; to decrease and minimize detours or delays; to encourage innovation that speeds project delivery or provides value; and lastly, to set a good price.

Obviously price is always a consideration. It has been our experience that project managers really balance good price against the other themes. Again these themes are considered for every project.

Slide 6:

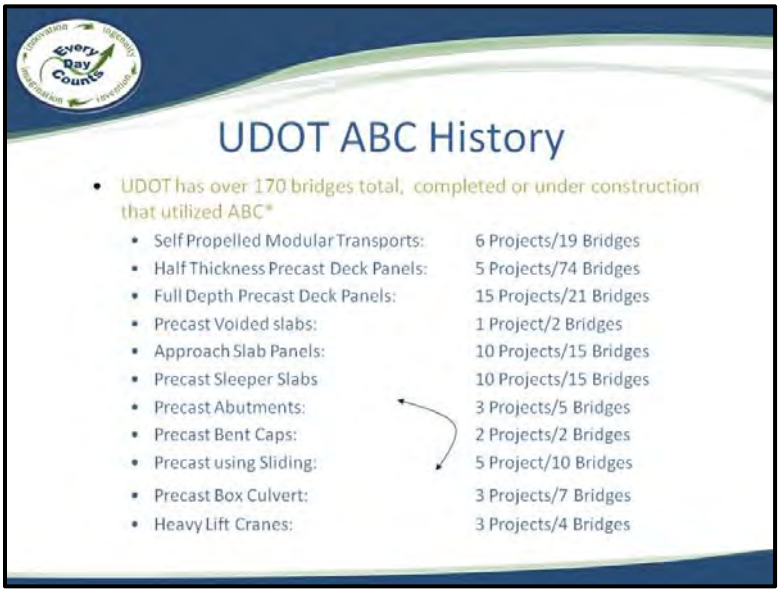
The last big thing that differentiates Utah from many other DOT's is this move to adopt a new business model. UDOT has moved away from the traditional business model that only considers construction cost when awarding projects. Utah's model for awarding projects includes the idea that there are user costs associated with *every* project.

This new business model adds together the construction costs and user costs. The total of these costs are called project costs. UDOT has moved from lowest construction cost to lowest project cost. In this model societal costs are minimized and the Utah DOT has received much public praise, and also much political capital.



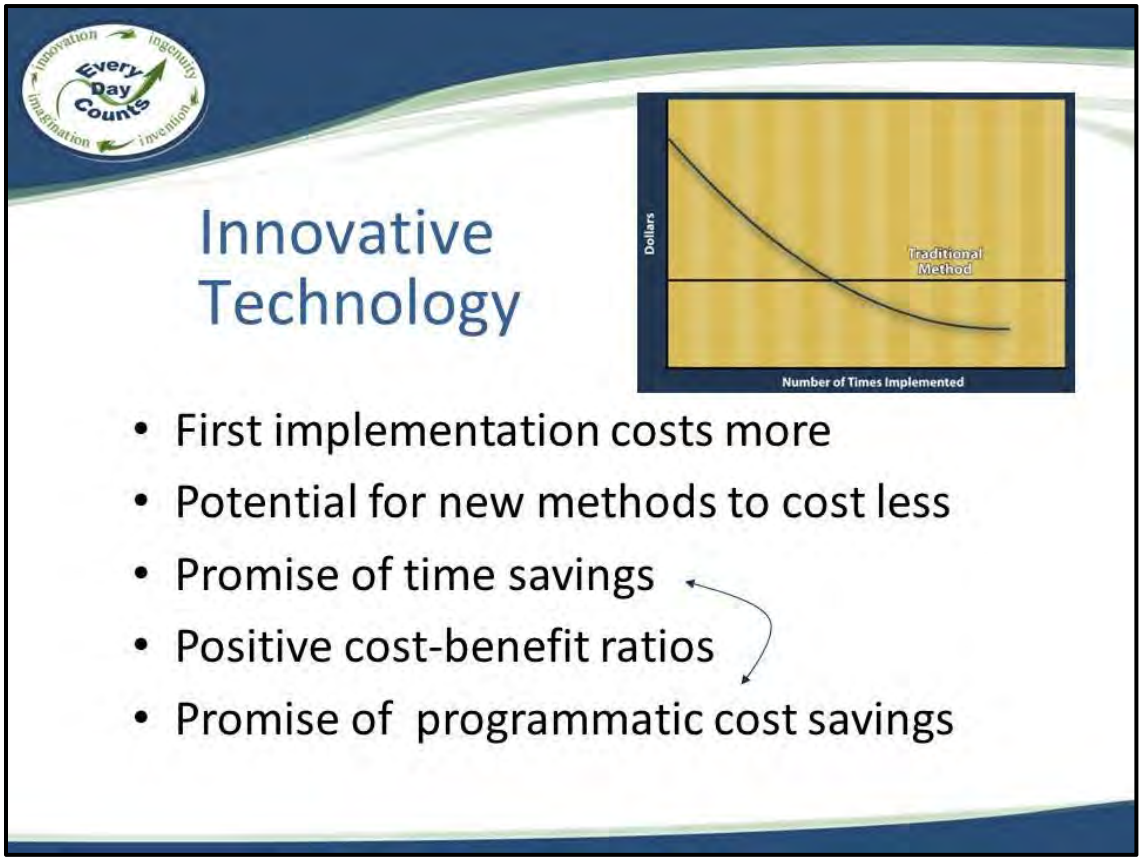
Slide 7:

So here we are five minutes into the presentation and were finally ready to start talking about the lessons learned in implementing prefabricated bridge elements and systems. Remember the definitions of what PBES is? First of all, it is innovative methods that decrease rich construction time. Second, the elements of the bridge are built off-site or outside of the traffic impacted area. Finally, the elements are then transported to the site and installed as rapidly as possible.



Slide 8:

Time=Money
We may argue over scale, but we cannot ignore this issue.



Slide 9:

Moving along to one of UDOTs largest lessons learned.

Utah developed this graph as a way to talk to with their transportation commission about what to expect with regard to costs as they implemented this new technology. As the graph suggests, the first time you try anything new is the most expensive it's ever going to be. However, as you do more and more of the same projects, it is typical to find that prices diminish.

Misunderstanding of this graph has killed many a good idea. How many times have we, as engineers, asked about a new idea only in terms of "*how much will it cost*?" Then removed the idea from further consideration because the first time it was used it was expensive? The truth is first implementations usually do cost more, however there is also a huge potential for new methods to become more cost efficient over the long term.

In the case of ABC, there are potential time savings, as well as the promise for considerable cost savings. Utah has tracked the costs of implementing PBES. At the time I left Utah the cost-benefit ratio of expense to user costs recouped was somewhere in the neighborhood of 5 or 6 to 1. This means that for every dollar of investment in PBES, there were between five and six dollars in user costs recouped. Understanding this graph is very important when considering PBES.

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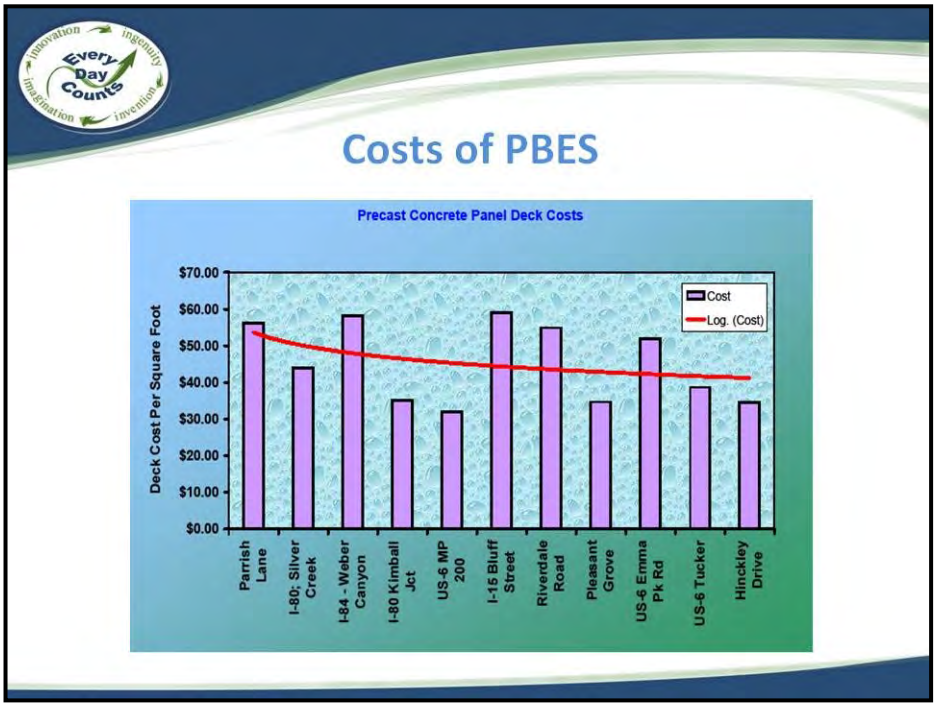


This graph shows a cost history of implementing full-depth pre-cast panels.

UDOT's traditional cast in place deck traditionally ran about $53 a square foot. When UDOT first bid for full-depth pre-cast panels they came in at $63 a square foot. By the time the 10th /11th projects came around, the cost had decreased to $37 a square foot. According to presentation by Carmen Swanwick, UDOT's state bridge engineer, those costs have held steady at about $37 a square foot.

Slide 11:

Okay, so I slipped this picture in to remind everyone of the promise of PBES. This project is Utah's innovate 80 project. It is an urban reconstruction project on I-80 in Salt Lake City. The picture shows what was called the Bridge Farm.

Seven bridges were constructed at the Farm, and then installed in the span of 41 days in the summer of 2008.

The contractor claimed that by using this technique he saved 2.5 million dollars in construction costs, and over 1 year in construction time. The user costs for 2008 were estimated at $25 million.

Slide 12:

Utah was lucky to host the 2002 Winter Olympic Games. One of the legacies of that effort was risk analysis and identification of contingencies. On their website UDOT has posted a more comprehensive checklist of considerations for PBES. The list posted here is what I think are the top five risks.

The risks themselves, however, aren't important. What I'm trying to convey is that for any process that has a lot of risks you should first develop a plan for mitigating those risks.

Thus, a good lesson learned or best practice for PBES implementation is to first examine the risks for any potential project, list those risks, and then begin working on ways to mitigate those risks.

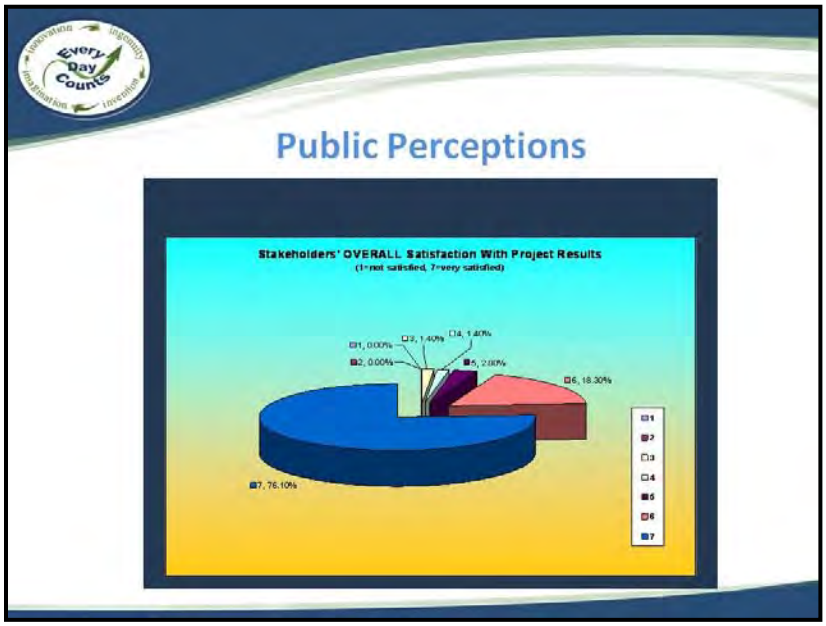
Slide 13:

This slide is about *innovation*. As Utah has advanced in their use of PBES, our contractors have begun to experiment and to suggest alternative methods of their own--simple things to help speed construction.

This slide shows one such innovation. On the right side we see the tried and true Hillman rollers most contractors are familiar with. The left side shows an innovative method implemented by a contractor. By simply using Teflon pads, steel channels, and lots of dishwashing liquid, this method accomplishes the same thing as the Hillman rollers at a significantly reduced cost. The lesson learned here is to allow both innovation and experimentation!

A good little story for the books – the first bridge move in the US took 53 hours. The last Self Propelled Modular Transport or SMPT move was accomplished in *less than* 15 hours. Fast right? One of our innovative contractors proposed an alternative method, slide in. The last slide in took *less than* six hours. The superintendent commented as the bridge was being moved, "if you'd let me move it with traffic on it we could get it down to 3 hours!"

Slide 14:



One of the first things I talked about was public support and political capital. This slide is all about public perceptions of PBES. These are the actual survey results from the 45th South project, which polled over 550 respondents. Typically when UDOT gets these surveys back, about a third of the people like the project, about a third of the people don't care about the project, and about a third of the people hate the project.

As you can see, this graph is vastly different. In this graph about 94% of the people either gave the project a perfect score or one less than a perfect score. Amazing results. With this kind of feedback from the public, is it any wonder that politicians support this effort as well?

This alone is a great reason to implement PBES on bridge projects.

Slide 15:

Here is a short laundry list of good practices with regard to implementing PBES.

In addition to these things, it is important to get department leadership committed and involved in PBES implementation. It is also important to allow the contracting industry enough time to become both comfortable and knowledgeable about using PBES.

A good strategy to get started is to obtain funding for demonstration projects. Programs such as Highways for LIFE, or IBRD are excellent sources of funding for implementing PBES.

Planning a *program* of projects is also an important idea. Instead of just completing one project, with a program of projects there is an opportunity to build momentum – a clear signal to the industry that the business model is changing.

Another best practice is to use innovative contracting. Innovative contracting encourages contractor led innovation. The ideas and synergy that comes from innovative contracting are very helpful when implementing PBES.
Scanning tours have proven to be very successful in Utah. Scanning tours are visits to out-of-state PBES projects to see the technology being used and to showcase that it can be done. Utah has taken their contractors and consultants on several of these tours with very successful results.

Lastly, it's very important to maintain regular communication with industry, utilities, local governments, and anybody else who might be a potential champion of PBES. In Utah we had regular meetings with all of these entities in order to keep them informed and updated regarding PBES implementation.

Slide 16:

Lastly, IF we want to be successful, we need to involve the *entire* industry.

Successful PBES implementation requires not only effective leadership, but also getting our partners to understand their role in implementing this exciting program. We need to make sure we fully engage both contractors and suppliers.

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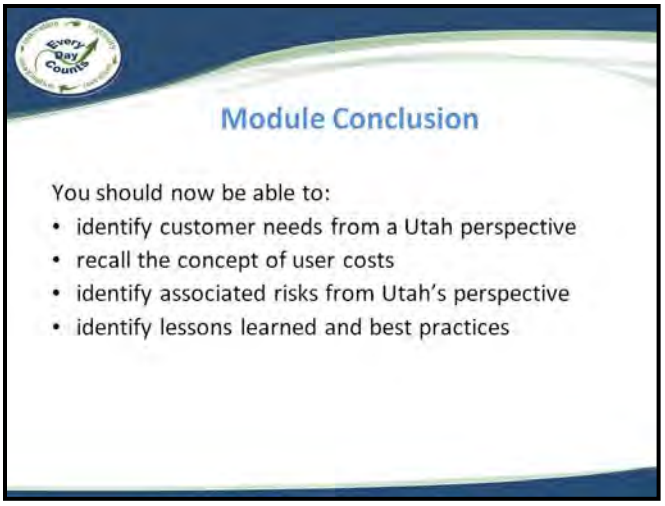

Slide 18:

You should now be able to:

- identify customer needs from a Utah perspective
- recall the benefits of using PBES
- recall the concept of user costs
- identify associated risks from Utah's perspective
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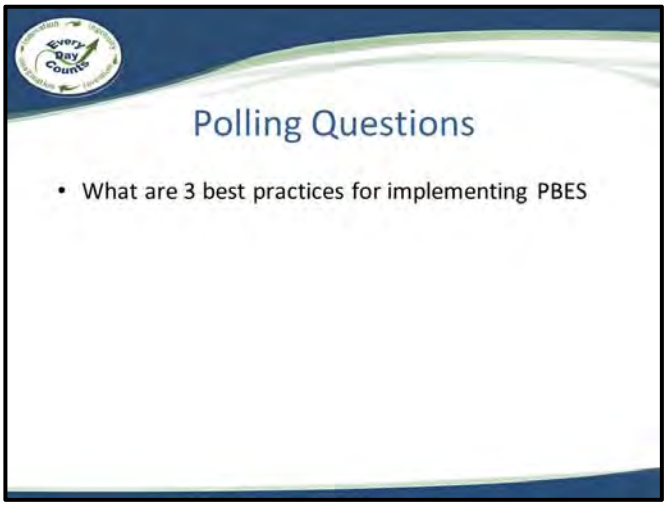

Slide 19:

Slide 20:

Module 3: Decision-Making Frameworks for Using PBES

MODULE LEARNING OUTCOMES

By the end of this Module, you will be able to:

- Understand the ABC viable concepts
- Understanding of barriers/obstacles to install PBES in hours or days
- Understand the needs/opportunities to install PBES in hours or days
- Recognize the PBES decision-making framework
- Be able to use flowchart and/or matrix questions for decision making to identify important considerations to determine best course of action for bridge construction
- List and define rapid onsite construction factors
- List and define other factors impacting the decision to use ABC or prefabricated structures
- List and define the different cost factors influencing the PBES decision
- Become a champion to promote PBES Technology

MODULE SLIDES & NOTES

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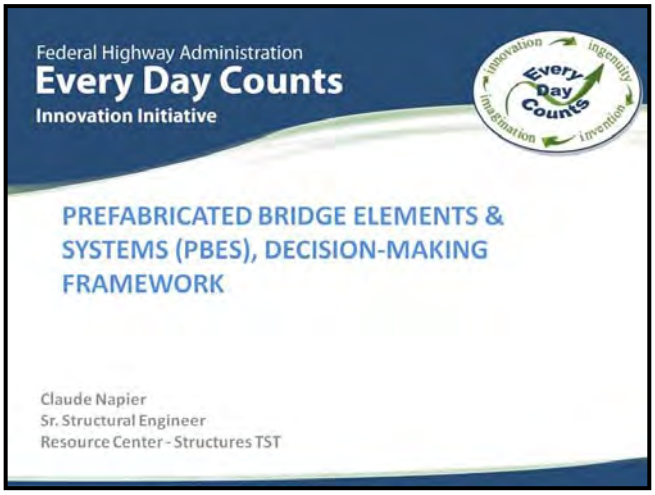

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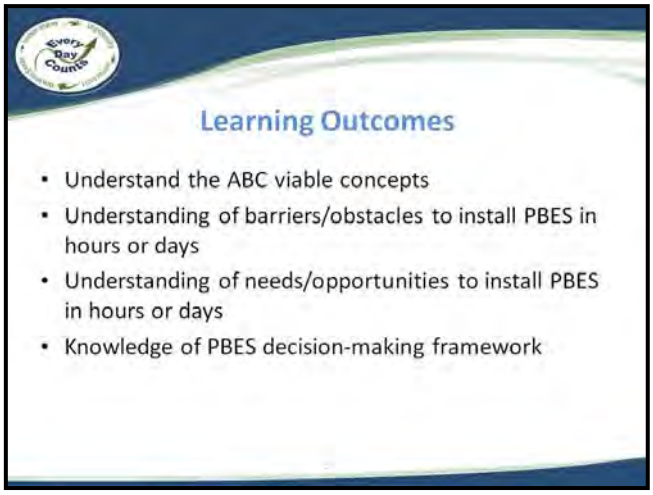

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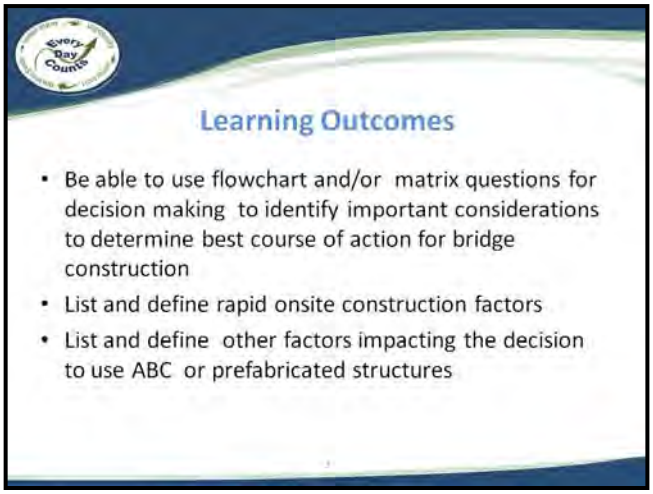

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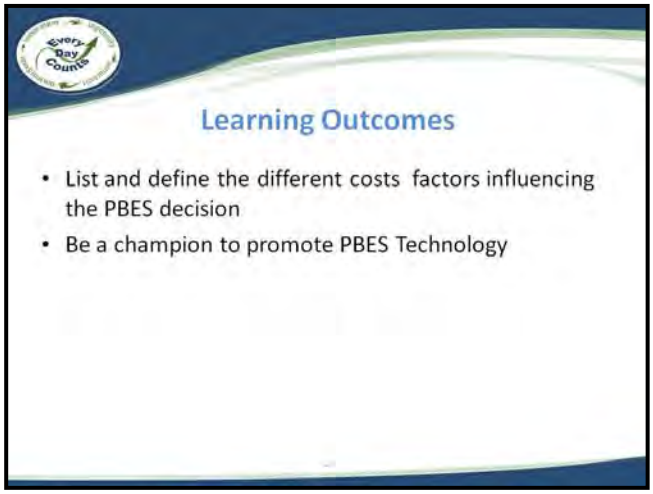

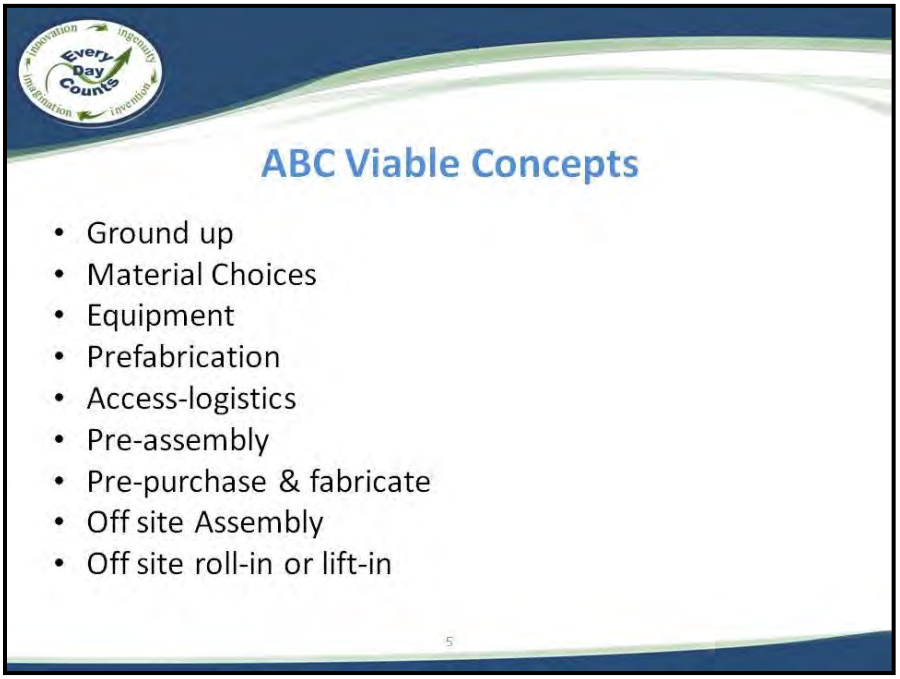

Slide 5:

The general approach will be to evaluate all reasonable concepts that are compatible with project objectives and constraints that can contribute to the acceleration of the construction, reduce the time for construction required at the site or contribute to the acceleration of the construction of interrelated project components. Listed below are some systems or concepts that have been used successfully in accelerating construction and should be well understood and receive priority consideration:

- Ground up: Consideration should be given to all components from the ground up including foundation systems. No component is sacred.
- Material Choices: Choice of materials should be unlimited but be compatible with the state-of-the-art technology and limitations on specific materials and site conditions.
- Equipment: The size, type and amount of equipment should be considerations in evaluating various concepts. Systems that require special equipment for restricted application shall be limited based on overall benefit to the project.
- Prefabrication: Prefabrication of components, sub-assemblies or the total structure has proven very successful in accelerating construction of bridges. Prefabricated substructure units (abutments, spread footings, pier columns, pier caps, pile bent caps) and superstructure components (girders, girder deck sub assembly, full depth precast decks and composite panels, proprietary components, total superstructure units) have a proven record for various site conditions.
- Access-logistics: The access and logistics of the site is a critical consideration is evaluating systems. Some of the considerations are the means and methods of getting components and equipment to the job site, operating space for equipment, site constraints, waterway access, right-of-way restrictions, etc.
- Pre-assembly: Pre-assembly of components off-site or near the site has proven effective for larger project components especially when adequate water access is available. Alternatively, pre-assembly can be effective for smaller projects such as combining girders and deck sections that can be placed and connected in place in the structure.
- Pre-purchase & fabricate: For some projects the concept of pre-purchasing materials and fabrication ahead of other contract work may provide for acceleration of the construction time in the field.
- Off-site assemble: Concept that has proven effective in reducing site construction time by assembly of several components off site and erecting at the site. This has worked especially well for large steel structures such as trusses and arches.
- Off-site roll-in/lift-in: A concept used extensively in railroad construction where a structure is constructed near the final locations on temporary false work and rolled in or lifted into final position.

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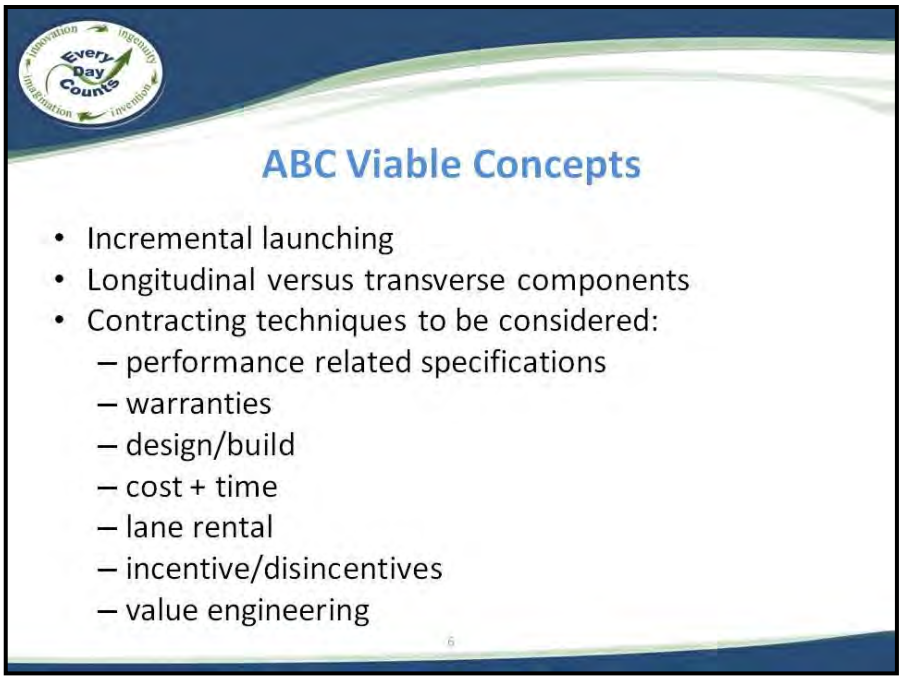

- Incremental launching: A concept that has been effectively used in other countries to keep the erection of main superstructure elements from significantly impacting traffic below. The superstructure is assembled or constructed at one end of the structure and pushed out over the substructure units, thereby having minimal effect on operations at ground level.
- Longitudinal vs. transverse components: Historically bridge design and construction has been based on the use of one or more longitudinally orientated supporting members. The use of full or partial width transverse components assembled in the field to form the completed superstructure has been successful in reducing construction time through the use of prefabrication and minimal site erection. An example of this is the normal segmental concrete box girder construction but the concept is equally applicable to other sections including composite steel and concrete or fiber reinforced composite materials.
- The above items should not be construed to be the only systems and restrict consideration of other systems and concepts. All viable options that will result in the acceleration of the construction of the structures associated with the project should be considered. Keep the goals of GET IN, GET OUT, and STAY OUT in the forefront when considering accelerating bridge construction.

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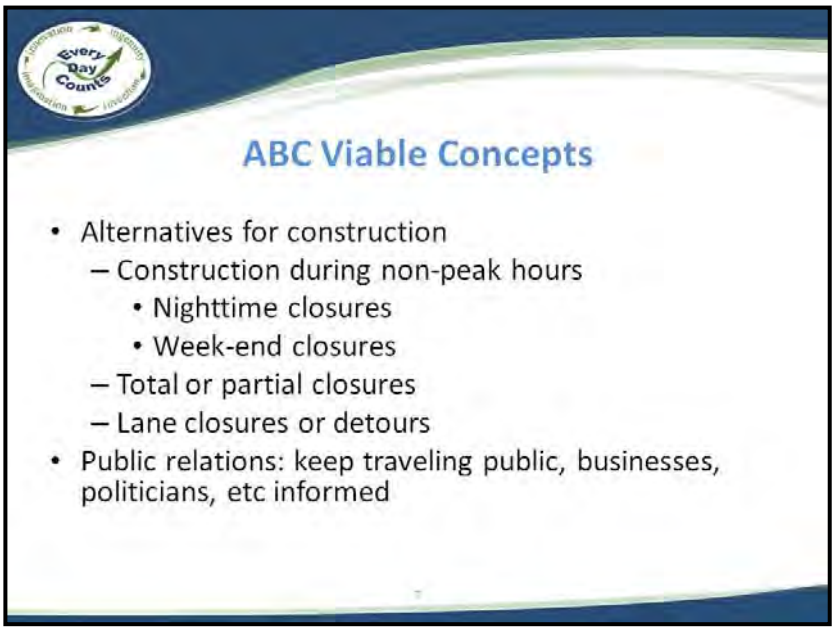

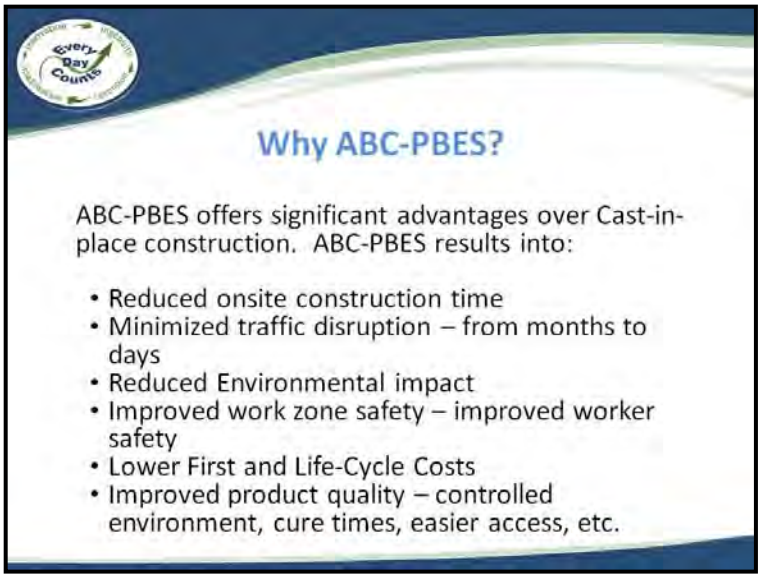

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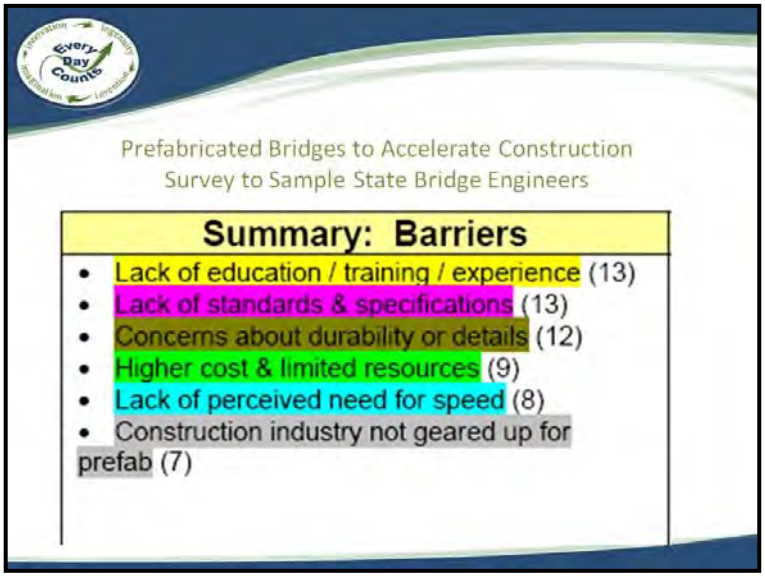
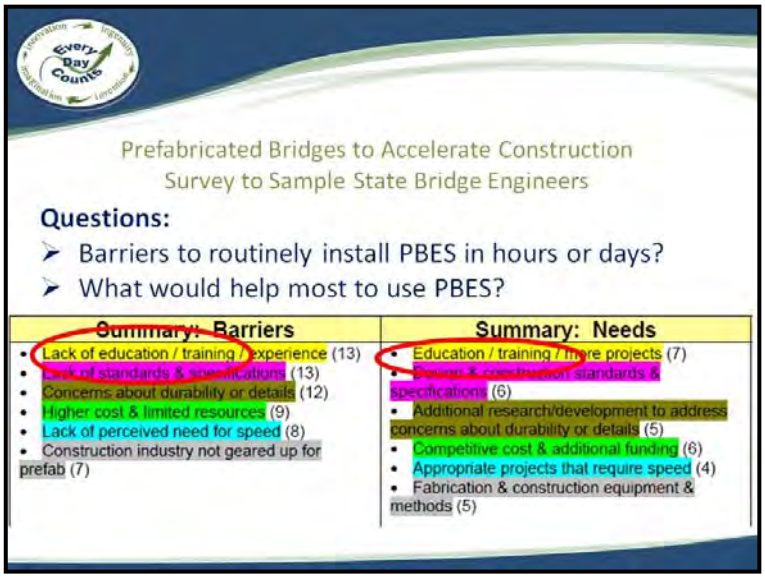


Slide 9:

The foremost barrier perceived identified was the lack of education, training and experience, followed by lack of standard details and specifications, then lack of connection details and their durability. It is generally perceived that prefabrication will tend to higher costs in compare to usual cast-in-place construction methods. And finally, construction industry not equipped to handle large loads to transport and erect prefabricated bridge elements.

Slide 10:

Needs related to those barriers were competitive costs and additional funding, appropriate projects that require speed, and fabrication and construction equipment and methods for use in prefabricated construction. These responses provided the basis for the development of the decision-making framework for the effective use of prefabricated bridges.



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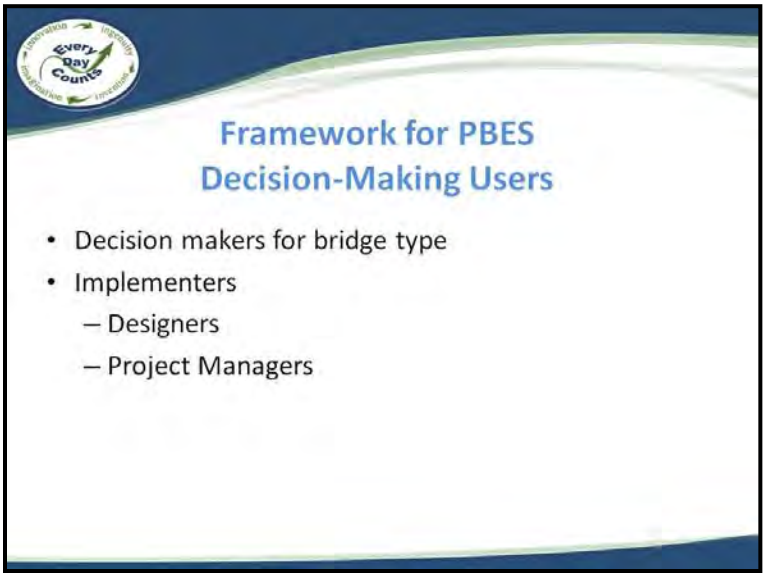
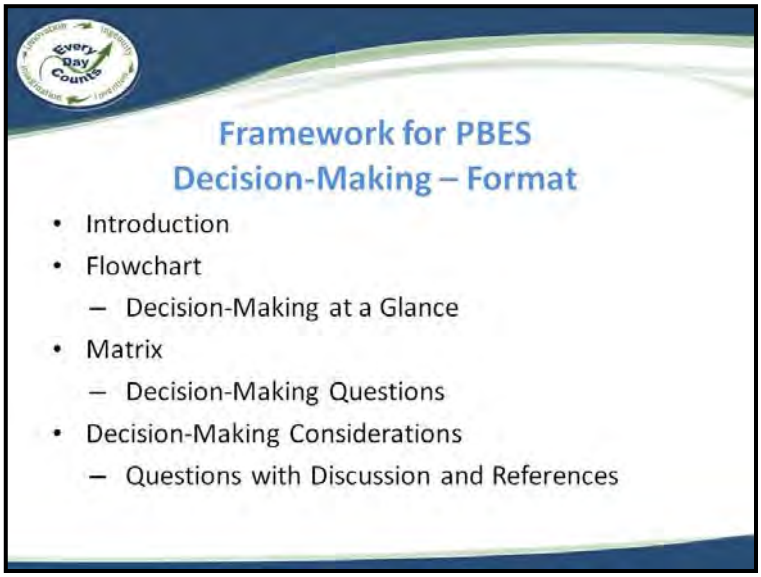
The framework addresses the need for education and training on prefabricated bridges. It also includes discussions related to the other identified barriers and needs.



Slide 12:

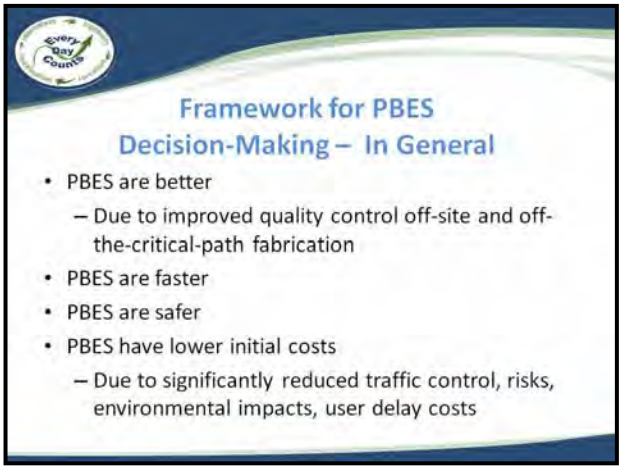
The framework was developed for use by the representatives of the owner agency and the contractor. The anticipated users include the decision makers for the bridge type as well as those developing and implementing the details, including designers and project managers.



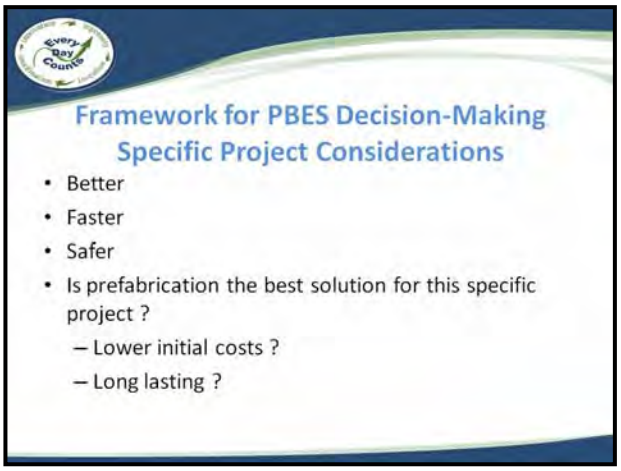
Slide 13;

The framework consists of an introduction, a one-page flowchart, a one-page “Yes-Maybe-No” matrix, and a more in-depth section that is in a question-and-discussion format with references.

Slide 14: In general, we know that prefabricated bridge systems have good quality because of the offsite or near-site fabrication that is off the critical path and in a more controlled environment. We know that it is faster than onsite because more of the work is done prior to final installation. Because it is faster onsite, we know that it is safer for both the traveling public and the construction crews. We also know that prefabricated bridge systems can have lower initial costs due to the significantly reduced traffic control, risks, environmental impacts, and user delay costs due to the reduced number of days of onsite exposure.

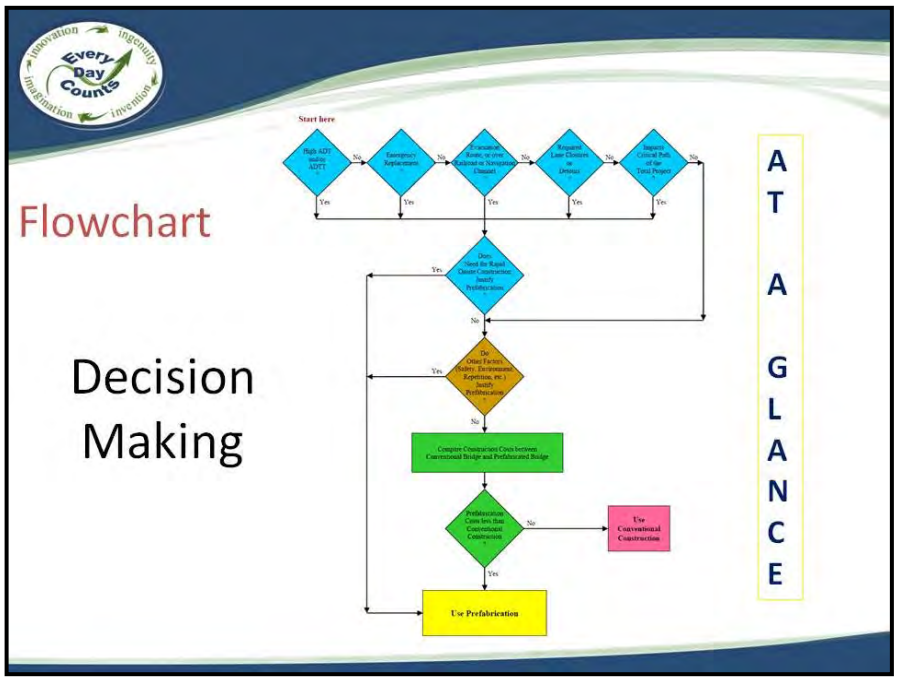


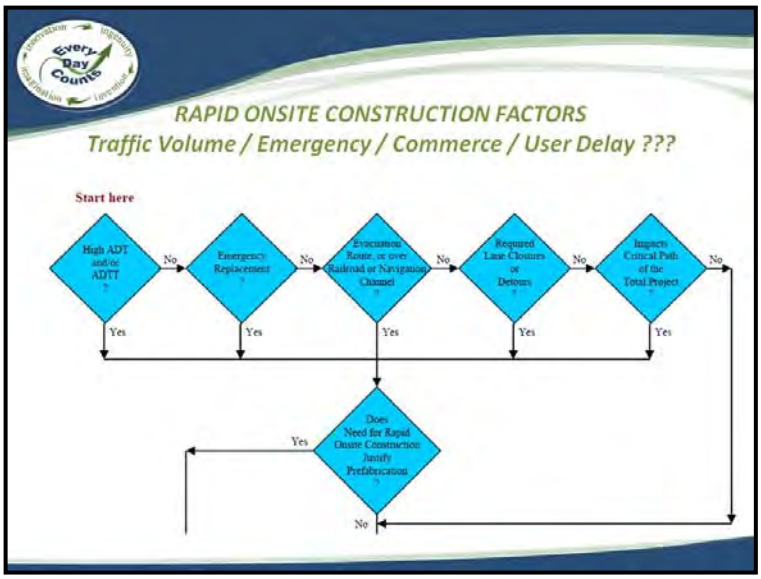
Slide 15: So we know that prefabricated bridges are in general better, faster, and safer. But, is a prefabricated bridge the best solution for the specific project under consideration? The framework was developed to help you answer that question.



Slide 16: The 1-page flowchart allows decision-making at a glance, for example, for a high-level decision-maker who wants a high-level tool for a quick decision without getting into the technical details of a project. *(Find full-sized drawing at end of this module)*

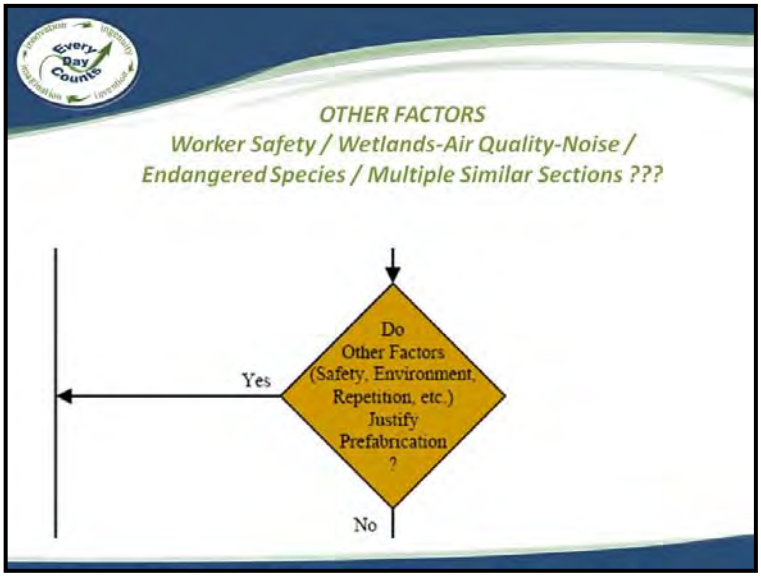
Note the color-coded categories. The blue diamonds are related to rapid construction issues (factors). The tan diamond is related to other issues that may drive a project. The green rectangle and diamond are related to cost issues. These three categories are consistent throughout the framework.





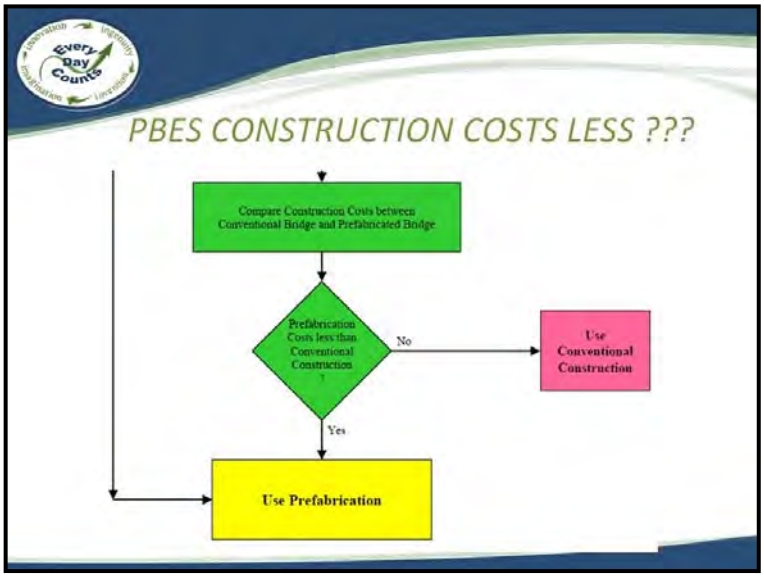
Slide 17:

Let's take a look at the rapid onsite construction issues. As you can see, this relate to such factors as whether the bridge will experience high traffic volumes, or is an emergency project, or would cause a significant negative impact to commerce, or is on the critical path of the construction project. Such considerations drive the need for rapid onsite construction, which makes prefabrication the preferred solution.



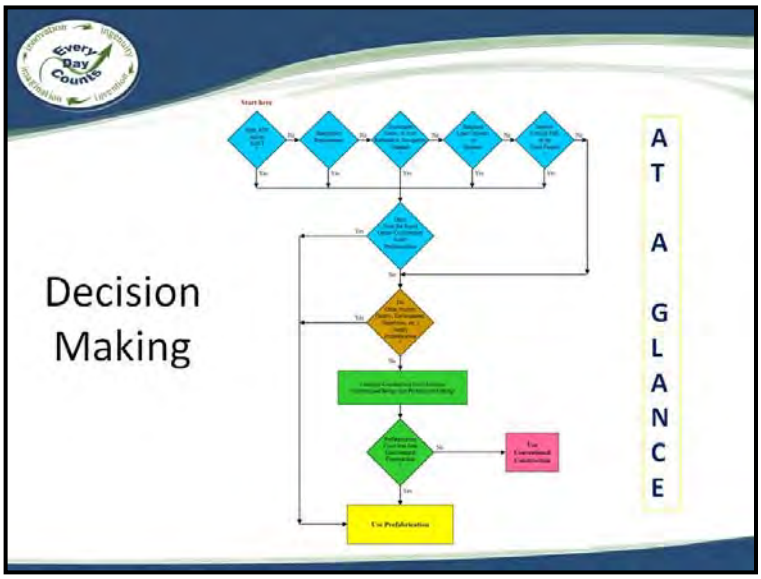
Slide 18:

If rapid onsite construction isn't required, do other factors such as worker safety, environmental issues, or the efficiency of similar sections make prefabrication the preferred solution?



Slide 19:

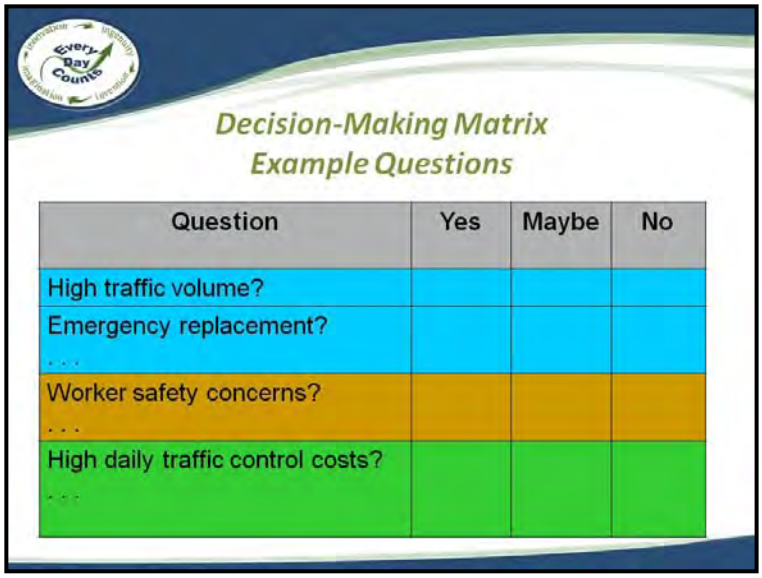
If rapid construction isn't needed, and other factors don't make prefabrication the preferred solution, what about initial construction costs? Is prefabrication anticipated to be less expensive because of the high daily expenses for traffic control through the work zone? Or are user delay costs a concern? Is liability or risk to the agency or contractor reduced with prefabrication due to the significantly reduced number of days of exposure? If so, then prefabrication is most likely the best choice.



Slide 20:

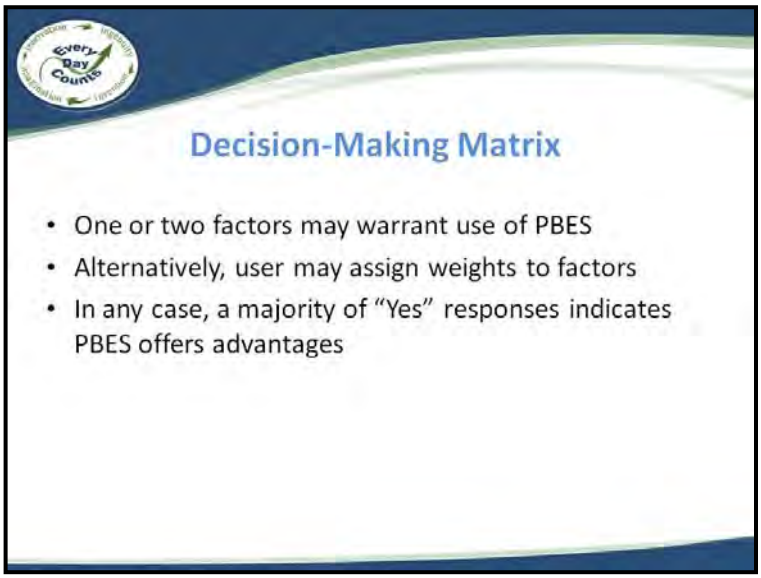
So that's how to use the flowchart to quickly decide whether prefabrication is the best solution for the specific project under consideration. You just follow the arrows depending on whether your answer is "Yes" or "No," and you will end at either "Use Conventional Construction" or "Use Prefabrication."

(Find full-sized drawing at end of this module)



Slide 21:

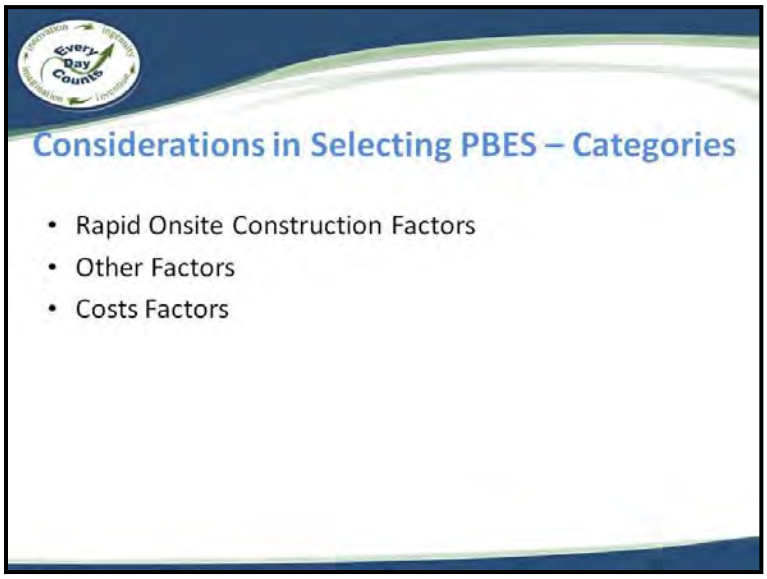
The one-page "Yes-Maybe-No" matrix may be used in conjunction with the flowchart or as an alternative to the flowchart. It includes the same color-coded categories as the flowchart, with additional factors in each of the categories. You simply go down the questions and respond with a "Yes," a "Maybe," or a "No." *(Find complete matrix at end of this module)*



Slide 22:

One or two factors may warrant the use of prefabrication. For example, the fact that the bridge is on an evacuation route may make prefabrication the preferred choice independent of other considerations.

Alternatively, you may want to assign weights to the factors to come up with the decision of whether or not to use prefabrication. In any case, a majority of "Yes" responses indicates that a prefabricated bridge offers advantages for the specific location under consideration.



Slide 23:

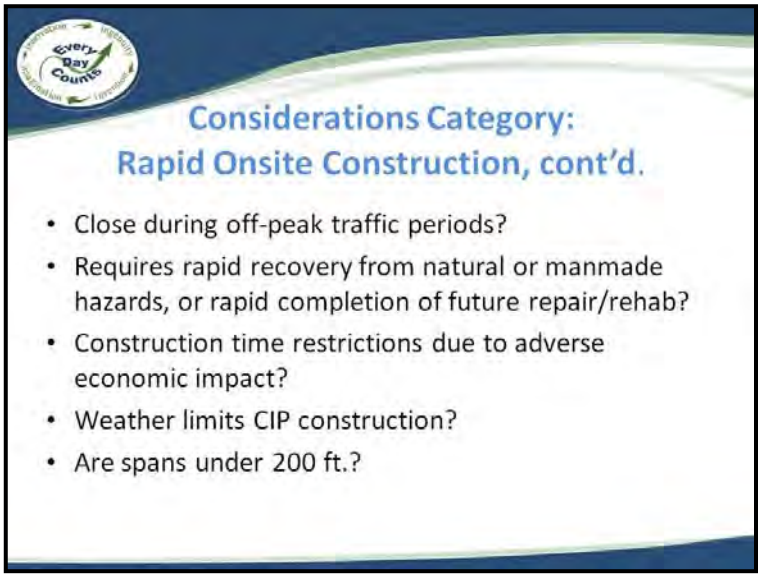
The third section is in a question-and discussion format that is broken into the same three categories of considerations as shown by color-coding on the flowchart and the matrix, i.e., rapid onsite construction, other factors, and costs. This section consists of the same questions as in the flowchart and the matrix, plus additional ones.

Slide 24:

Let's go over the categories in more detail.

The "*Rapid Onsite Construction*" category includes questions related to:

- *ADT/ADTT*
- *Emergency bridge replacement*
- *Evacuation routes*
- *Lane closures*
- *Detours*
- *Critical path impacts*



Slide 25:

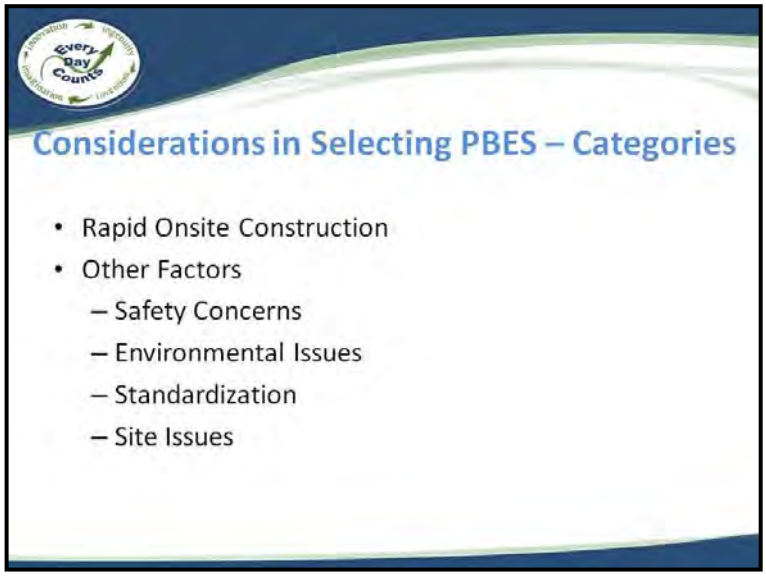
… continued.

Slide 26:

The first category of questions and discussion is "*Rapid Onsite Construction*."

This category is followed by the second category of "*Other Factors*," which is broken into the following subcategories:

- *Safety Concerns*
- *Environmental Issues*
- *Standardization*,
- *Site Issues*



Slide 27:

The "*Other Factors*" category includes questions related to safety concerns and environmental issues. Questions related to environmental issues include:

- Environmentally sensitive area? (e.g. wetlands, air quality, and noise)
- Natural or endangered species? (e.g. fish passage, or peregrine falcon nesting)
- Historic bridge?

Slide 28:

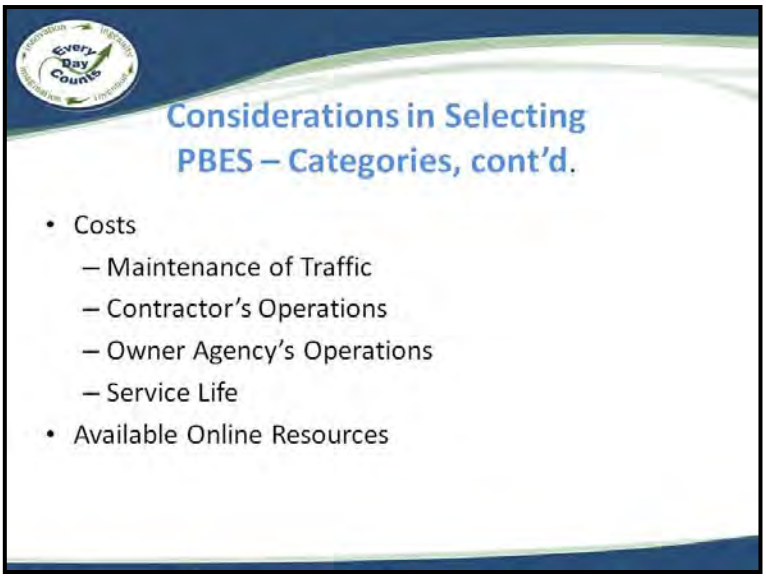
Also included in the "*Other Factors*" category are questions related to standardization.

Slide 29:

The last group of questions in the "Other Factors" category relate to site issues.

Slide 30 :

… continued.



Slide 31:
The third and final category is "*Costs*," which is broken into the subcategories:

- *Maintenance of Traffic*
- *Contractor's Operations*
- *Owner Agency's Operations*
- *Service Life.*

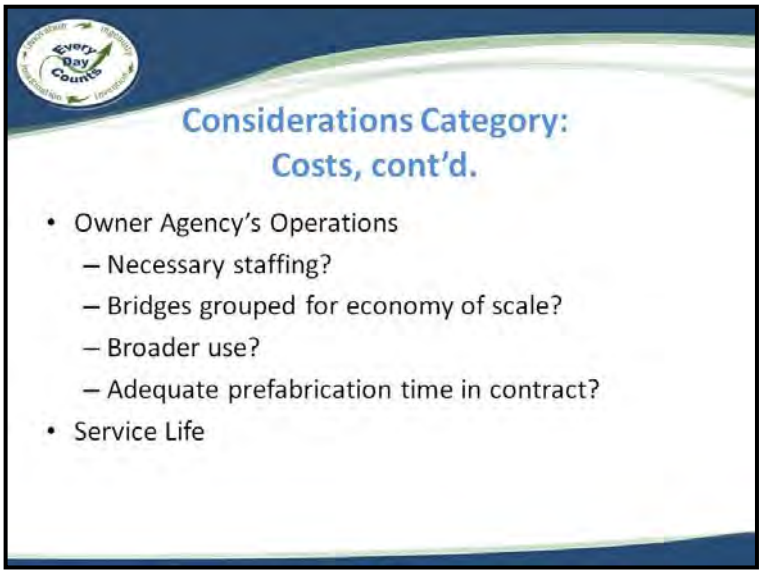
The framework ends with a brief conclusion paragraph and a listing of available online resources.

Slide 32:

The final category is "Costs." This category includes questions related to maintenance of traffic and contractor's operations.

Questions related to the contractor's operations include:

- *Contracting strategies*
- *Innovative equipment*
- *Insurance/bonding costs*

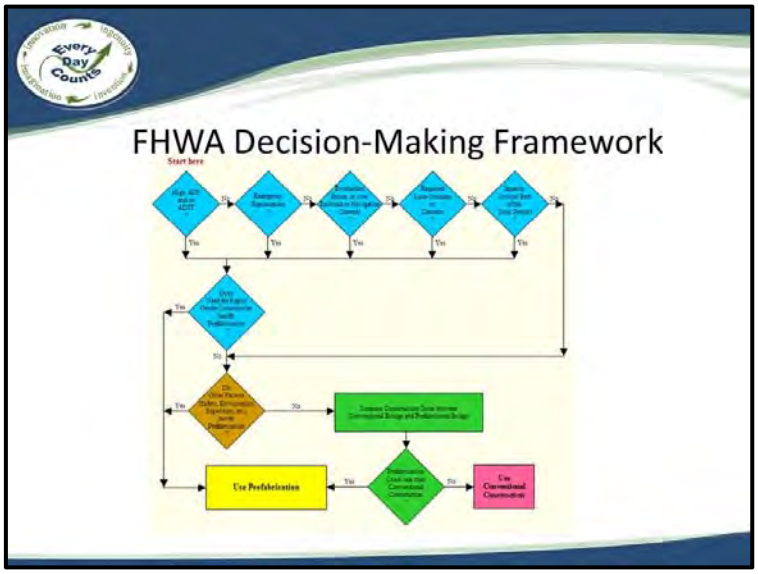


Slide 33:

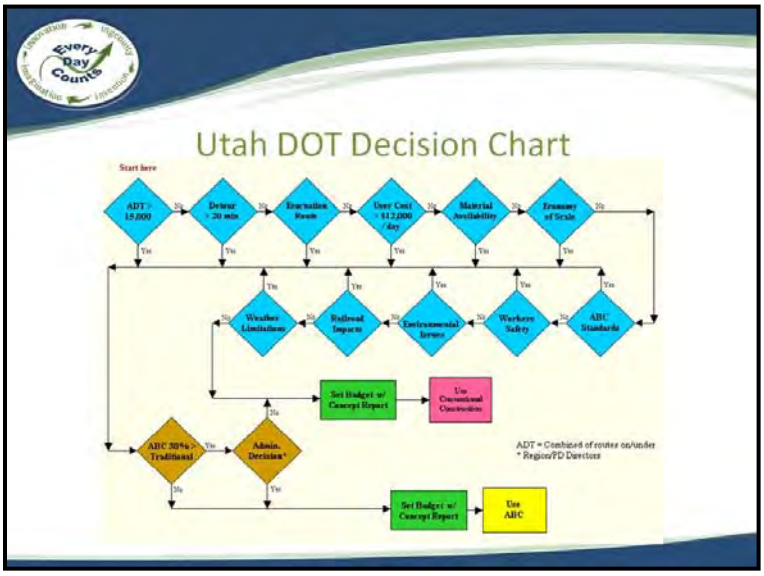
Also included in the "Costs" category are questions related to the owner agency's operations, including:

- *Staffing*
- *Grouping*
- *Broader use*
- *Prefabrication time*

The last subcategory under "Costs" is service life, which includes references to available life-cycle cost evaluation models.



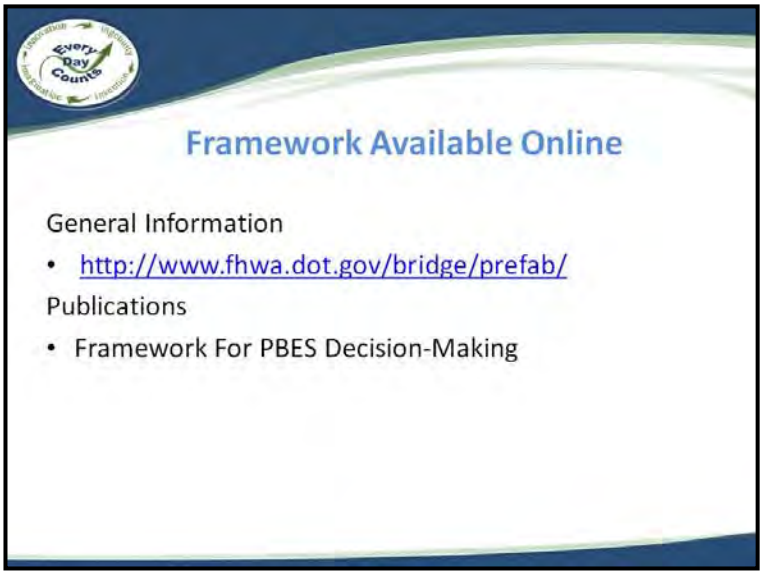
Slide 34:



Slide 35

See the Utah Case Study Example in the Student Handbook.

A performance goal is for States to include the decision-making framework into their project development process to evaluate ABC-PBES as early in the process as possible, similar to what the State of Utah has done.

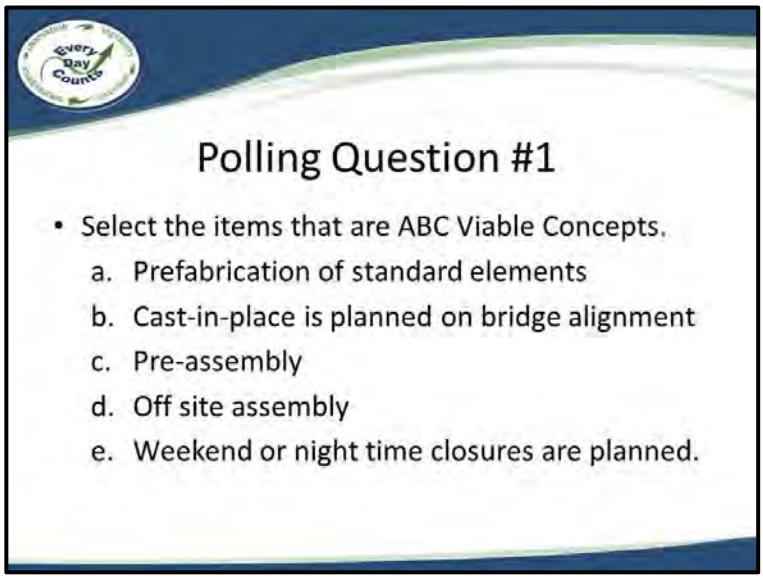


Slide 36:

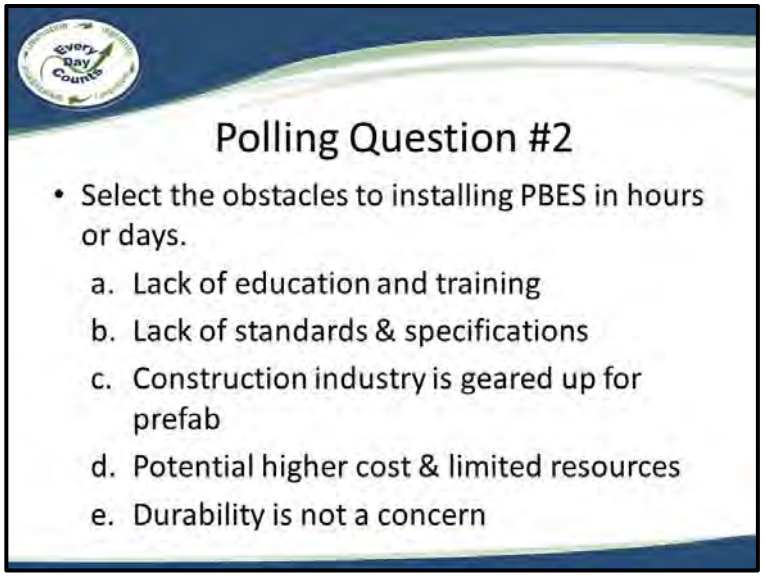
Available online resources are listed at the end of the framework for use in obtaining additional information, including completed prefabricated bridge projects with contact information, publications, research, and a calendar of upcoming events.

The framework is available at this website, which is continually being populated with additional information. We encourage you to visit it often to stay current with the latest PBES developments.

Slide 37:



Slide 38:



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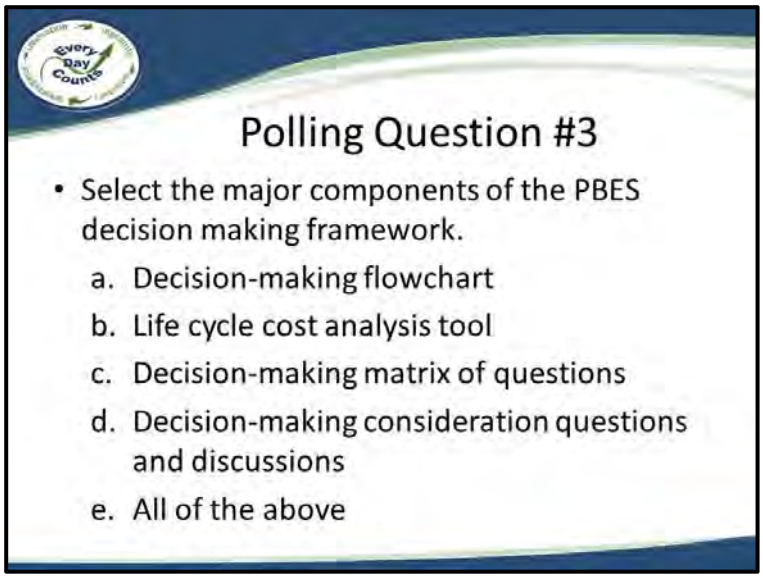

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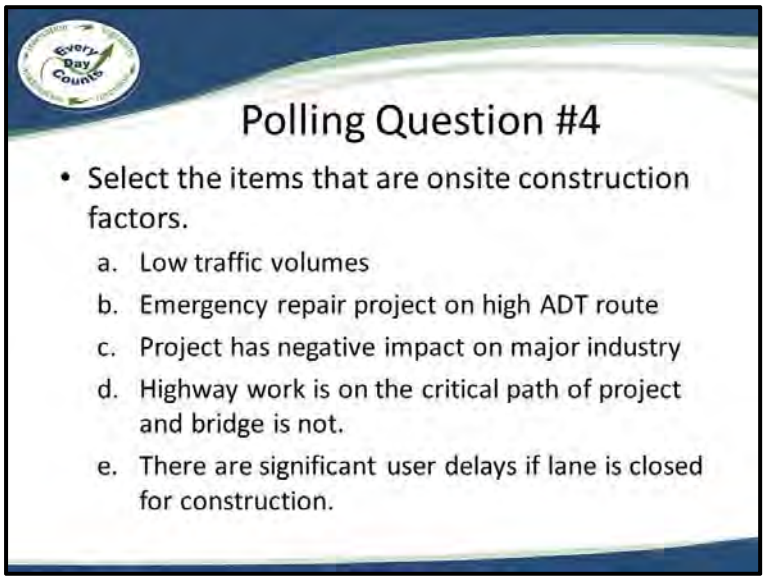

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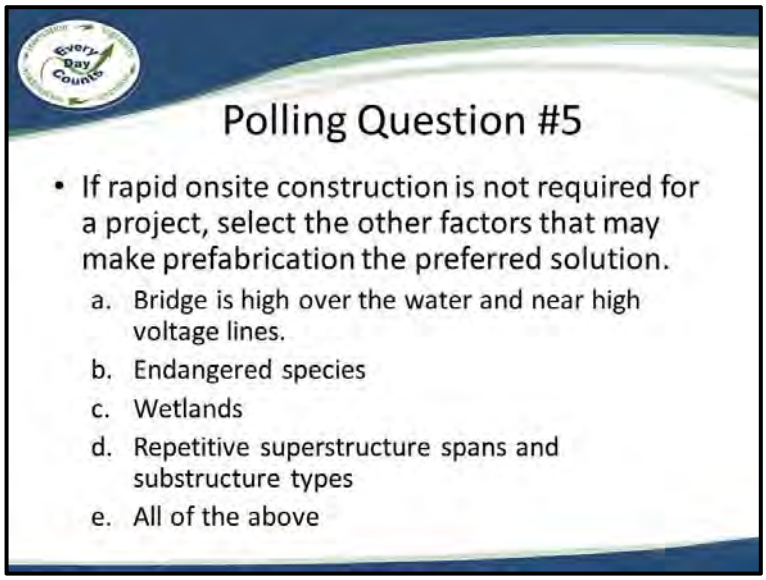

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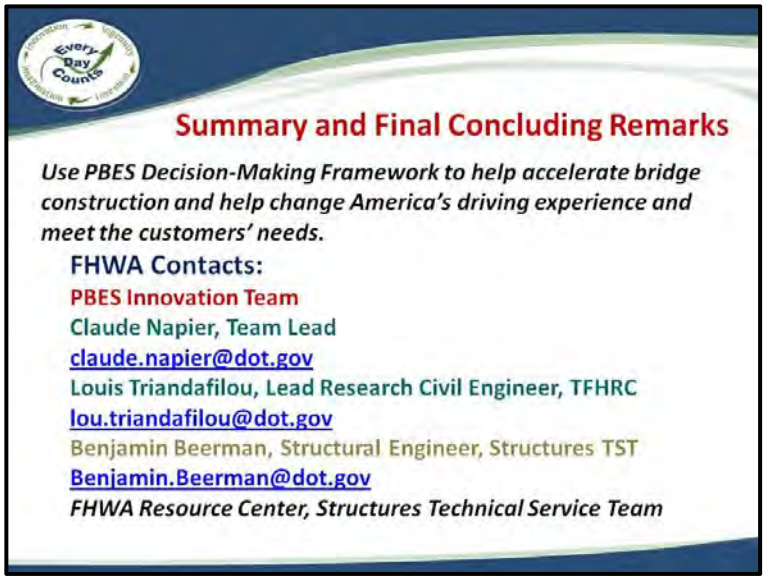
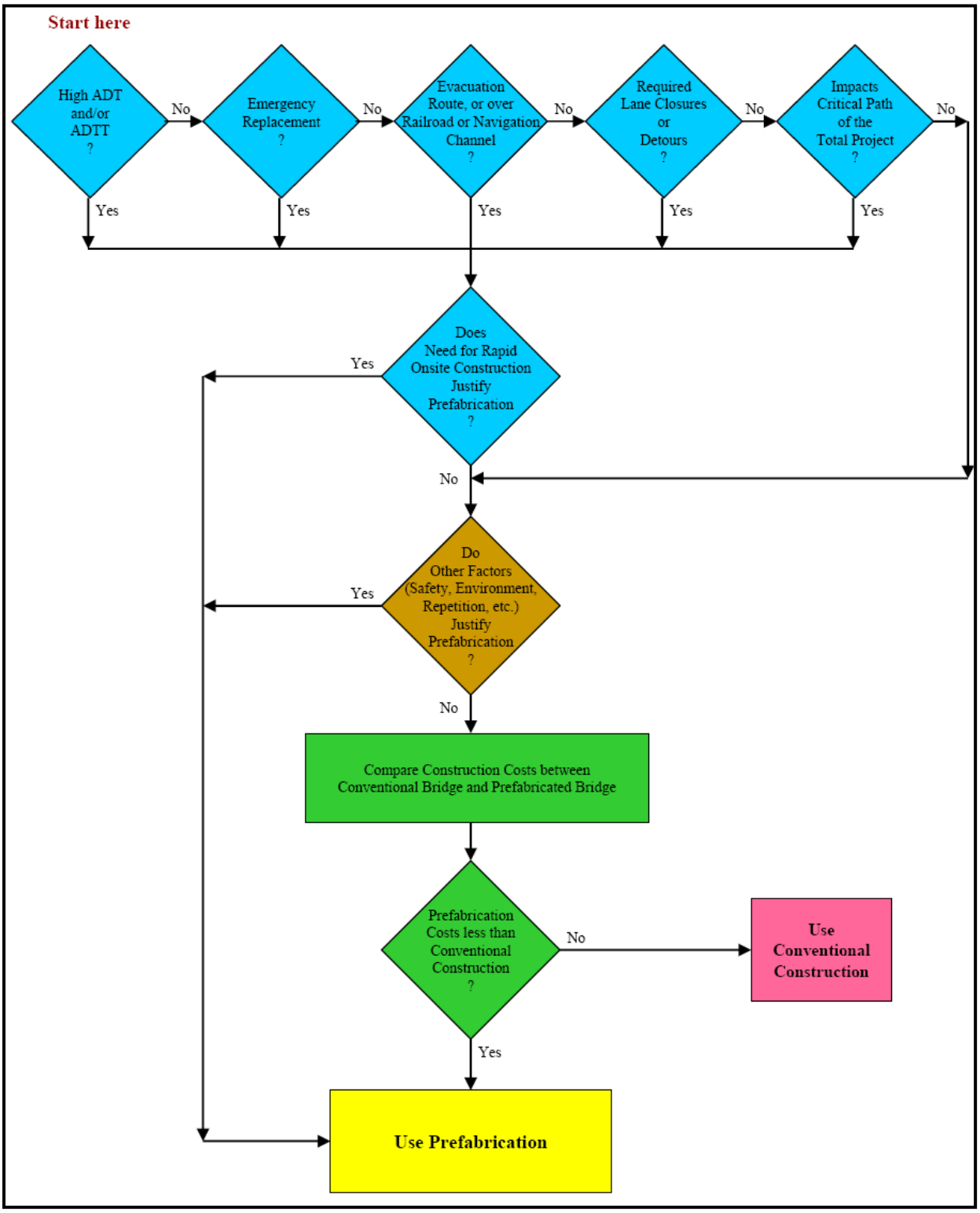


Slide 43:

FLOWCHART FOR HIGH-LEVEL DECISION ON WHETHER A PREFABRICATED BRIDGE SHOULD BE USED IN THIS PROJECT



MATRIX QUESTIONS FOR HIGH-LEVEL DECISION ON WHETHER A PREFABRICATED BRIDGE SHOULD BE USED IN THIS PROJECT

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 this project an emergency bridge replacement?			
Is the bridge on an emergency evacuation route or over a railroad or navigable waterway?			
Will the bridge construction impact traffic in terms of requiring lane closures or detours?			
Will the bridge construction impact the critical path of the total project?			
Can the bridge be closed during off-peak traffic periods, e.g., nights and weekends?			
Is rapid recovery from natural/manmade hazards or rapid completion of future planned repair/replacement needed for this bridge?			
Is the bridge location subject to construction time restrictions due to adverse economic impact?			
Does the local weather limit the time of year when cast-in-place construction is practical?			
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, and noise)?			
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?			
Can this bridge be designed with multiple similar spans?			
Does the location of the bridge site create problems for delivery of ready-mix concrete?			
Will the traffic control plan change significantly through the course of the project due to development, local expansion, or other projects in the area?			
Are delay-related user costs a concern to the agency?			
Can innovative contracting strategies to achieve accelerated construction be included in the contract documents?			
Can the owner agency provide the necessary staffing to effectively administer the project?			
Can the bridge be grouped with other bridges for economy of scale?			
Will the design be used on a broader scale in a geographic area?			
Totals:			

Note: *One or two of the above factors may warrant the use of prefabrication to achieve rapid and limited-impact onsite construction. Alternatively, the user may wish to assign weights to the above questions based on the unique circumstances of the project in order to determine whether prefabrication should be used. In any case, prefabrication offers advantages for projects with a majority of "Yes" responses; a more detailed evaluation using the considerations in the next section would then be appropriate.*

Module 4: ABC/PBES Costs

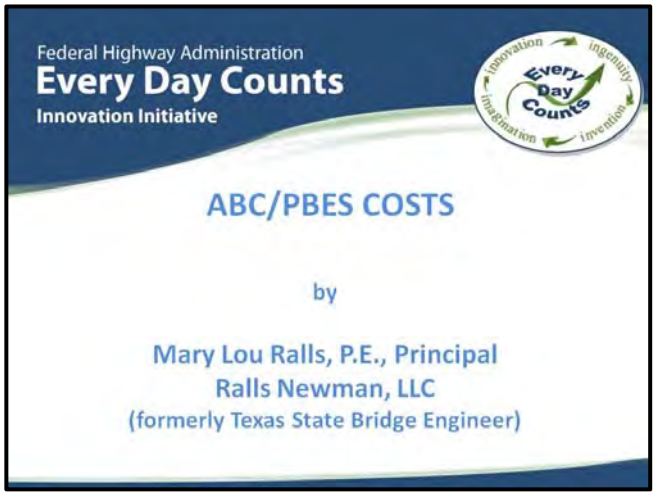
MODULE LEARNING OUTCOMES

By the end of this Module, will be able to:

- Identify examples of ABC/PBES replacement projects that achieved onsite construction time and cost savings, and locate project contacts
- Describe combinations of PBES and contracting strategies that achieved accelerated onsite construction timelines at lower costs
- Explain why comparison of ABC costs and conventional construction costs may not be appropriate Explain why moving to ABC/PBES as a standard practice will achieve cost savings

MODULE SLIDES & NOTES

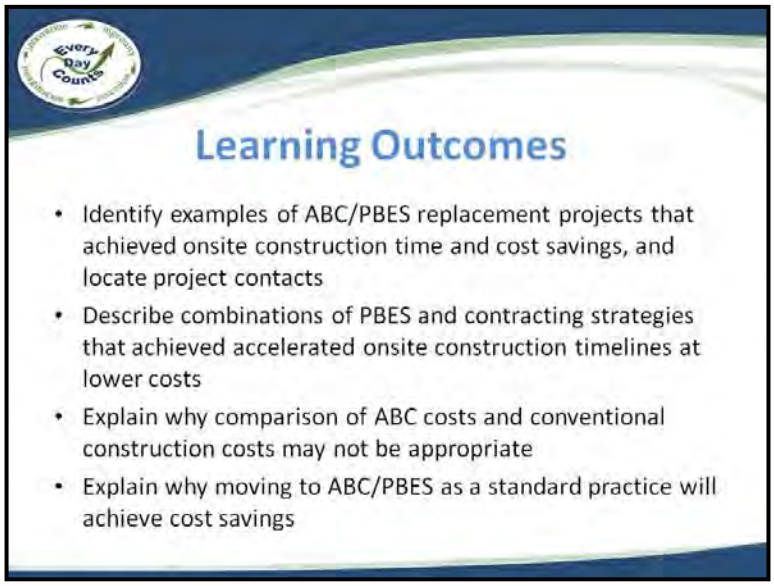
Slide 1: The purpose of this module is to assist participants in understanding: That a number of ABC/PBES projects have been built with shorter onsite construction timelines and lower construction costs relative to conventional construction; what made those projects successful; and, the relevant issues when comparing ABC costs and conventional construction costs, and the drivers for cost savings.



Slide 2:

Upon completion of this module, participants will be able to:

- Identify examples of ABC/PBES replacement projects that achieved onsite construction time and cost savings, and locate project contacts
- Describe combinations of PBES and contracting strategies that achieved accelerated onsite construction timelines at lower costs
- Explain why comparison of ABC costs and conventional construction costs may not be appropriate
- Explain why moving to ABC/PBES as a standard practice will achieve cost savings

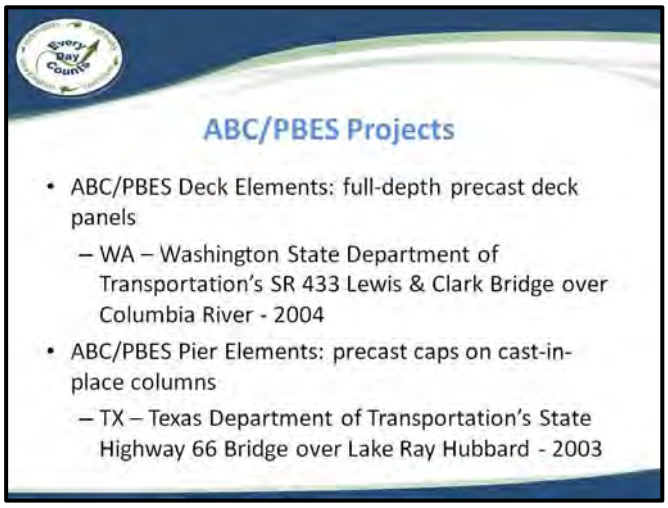


Slide 3: I will be presenting five of the nine projects described in the 2006 FHWA-sponsored PBES Cost Study that is available from the FHWA prefabricated bridges website; the website address is shown at the bottom of this slide. The report provides significantly more detail than will be discussed in this module.

All projects are replacement projects, and as such reducing the impact of onsite construction to motorists was a priority. Each project is an example of how various combinations of prefabrication and effective contracting strategies were used to achieve the accelerated onsite construction timeline at competitive cost.

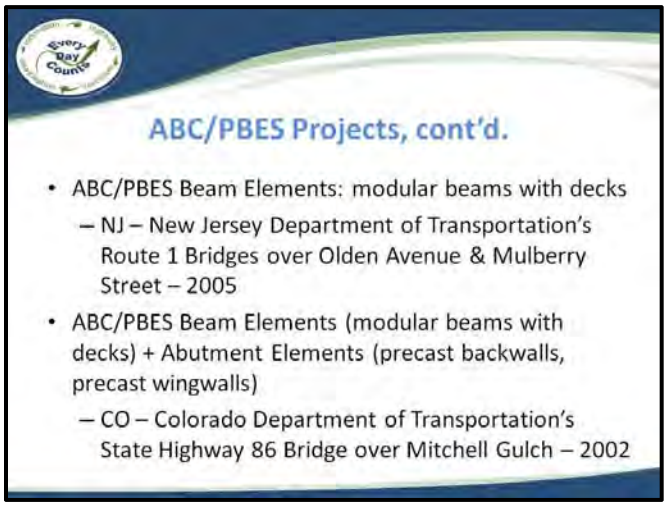
Slide 4:

The first project to be discussed includes ABC/PBES Deck Elements, specifically full-depth precast concrete deck panels. The second includes ABC/PBES Pier Elements, specifically precast concrete caps on cast-in-place concrete columns.



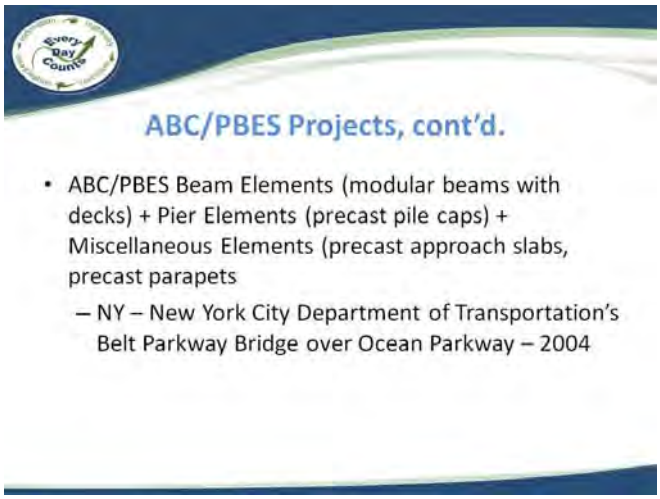
Slide 5:

The third project includes ABC/PBES Beam Elements, modular beams with decks, while the fourth project includes ABC/PBES Beam Elements plus Abutment Elements, modular beams with decks plus precast backwalls and wingwalls. The first of these two projects is in an urban setting, while the second is a rural project.



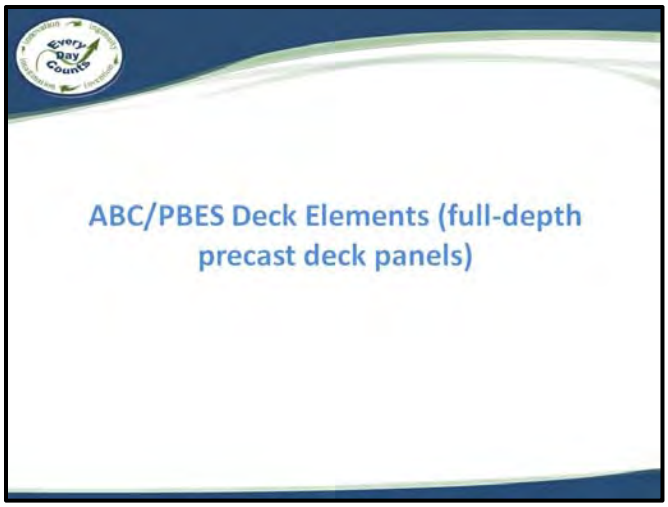
Slide 6:

The last project discussed in this presentation uses a variety of ABC/PBES elements. The Beam Elements are modular beams with decks, the Pier Elements are precast pile caps, and the Miscellaneous Elements are precast approach slabs and precast parapets.



Slide 7:

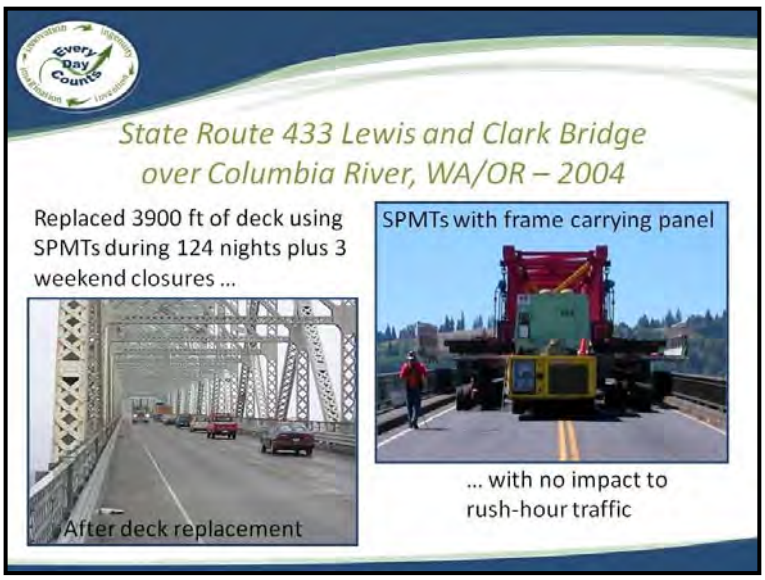
A number of precast full-depth decks have been installed across the country using various construction methods.



Slide 8:

The full-depth deck project discussed today used self-propelled modular transporters (SPMTs) combined with a gantry framing system to install the deck panels. Other projects have installed panels with cranes. Local construction capabilities and site requirements determine the most appropriate construction method.

The Lewis and Clark Bridge over the Columbia River spans the state line between Longview, Washington and Rainier, Oregon and is jointly owned by the Washington State Department of Transportation and the Oregon Department of Transportation. The 1929 steel through-truss bridge provides access across state lines for 18,000 vehicles each day.



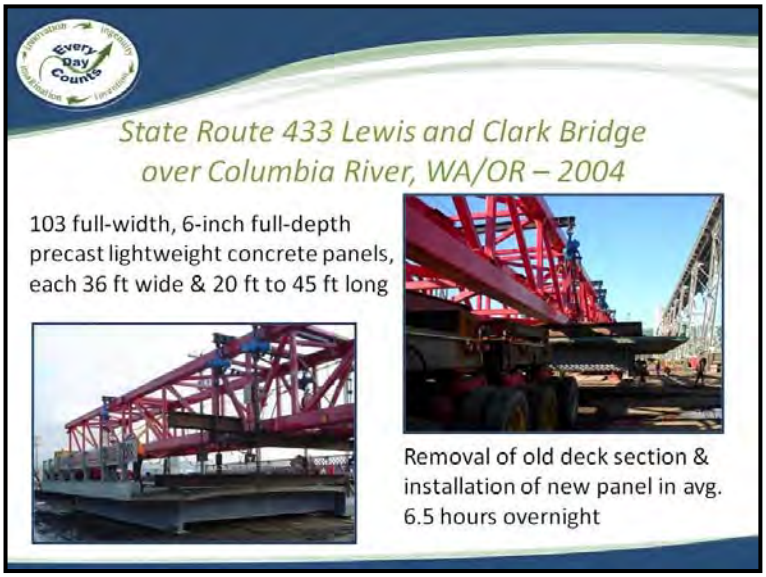
In early 2000 its deck was severely deteriorated and required replacement. Accelerated onsite construction was needed to limit the impact to emergency services and to avoid extended use of a 40-mile detour west that included a ferry ride or an 80-mile detour south.

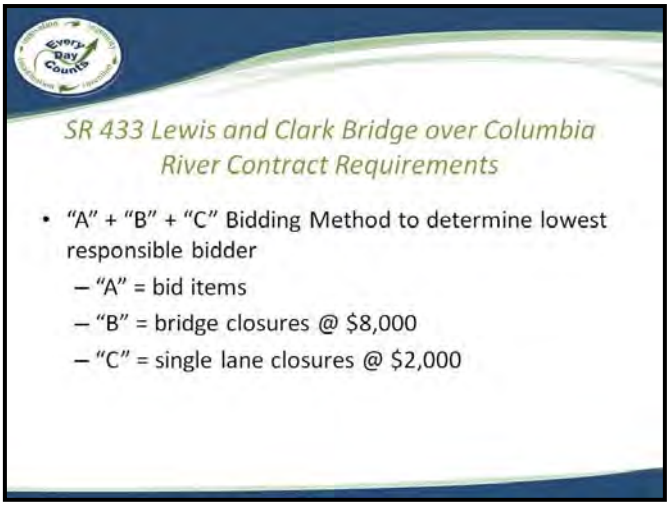
In 2004 WSDOT completed replacement of the bridge deck on this mile-long bridge with no impact to rush-hour traffic. A total of 3,900 ft. of deck were replaced during 124 night closures plus 3 weekend closures. Construction using conventional cast-in-place methods would have required 4 years. The deck replacement extended the life of the bridge another 25 years.

Slide 9:

A total of 103 prefabricated deck panels were installed. They were 36 ft. wide and 20 ft. to 45 ft. long. The lightweight concrete panels were 6-in. thick plus 1-in. thick overlay. Each panel was supported on two longitudinal steel beams. The panel units had a maximum weight of 96 tons.

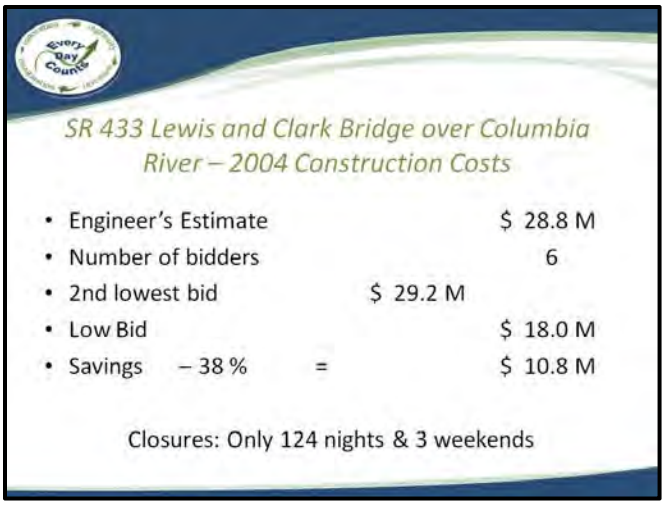
The bridge was closed on Sunday through Thursday nights from 9:30 p.m. to 5:30 a.m. The SPMTs with truss frame moved a new panel to the bridge, lifted the old panel out, and then lowered the new panel into place before taking the old panel off the bridge. Each panel movement took an average 6.5 hours.





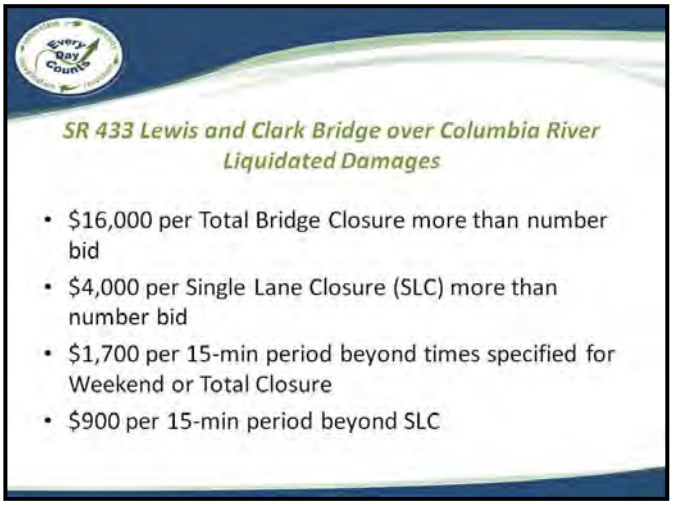
Slide 10:

WSDOT utilized an "A" + "B" + "C" bidding method to determine the lowest responsible bidder, where "A" equals the bid items, "B" equals the total number of bridge closures established by the bidder to complete the work times the Total Bridge Rental Closure Cost, and "C" equals the total number of single lane closures established by the bidder to complete the work times the Bridge Single Lane Rental Cost. The "B" and "C" parts of the bid were only used to determine the lowest responsible bidder, not to determine final payment to the contractor.



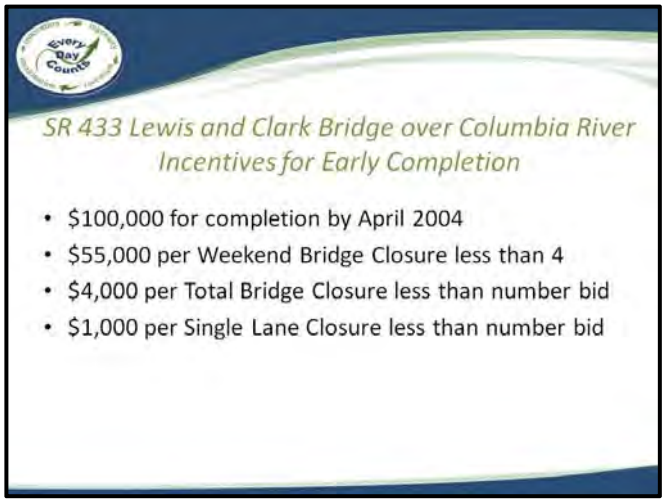
Slide 11:

The contract included several incentives for early completion. If the contractor finished all work requiring Weekend or Total Bridge Closures by April 30, 2004, he would receive $100,000. This was put in the contract as a neutral cost to the owner because a $100,000 extension was due then for a helicopter with landing pad on the south side of the river for emergency crossings during the closures. Other incentives were also included as shown on the slide.



Slide 12:

The contract also included liquidated damages for not meeting the time constraints for accelerated construction at the amounts shown on the slide.

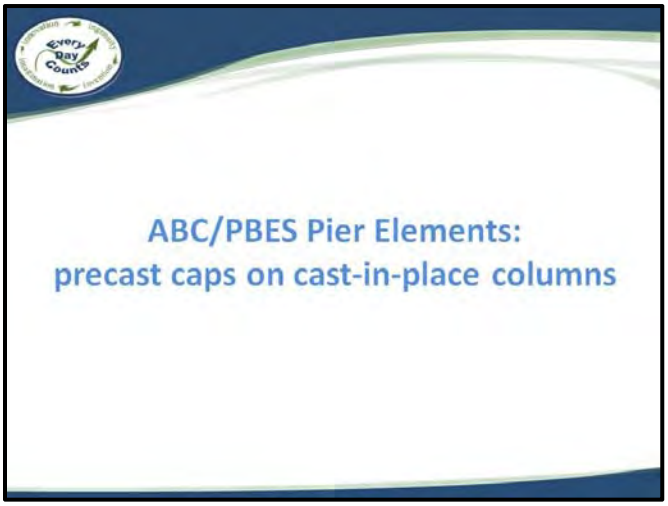


Slide 13:

The engineer's estimate for this project was $ 28.8M. The low bid of $18.0M was 38% or $10.8M less than the engineer's estimate. There were 6 bidders on this project.

The contractor completed all work requiring Weekend or Total Bridge Closures by the end of April 2004 and, therefore, received the $100,000 incentive. He also received an incentive of $55,000 for using 3 instead of 4 Weekend Bridge Closures, and an additional $30,000 for having 30 fewer Single Lane Closures than the 173 allowed. The contractor received a total incentive of $185,000. No liquidated damages were assessed. 3900 linear feet of deck were replaced during only 124 nights plus 3 weekend closures. Use of this prefabricated deck system in combination with the innovative SPMT equipment reduced construction workers' exposure to traffic during construction, improved the constructability of the bridge, and allowed the bridge to remain open for normal weekday operations with no impact to rush-hour traffic.

The Washington State DOT also obtained the new deck ahead of time and significantly under budget.



Slide 14:

The second element to be discussed is caps. The terms pier cap and bent cap are used interchangeably to describe this prefabricated substructure element. Prefabricated caps are increasingly being specified to speed substructure construction.

Slide 15:

In 2000 the Texas Department of Transportation's State Highway 66 over Lake Ray Hubbard near Dallas was a narrow, congested, 40-year-old 2-lane bridge. It was replaced with a pair of bridges, completed in early 2003. The new 4,360-ft long, 40-ft wide eastbound bridge has two traffic lanes and shoulders, and precast bent caps as part of its substructure due to a contractor-initiated field change.

Pre-casting 43 identical caps resulted in a time savings of 5 to 7 days per cap, at least 215 days of effort. Forming, concrete placement, and curing for conventional bent caps would have required 7 days of critical path activity per cap. This represented a total potential delay of 9 months for the 43 bent caps.

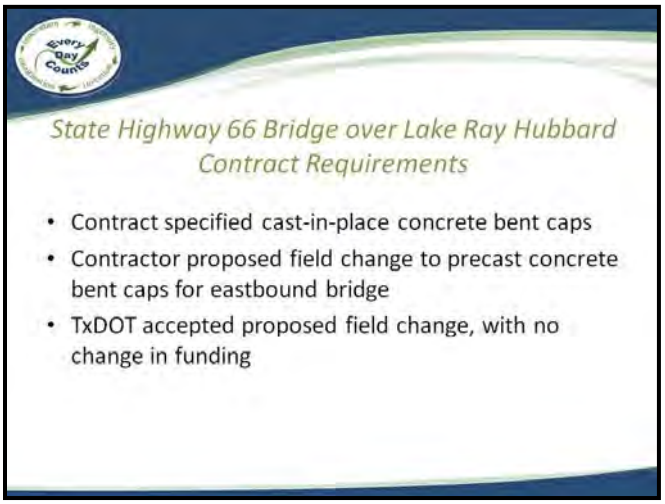
Slide 16:

First the new westbound bridge was built adjacent to the existing bridge using conventional construction. Traffic was then moved to the new bridge, the old bridge was demolished, and the eastbound bridge was built approximately on the bridge's original alignment.

The contractor fabricated the 43 identical caps

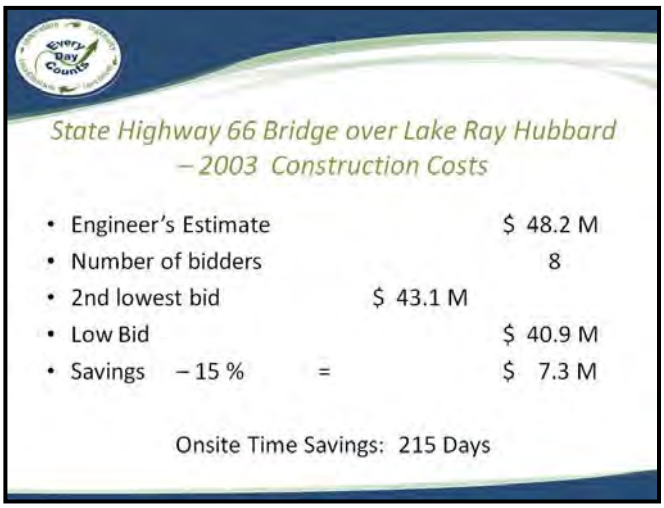
adjacent to one end of the bridge. Each cap is supported by three cast-in-place columns, and provides the bearing for the five beams per typical 100-ft span. TxDOT designed grouted-duct connections between the precast caps and the cast-in-place columns based on previous research at the University of Texas at Austin. Seismic design was not required.

In addition to speeding onsite construction, fabricating the bent caps off the critical path allowed the use of a normal-strength high performance concrete mix design that results in greater durability but with a slower strength gain due to the 35 percent replacement of cement with ground-granulated blast-furnace slag.



Slide 17:

The contract specified conventional cast-in-place construction for the substructures. Early in the project the contractor proposed a field change to precast reinforced concrete bent caps as a way to speed construction, to avoid the difficulties in handling formwork and materials over water, and to minimize the construction workers' exposure to high-voltage transmission lines running adjacent to the bridge. TxDOT approved the contractor's proposal with no change in funding. The contract did not include incentives or disincentives.

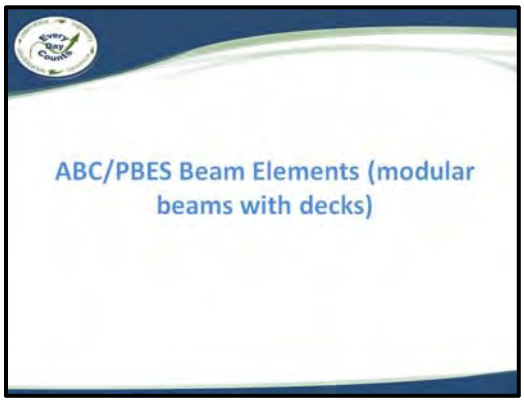


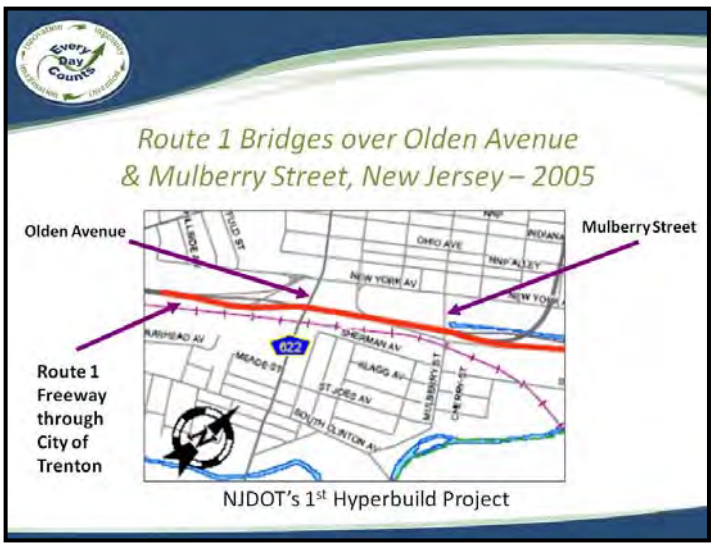
Slide 18:

The engineer's estimate for this project was $48.2M. The low bid of $40.9M was 15% or $7.3M less than the engineer's estimate. There were 8 bidders on this project. Using the 43 precast bent caps reduced onsite construction time by 215 days. TxDOT obtained the bridge ahead of schedule and under budget.

Slide 19:

The next project to be discussed in this presentation has ABC/PBES Beam Elements. Many superstructures consisting of modular beams with decks have been installed across the country. The project presented here was installed with conventional construction equipment including cranes, and many superstructures across the country have been installed with similar methods.





Slide 20:

Each day the New Jersey Department of Transportation's Route 1 carries more than 50,000 vehicles through the city of Trenton. Three bridge decks on Route 1, one at the Olden Avenue Connector and two at Mulberry Street, were deteriorated and in need of constant maintenance. In 2005 the replacement of these three bridges was the NJDOT's first Hyperbuild project.

Each of the three bridges was replaced over a weekend during three consecutive months, with no impact to rush-hour traffic. Design and construction would have taken 22 months using conventional methods.

Slide 21:

The 2-lane 87-ft long, 35-ft wide single-span Route 1 bridge over the Olden Avenue Connector is a highly-skewed steel girder bridge with concrete deck. The 4-lane 60-ft long, 82-ft wide single-span Route 1 bridge over Mulberry Street consists of two bridges with a median barrier separating each direction of traffic.

Slide 22:

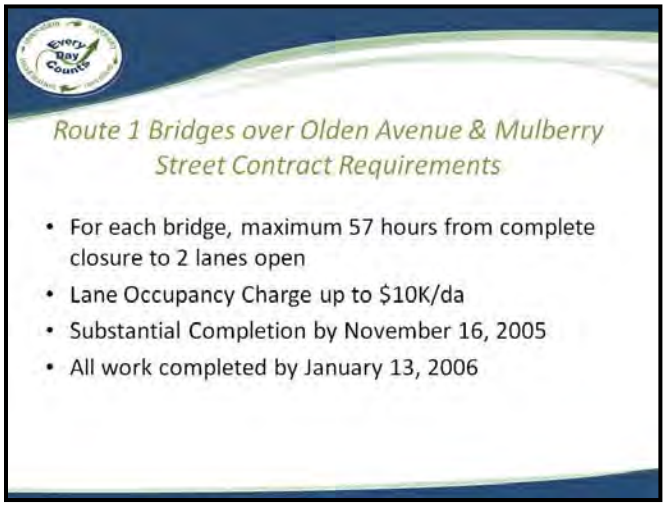
Construction photos are shown here. Each bridge was closed at 7 p.m. on a Friday and traffic was rerouted. The bridge was demolished in place using conventional methods. The existing abutments were repaired and new bearing seats constructed. The prefabricated superstructure was then erected. Parapets and median barriers were cast-in-place concrete.

Each superstructure span consists of 5 full-length segments of varying width, each with two steel girders and a 9-inch thick composite concrete deck (Inverset) system. The segments were required to be onsite 24 hours prior to the start of demolition of the existing bridge. The contract specified high performance concrete for all concrete on the job.

Each bridge is expected to see a 75-100 year service life due to the quality of its prefabricated superstructure, the use of high performance concrete, and the attention given to connection details. Conventionally constructed bridges have an average minimum 50-year life in New Jersey.

Slide 23:

Each of the 3 bridges was allowed a 57-hour window from complete closure to re-opening of both lanes. If this window was exceeded, a Lane Occupancy Charge would be assessed. In addition, Substantial Completion of all 3 bridges was required by a specified date, and all work was to be completed four months later.



Slide 24:

Incentives were also included as shown here.

Slide 25:

Liquidated damages were also specified.

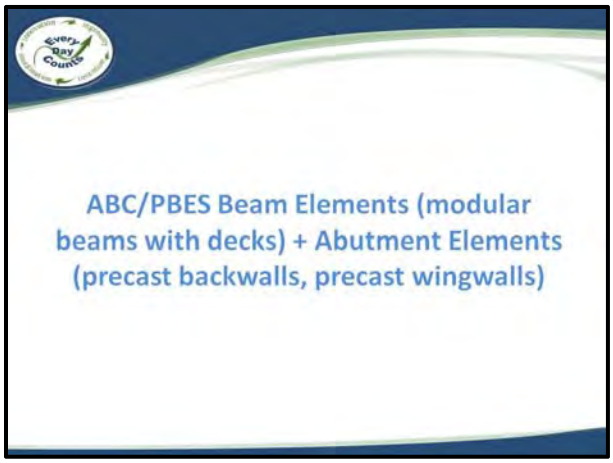
Slide 26:

The engineer's estimate for this project was $ 3.8M. The low bid of $3.5M was 8% or $297,000 less than the engineer's estimate. There were 5 bidders on this project. All three bridges were opened in less than the required 57 hours. The replacements were completed in 6 days over 3 consecutive months, in significantly less than the 22 months required for conventional design and construction, and they were completed under budget.

The design and construction savings, including delay-related user costs, are in excess of $2M.

Slide 27:

The second system to be discussed in this presentation is the total bridge. Replacing both the superstructure and substructure with prefabricated elements and systems is being done more frequently as owners become comfortable with prefabrication and as the performance of more connection details are confirmed. In the US totally prefabricated bridges have been assembled from elements brought to the site. Unlike in Europe, to date in the US no superstructure complete with substructure has been rolled in with SPMTs. This presentation describes two totally prefabricated bridges, one constructed in a rural area and one constructed in an urban area.

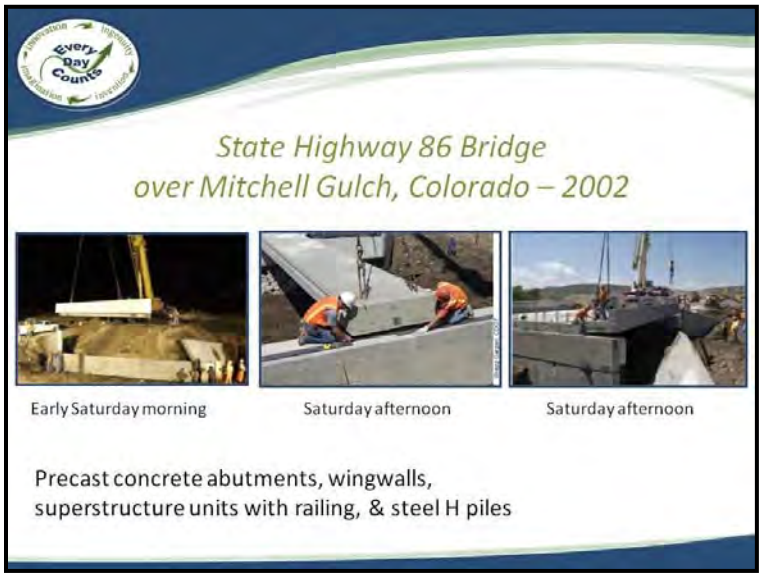


Slide 28

The State Highway 86 Bridge over Mitchell Gulch southeast of Denver was a timber bridge built in 1953 and rated in 2002 as one of Colorado's worst 10 bridges. It was replaced with a totally prefabricated bridge over a weekend in August 2002. During construction the bridge was closed and the 12,000 vehicles per day were diverted to a short detour around the bridge site.

The existing 40-ft long, 26-ft wide 2-span bridge was replaced with a 40-ft long, 43-ft wide single-span bridge. The new prefabricated bridge was opened just 46 hours after closure. Construction occurred over a weekend, with no impact to rush-hour traffic. Construction would have taken 2 to 3 months using conventional methods.

Slide 29: Prior to the bridge closure, the contractor drove steel H piles at the abutments in the stream banks just outside the existing roadway width. The precast concrete abutments, wingwalls, and superstructure units were shipped to the site just before being installed.



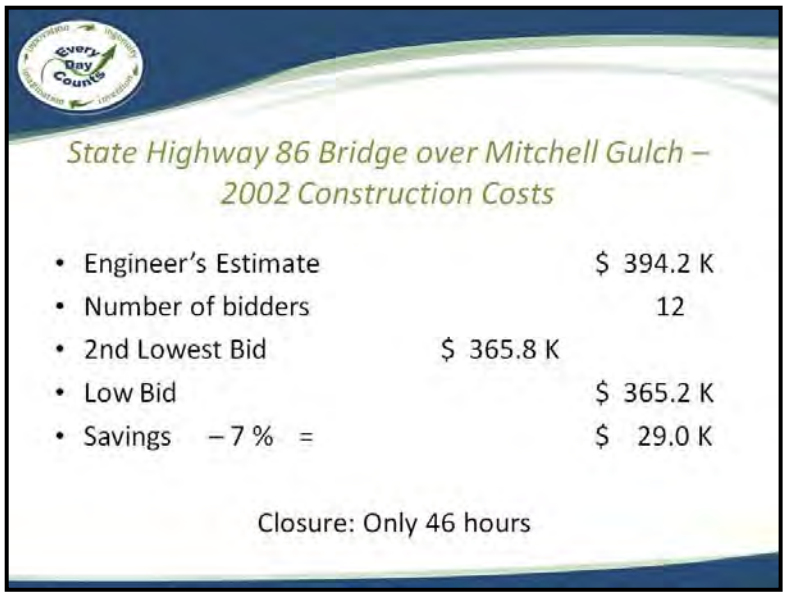
At 7 p.m. on a Friday the bridge was closed and traffic detoured. The existing timber bridge was demolished. Early Saturday morning, 44-ft wide precast abutments and 23-ft long precast wingwalls with embedded steel plates were erected with a crane and welded to the steel H piles and to each other prior to placing flowable fill behind the abutments. On Saturday afternoon, the eight precast superstructure units were erected, including the edge units complete with precast railing. The units were then transversely post-tensioned and grouted. On Sunday the earthwork and asphalt overlay were completed.

The bridge was reopened to traffic at 5 p.m. on Sunday, 46 hours after closure of the existing bridge. Only 38 hours of construction work were required for the replacement.

The bridge is expected to see a 75-year service life due to the quality of its prefabricated components and the attention given to connection details.

Slide 30: The Colorado DOT awarded the construction contract to replace the deteriorated bridge with a conventional 3-cell cast-in-place concrete box culvert. However, the contractor was concerned about the safety of his construction crews on this project because of the steep downward grade of the highway approach in combination with the nearby curve of the detour around the bridge site. The contractor teamed with a local design firm to submit a value engineering change proposal to build the single-span totally prefabricated bridge over a weekend to limit the onsite exposure time of his crew.

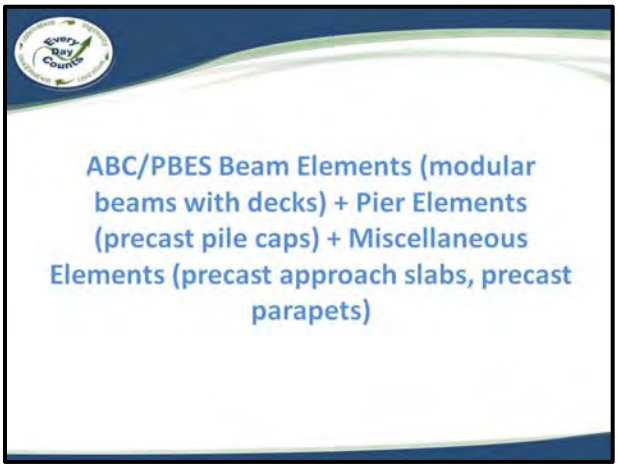
Slide 31: The Colorado DOT accepted the value engineering change proposal, with no change to the project funding. However, as part of the acceptance of the proposal, CDOT implemented a lane rental specification that imposed fees should the contractor exceed the allowed weekend closure. The lane rental was based on road user costs to occupy SH 86. No incentives were included in the contract.



Slide 32:

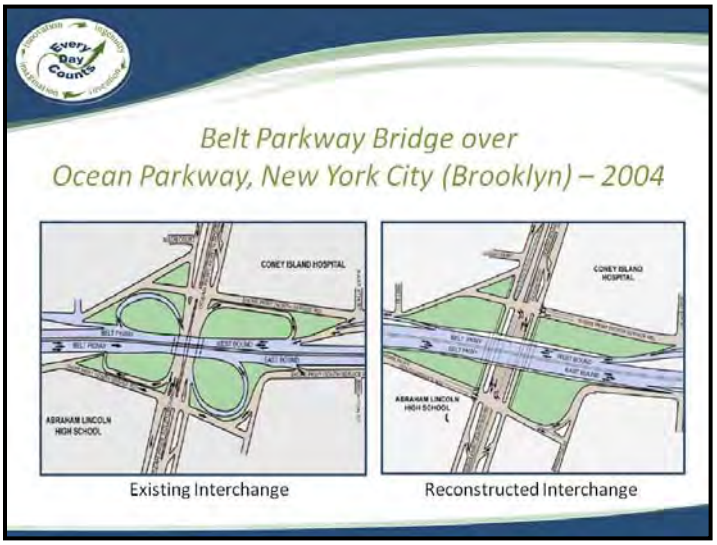
The engineer's estimate for this project was $ 394.2K. The low bid was 7% less than the engineer's estimate. Twelve contractors bid on the project. The 5 p.m. Sunday opening of the new bridge was 13 hours earlier than the required 6 a.m. Monday opening. No rush hours were impacted and, therefore, no lane rental fees were charged.

The contractor said that he expects to cut the 46-hr closure time in half on similar subsequent projects due to his learning curve.



Slide 33:

The final project to be discussed has ABC/PBES Beam Elements, Pier Elements, and Miscellaneous Elements. The Beam Elements consist of modular beams with decks, similar to the New Jersey project previously discussed. The Pier Elements are precast pile caps. The Miscellaneous Elements are precast approach slabs and precast parapets.



Slide 34:

The New York City DOT's Belt Parkway Bridge over Ocean Parkway in south Brooklyn. This bridge was deteriorated and required complete replacement. The entire design-build project included replacing the existing bridge with a longer and wider bridge, reconfiguring the existing outdated cloverleaf interchange into a modified tight diamond interchange, and other rehabilitation and upgrade work to the Parkways.

The selected design-build team specified extensive use of prefabricated bridge components to achieve an accelerated onsite construction timeline. The rapid construction was required to minimize disruption to the 166,000 average daily traffic volume that used the Belt Parkway, a major artery through Brooklyn that also had a large hospital and two schools fronting on the project limits.

Onsite installation of each half of the new bridge took only a few nights in each of two weeks. The entire design-build project was completed in 14 months, including a 3-month winter shutdown. Construction would have taken 3 to 4 years using conventional methods.

Slide 35:

The old bridge was lengthened and widened to add shoulders and acceleration/deceleration lanes at the entrance and exit points, in addition to the existing 3 lanes in each direction.

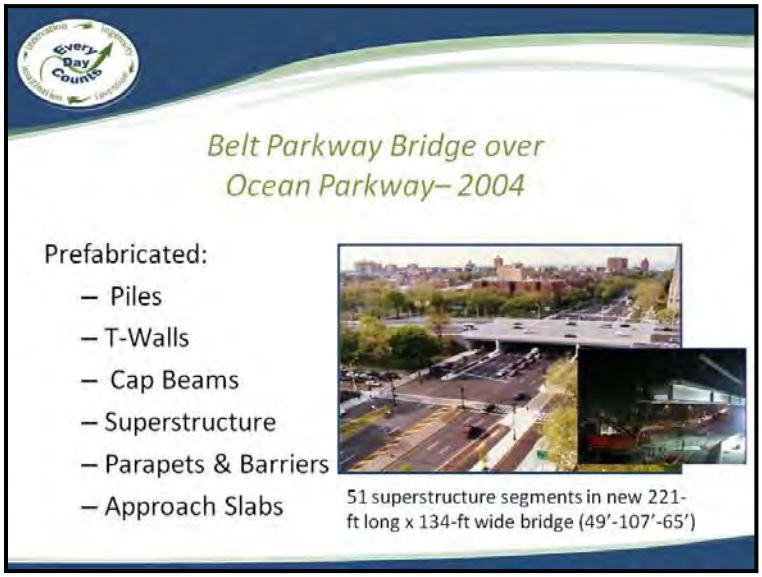
Throughout the project, six lanes of traffic remained open during rush hour, with limited lane closures as needed during off-peak hours. A temporary bridge was erected adjacent to the south side of the existing bridge to maintain the existing number of lanes on Belt Parkway during the bridge reconstruction. Traffic was diverted onto the temporary bridge and the south portion of the existing bridge while the north portion of the existing bridge was demolished and reconstructed. Traffic was then rerouted to the six lanes, three in each direction, on the new north portion of the bridge and the remaining existing bridge was then demolished and reconstructed.

Slide 36:

To minimize traffic disruption, prefabricated components were used extensively. Prefabricated components included concrete-filled steel pipe piles, precast T-walls, precast post-tensioned cap beams, prefabricated superstructure segments, precast bridge parapets, median barriers, and approach slabs. High performance concrete with 4000 psi compressive strength was specified for all precast components. Stainless steel reinforcement was specified for the precast decks, parapets, and median barriers. While the stainless steel reinforcement increased the cost of the bridge by approximately one percent, the bridge is anticipated to last twice as long as the 45-year-old bridge it replaced.

The 51 span-length prefabricated superstructure segments, as well as the other precast concrete components, were fabricated in upstate New York and shipped 200 miles to the jobsite. Each (Inverset) superstructure segment consisted of two steel girders and a composite deck.

The bridge is expected to see a 75-100 year service life due to the quality of its prefabricated components and the attention given to connection details, including the loop-on-loop closure joints connecting the deck segments.

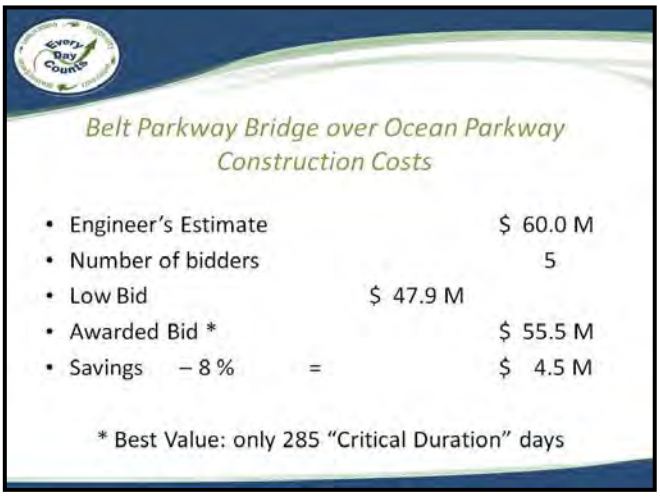


Slide 37:

The NYCDOT utilized a modified "A" + "B" bidding method, where "A" equals the bid items and "B" equals a "Critical Duration" (number of days specified by the contractor) times $85,000 to translate the duration into a delay-related user cost. "Critical Duration" was defined as the period of time from when the design-build team permanently impacted the roadways for construction until the time that all new roadways were in their final completed configuration.

Slide 38:

Incentive/disincentive and liquidated damages clauses were included in the contract as shown here.



Slide 39:

The engineer's estimate for this project was $ 60.0M. The awarded bid of $55.5M was 8% or $4.5M less than the engineer's estimate. There were 5 bidders on this project. The awarded bid proposed a "Critical Duration" of only 285 days, which was 300 "Critical Duration" days shorter than the low bid. Therefore, at $85,000 per day, the awarded bid was the best value, with a delay-related user cost that was $25M lower than the low bid.

The bridge was completed 29 days ahead of the "Critical Duration" of 285 consecutive calendar days that was bid in the contract. The actual number of "Critical Duration" days was just 256 days, with no lane closures during peak traffic hours. The contractor received the maximum $2M incentive.

The bridge work on this design-build project was approximately a third of the total project cost. The project replaced the existing high-traffic-volume bridge with a longer and wider bridge, reconfigured the interchange, and completed other rehabilitation and upgrade work in significantly less time than conventional construction, and it was completed under budget.

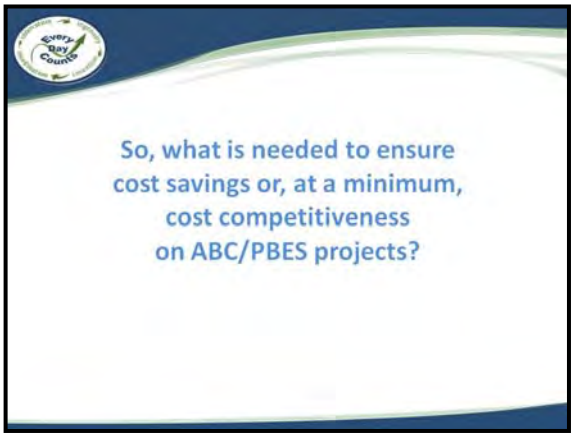
Slide 40:

Did these projects cost less than conventional construction? When projects have high-traffic volumes that must be maintained, conventional construction is frequently not even a possibility. We know that the construction projects went well because they were all completed under the engineer's estimates, but we don't know what the engineer's estimates for conventional construction, if it were possible, would have been for these projects.

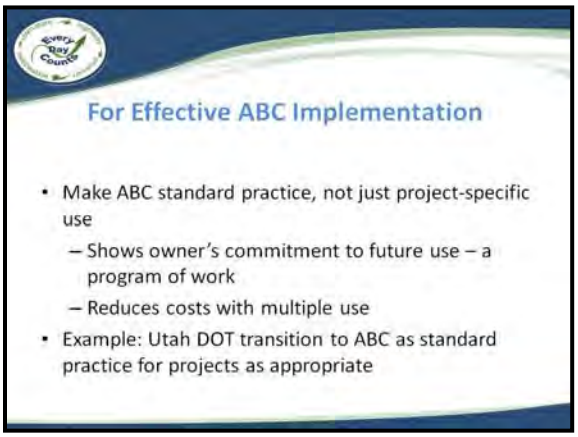
Slide 41:

The Lake Ray Hubbard precast bent cap project and the Mitchell Gulch totally prefabricated bridge project are the closest we can come to comparing ABC costs to conventional bridge construction costs. For both of these projects, the engineer's estimate was based on conventional construction and the contractor was required to bid the job for conventional construction. The contractor could then request a change to prefabrication, which the owner would have to approve after bid award. Because the bid came in under the engineer's estimate for each of the two projects, we can assume the prefabricated bridge costs were less than or equal to conventional construction.

Project	Engineer's Estimate	Awarded Bid	Cost Savings	
			$	%
WSDOT Lewis & Clark Bridge	$ 28.8M	$ 18.0M	$ 10.8M	38
TxDOT SH 66 Bridge over Lake Ray Hubbard	48.2M	40.9M	7.3M	15
NYCDOT Belt Parkway Bridge	60.0M	55.5M	4.5M	8
NJDOT Rt. 1 Bridge	3.8M	3.5M	0.3M	8
CDOT Mitchell Gulch Bridge	0.394M	0.365M	0.029M	7
Totals	$ 141.2M	$ 118.3M	$ 22.9M	16% avg.

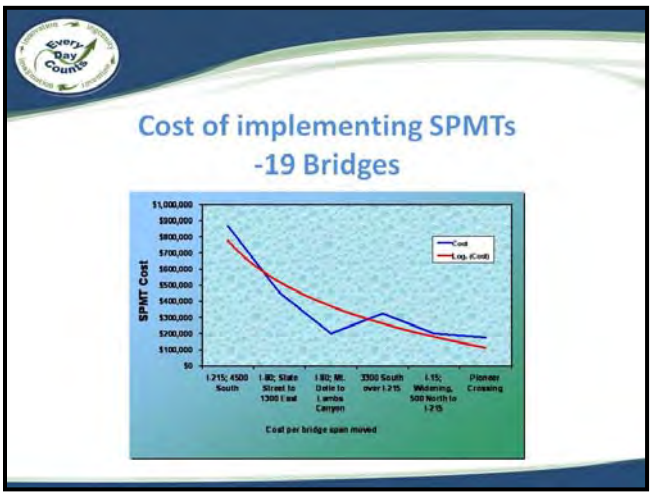


Slide 42: So, what is needed to ensure cost savings or, at a minimum, cost competitiveness on ABC/PBES projects?



Slide 43: The answer is making ABC/PBES a standard practice rather than a project-specific use. In this way the contractor can feel that spending the money to gear up his operations for ABC/PBES will be cost-effective because of the potential for future similar projects. The owner must show a commitment to the use of ABC/PBES on future projects, that is, the owner should have a program of ABC/PBES work. Also, costs will decrease with increasing use as risk is lowered.

The Utah DOT is one example of the lower costs that can be achieved with making ABC/PBES a standard practice. They are now seeing lower costs on their ABC/PBES projects.



Slide 44: The use of SPMTs to move bridges in Utah is an example of the reduced cost that can occur with multiple use. This graph shows the costs per bridge span moved for the purpose of identifying the decreasing cost trend.

The SPMT costs for I-215; 4500 South and I-80; State Street to 1300 East were bid items on the projects. The other projects' SPMT costs were estimated.

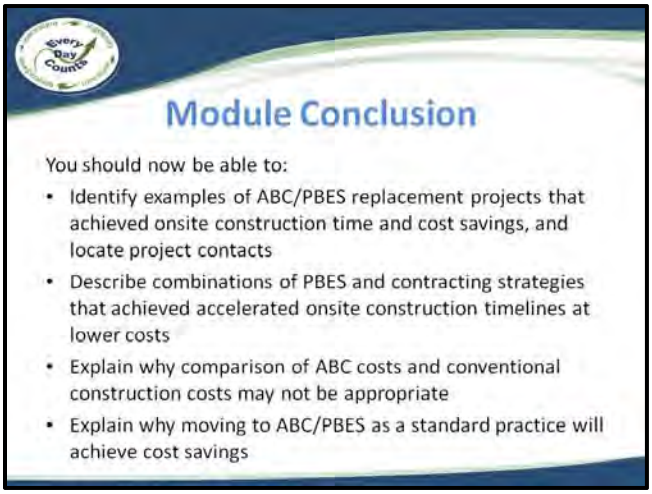
The SPMT move for 4500 South was the first of its kind in Utah. It was also the most difficult move that the subcontractor (Mammoet) had ever performed.

There are two reasons for the lower than expected cost for the I-80; Mountain Delle to Lamb's Canyon project:

A. The SPMTs used on the I-80 Mountain Delle to Lamb's Canyon were already mobilized for the I-80 State Street to 1300 East project.

B. The moves for the Mountain Delle and Lamb's Canyon were short and relatively simple for the subcontractor (Mammoet).

The 3300 South move cost more that the I-80; Mountain Delle and Lamb's Canyon moves due to the distance and grade of the move.



Slide 45:

Participants should now be able to:

- Identify examples of ABC/PBES replacement projects that achieved onsite construction time and cost savings, and locate project contacts
- Describe combinations of PBES and contracting strategies that achieved accelerated onsite construction timelines at lower costs
- Explain why comparison of ABC costs and conventional construction costs may not be appropriate

- Explain why moving to ABC/PBES as a standard practice will achieve cost savings

Slide 46:

Thank you for your attention. Questions?

Module 5: ABC/PBES SPECIFICATIONS, PLANS, AND DETAILS

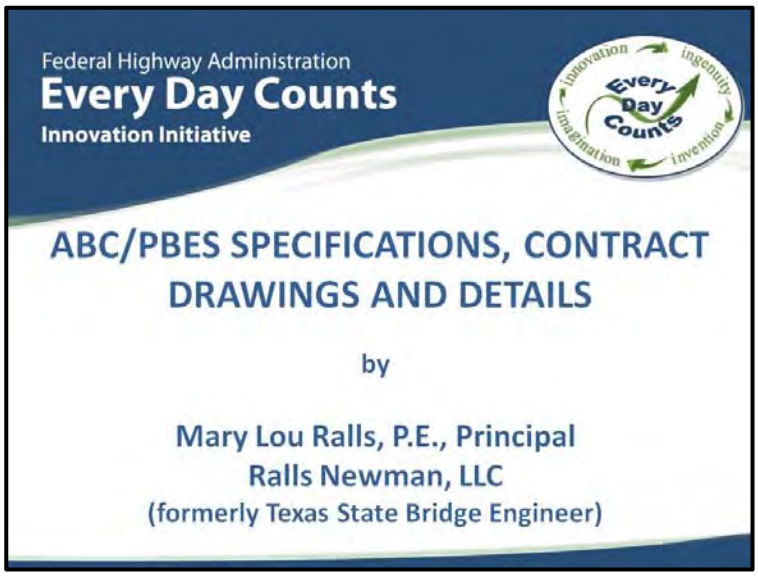
MODULE LEARNING OUTCOMES

By the end of this Module, you will be able to:

- identify resources for examples of various ABC/PBES projects
- acquire specifications, plans, and details for various completed ABC/PBES projects
- describe issues concerning regional versus national details/standards
- describe seismic considerations and research

MODULE SLIDES & NOTES

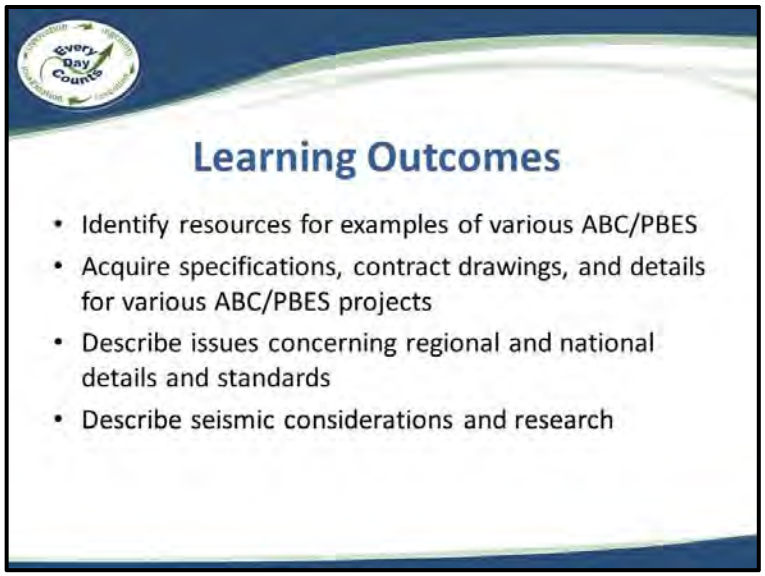
Slide 1:

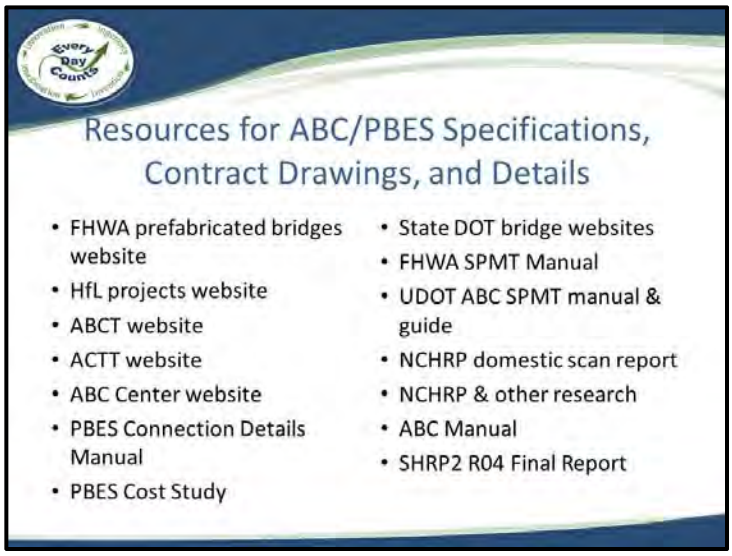


Slide 2:

Upon completion of this module, participants will be able to:

- Identify resources for examples of various ABC/PBES
- Acquire specifications, plans, and details for various ABC/PBES projects
- Describe issues concerning regional and national details and standards
- Describe seismic considerations and research

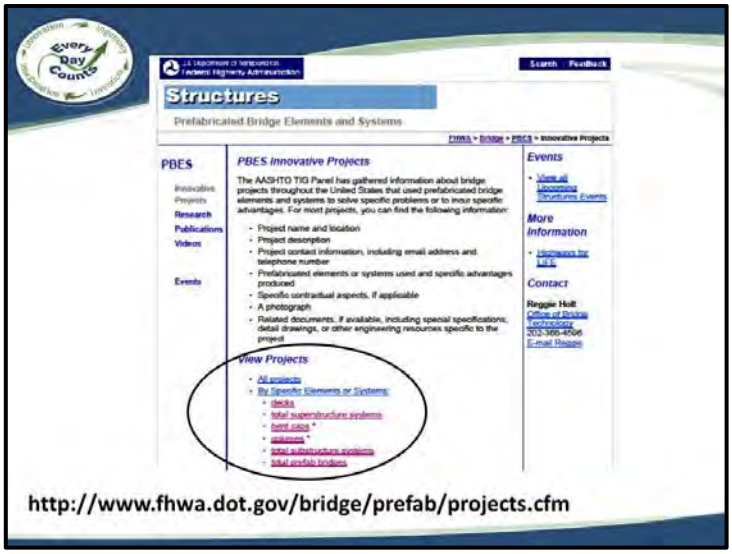




Slide 3:

While there is no one source to obtain a compilation of ABC/PBES specifications, contract drawings, and details, a number of resources are available to acquire examples used in previous ABC/PBES projects. The intent of acquiring these specifications, contract drawings, and details is to have a starting point for a new project to take advantage of lessons learned from a similar previously constructed project.

This module discusses each of the resources shown on this slide.



Slide 4:

The first resource to be discussed is the FHWA prefabricated bridges “Innovative Projects” website. A screen shot of the home page for this website is shown.

Slide 5:

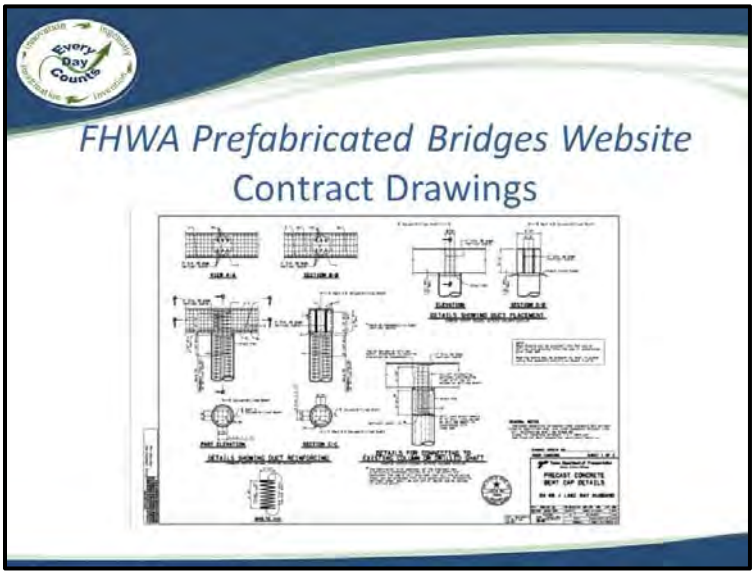
Over 50 PBES projects from around the country are included in this website. Only completed projects are included. The projects are categorized by specific element or system type. The types of elements are decks, bent caps, and columns. The types of systems are superstructures, substructures, and total bridges.

Slide 6:

The information provided for each project includes the location, the state, the year built, the contact person, a brief description of the project, and a project photo. Also included for each project is the PBES type (for example, deck), the advantages of using PBES for the project, and related documents.

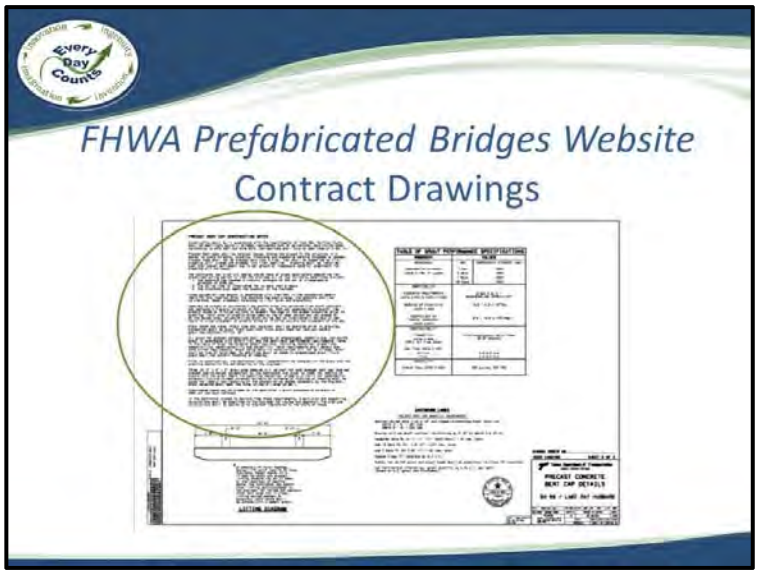
Slide 7:

Related documents may include plan sheets, detail drawings, construction photos, and a description of the construction process. Currently only a limited number of projects have related documents posted on the website.



Slide 8:

Various plan sheets included in the contract documents are available for download in pdf format. This example is a plan sheet for precast bent caps used in a Texas project.



Slide 9:

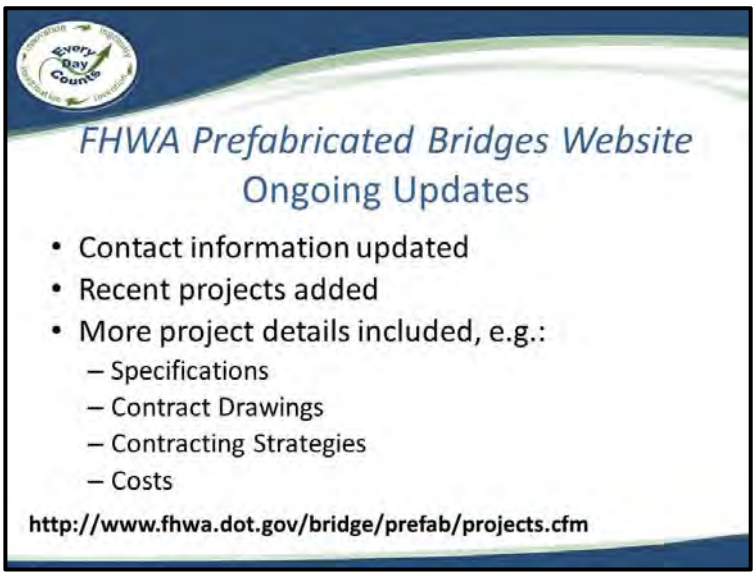
As shown here, some of the plan sheets have extensive construction notes.

Slide 10:

For this precast bent cap project, the construction notes include such details as which construction specification items to build in accordance with, how the caps are to be handled, concrete mix design requirements, grouting requirements, and the required construction process. A note is also provided that says what the contractor must do if deviating from those requirements.

Slide 11:

Related documents may also include detail sketches, as shown here for the New Hampshire Epping prefabricated bridge.



Slide 12:

The website is currently being updated. Contact information is being checked and updated as needed. Recent projects are being added, and other related information is being added. In addition to specifications and contract drawings, contracting strategies, costs, bid tabs, and schedule are being added as available. These updates will be posted as available, so check the website periodically for updates.

Slide 14:

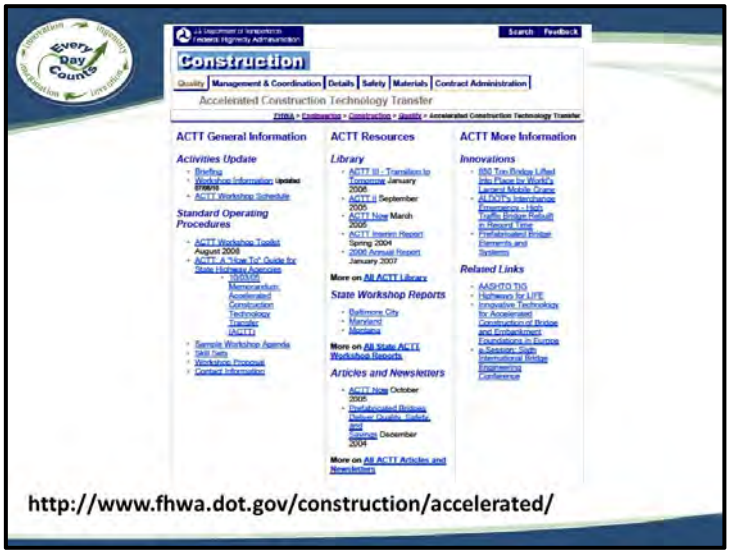
Another resource is the Highways for LIFE demonstration projects website. A screen shot of the home page for this website is shown.

Slide 14:

HfL project summaries can be accessed from the HfL home page. Shown here are several of the HfL-sponsored ABC/PBES projects. A final report can be downloaded for each of these projects.

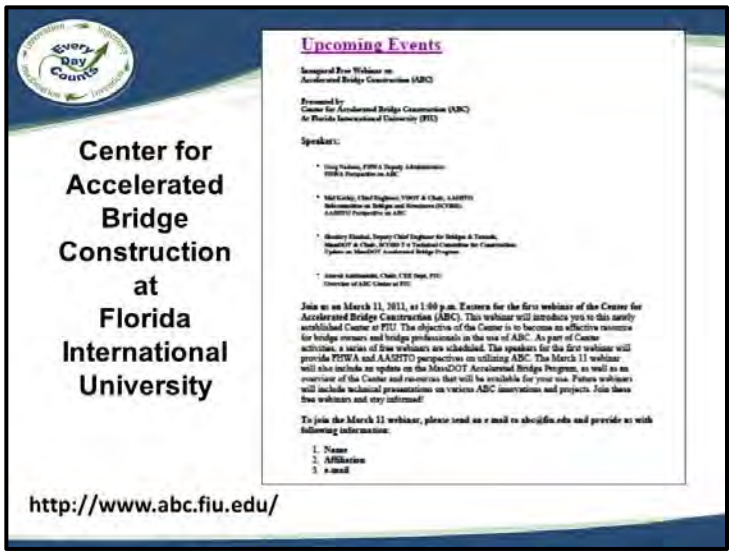
Slide 15:

Another resource is the Accelerated Bridge Construction Technology (ABCT) website. A screen shot of the home page for this website is shown. As you can see, reports and presentations can be downloaded from this website.



Slide 16:

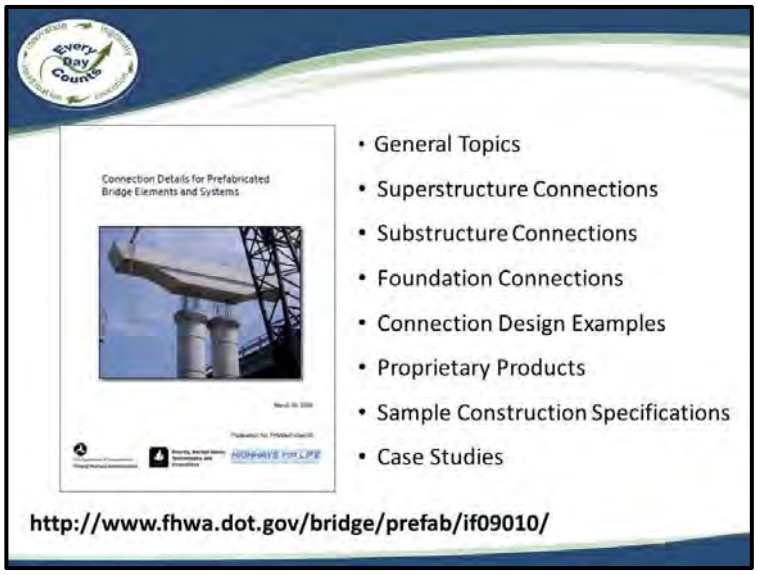
The Accelerated Construction Technology Transfer (ACTT) website is another resource that provides links to various articles and reports on ABC projects. A screen shot of the home page for this website is shown.



Slide 17:

The Center for Accelerated Bridge Construction at Florida International University is a new ABC resource that is available to you. The purpose of the Center is to promote and expand the use of ABC by being the place to go to get information and support to design and build projects using ABC technologies and techniques in a cost-effective manner. The Center will also identify needed research and resources, and develop new technologies. A screen shot of the "Upcoming Events" page shows details about the Center's kickoff webinar.

This website is currently being populated with ABC information. You may access the website at the link shown at the bottom of the slide.

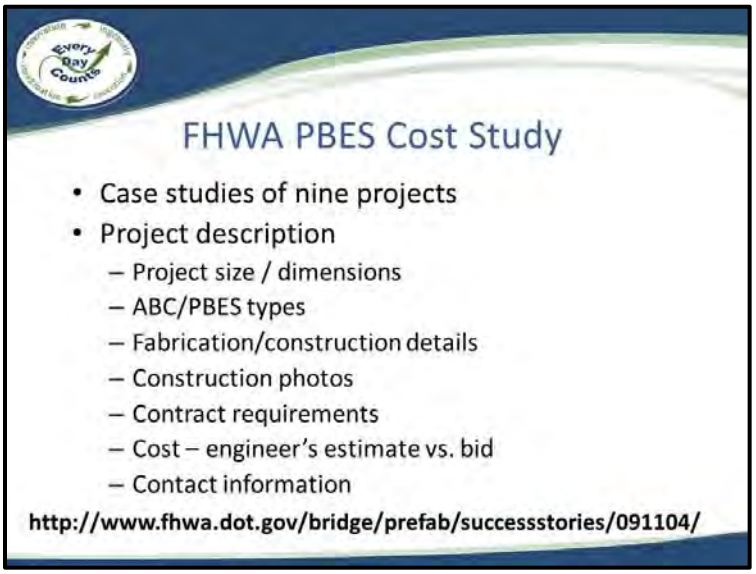


Slide 18:

Another resource is the Connection Details Manual. It includes connection details used across the US. Sample construction specifications and case studies are also included. A module will be presented on this manual.

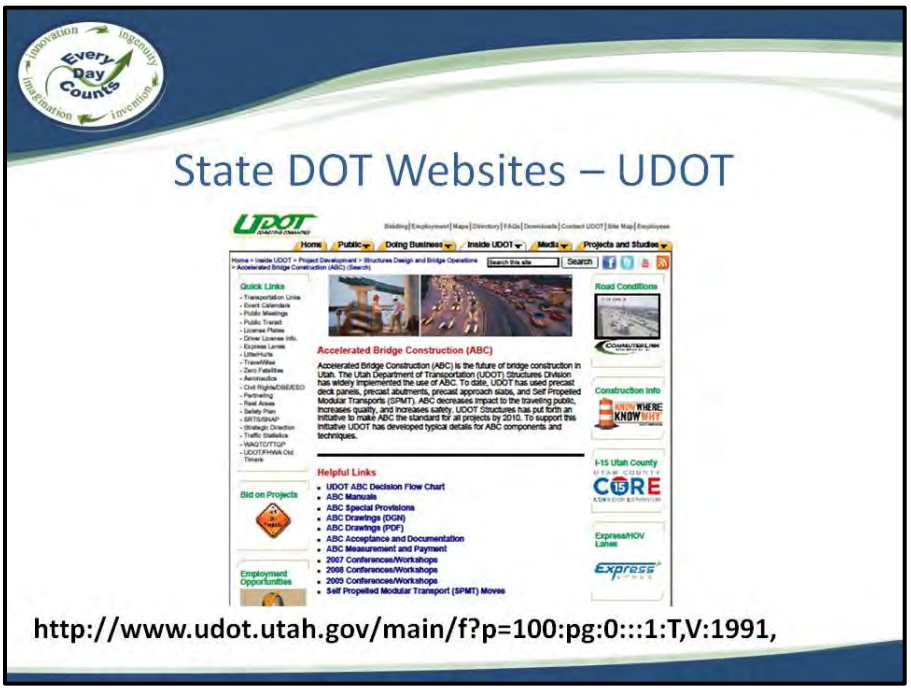
Slide 19:

Another resource is the 2006 FHWA PBES Cost Study that was discussed in the previous module.



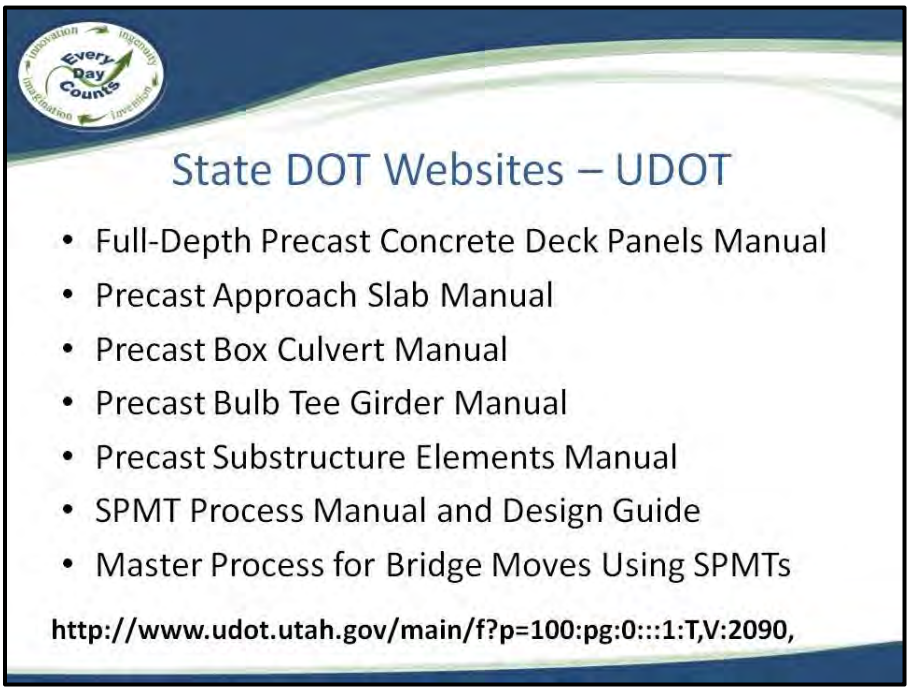
Slide 20:

In addition to a discussion of the costs for each of the nine case studies, a project description includes project size and dimensions, ABC/PBES types, fabrication and construction details, construction photos, contracting strategies, and contact information.



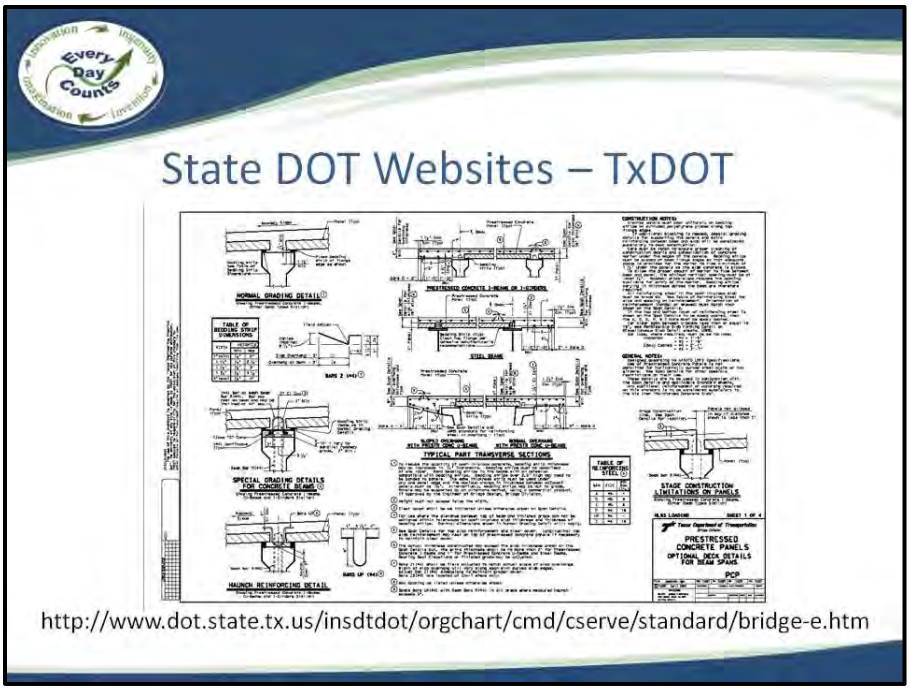
Slide 21

State DOT bridge websites are another resource for PBES specifications, contract drawings, and details. Shown here is the Utah DOT's ABC home page. As you can see, a number of resources are available for download.



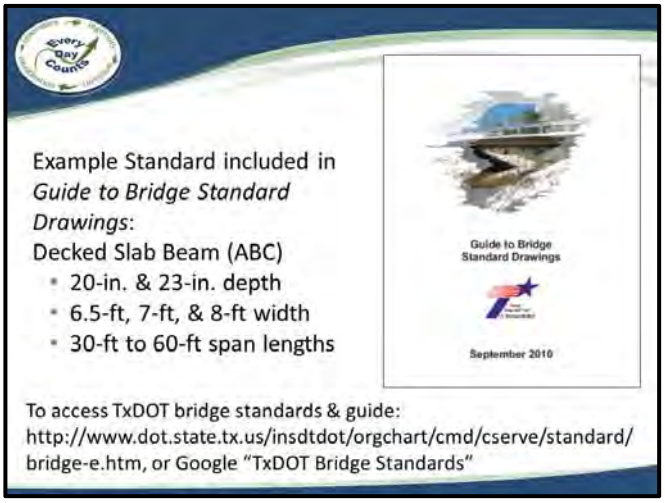
Slide 22:

For example, included are ABC manuals on full-depth precast concrete deck panels, precast approach slabs, precast box culverts, precast bulb tee girders, precast substructure elements, and SPMT bridge moves.



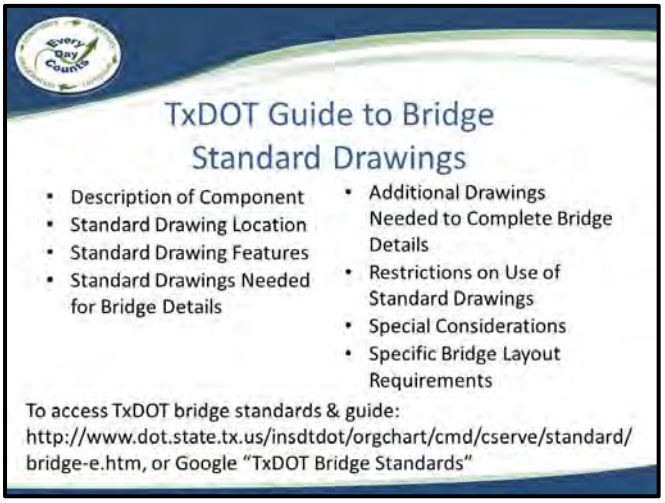
Slide 23:

The Texas DOT also has an extensive bridge website. Shown here is a contract drawing for the Texas partial-depth precast concrete deck panels downloaded from the TxDOT bridge standards website.
A number of other state DOTs have similar websites.



Slide 24:

Also available for download from the TxDOT bridge standards website is their *Guide to Bridge Standard Drawings*. It provides guidance for several of TxDOT's bridge standards, including the decked slab beam that they consider one of their ABC standards.



Slide 25:

The TxDOT *Guide to Bridge Standard Drawings* includes a description of a number of its standard bridge types and for each provides guidance such as the website location that the standard can be found, features of the standard, and drawings that need to be included for a bridge project.

Slide 26:

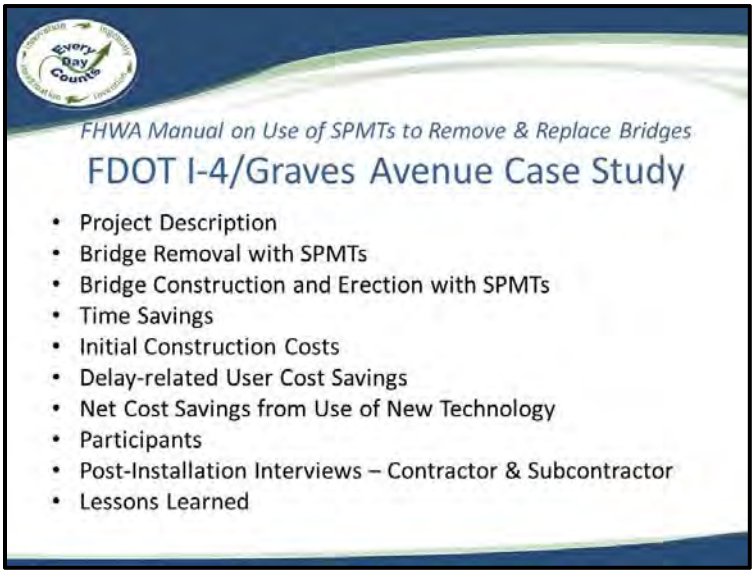
The 2007 FHWA *Manual on Use of Self-Propelled Modular Transporters to Remove and Replace Bridges* is another ABC/PBES resource. It is available for download electronically at the FHWA prefabricated bridges website, or in print from the FHWA Office of Bridge Technology.

Slide 27:

The manual includes 15 appendices with various example specifications, contract drawings, details, and other information.

Slide 28:

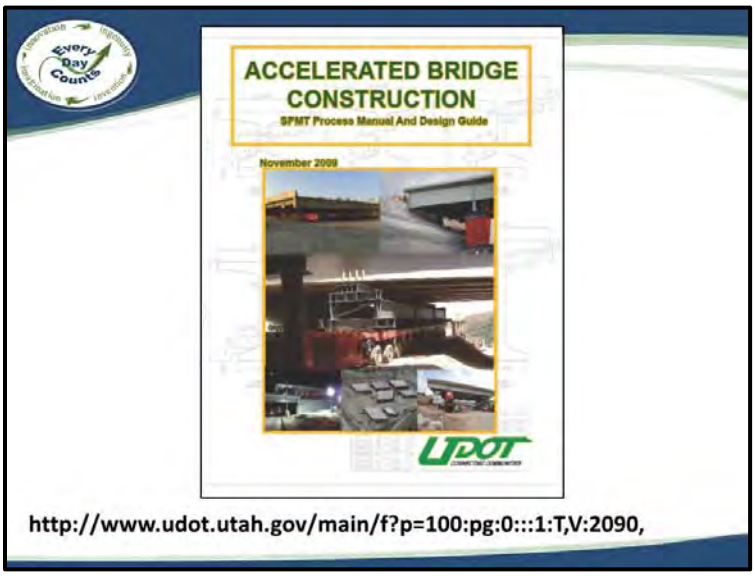
These examples are intended to serve as a starting point for new projects.



Slide 29:

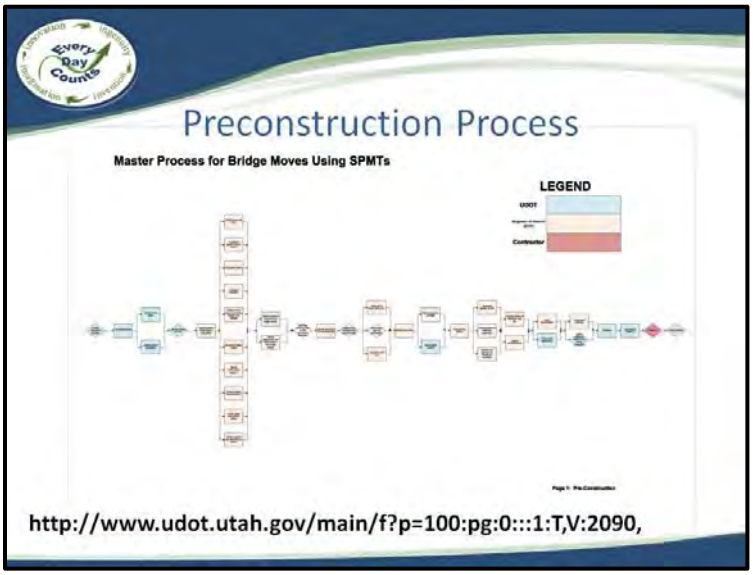
The manual also has an extensive case study of the 2006 FDOT I-4 / Graves Avenue bridge project. It provides a project description, details on the removal of the existing bridge and construction of the new bridge in the staging area, erection of the new bridge with SPMTs, and the onsite construction time savings.

The case study also discusses construction costs, delay-related user cost savings, and the net cost savings from use of SPMTs. It also includes post-installation contractor and sub-contractor interviews and lessons learned.



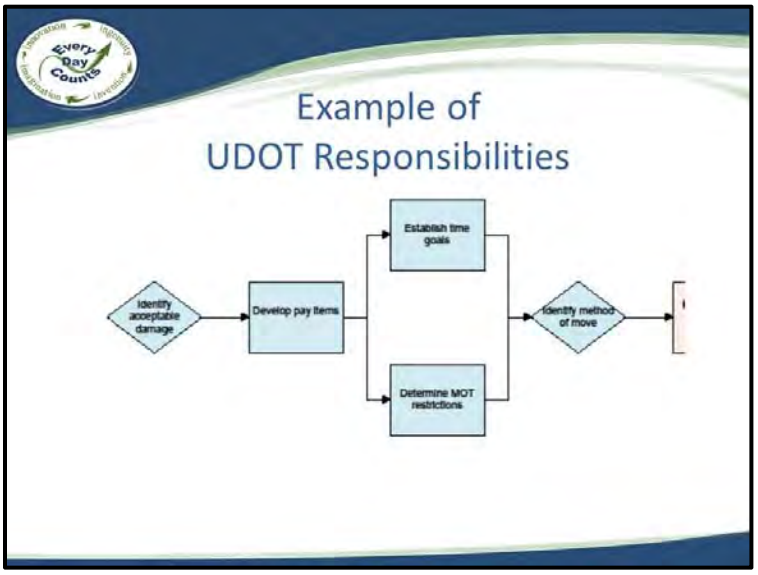
Slide 30:

The Utah DOT has developed a more detailed manual on the use of SPMTs to move bridges. The *Accelerated Bridge Construction SPMT Process Manual and Design Guide* can be downloaded from the UDOT website.



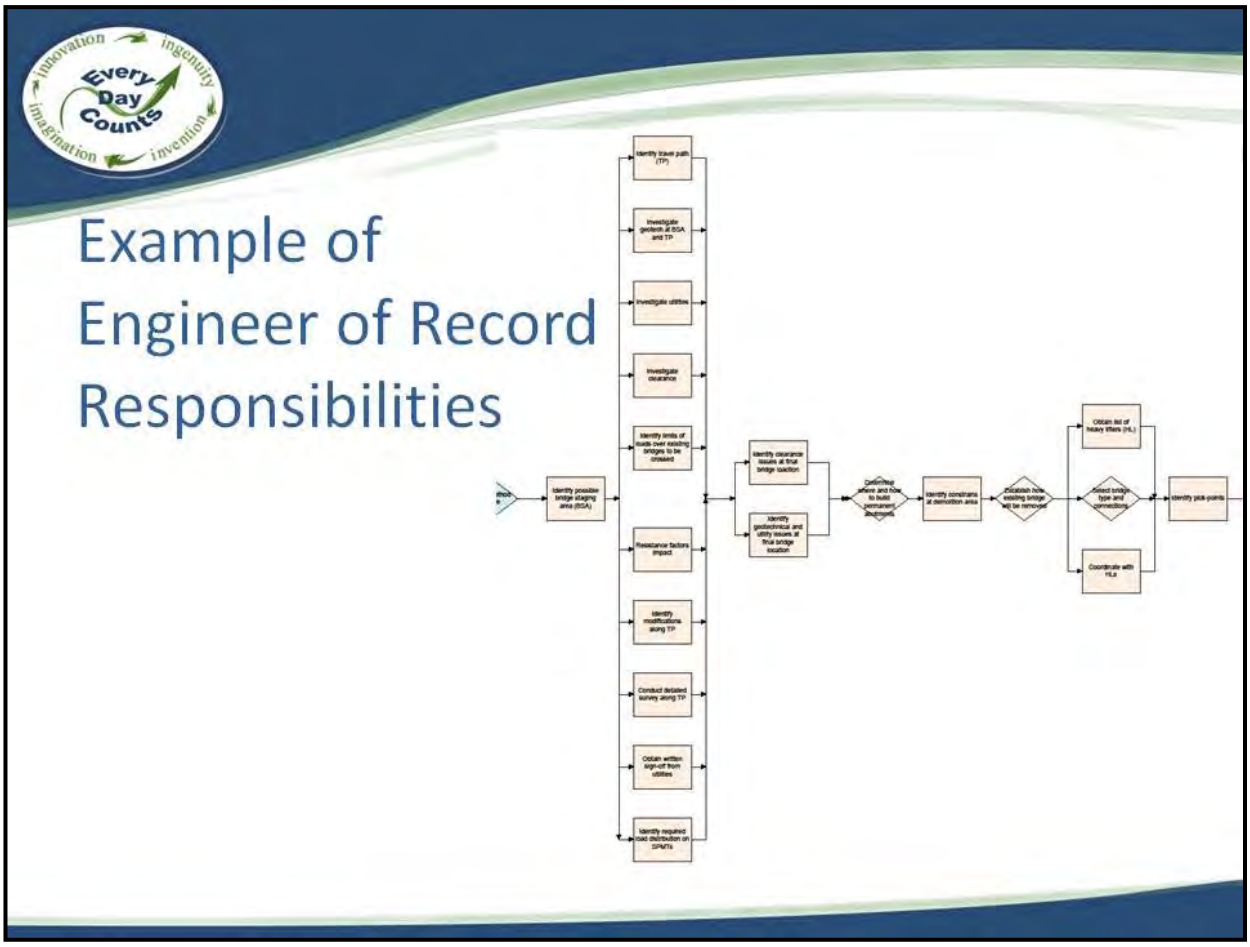
Slide 31:

Also available from the UDOT website to assist an owner with SPMT bridge moves is a pre-construction process flowchart that defines the responsibilities of the owner, contractor, and engineer of record.

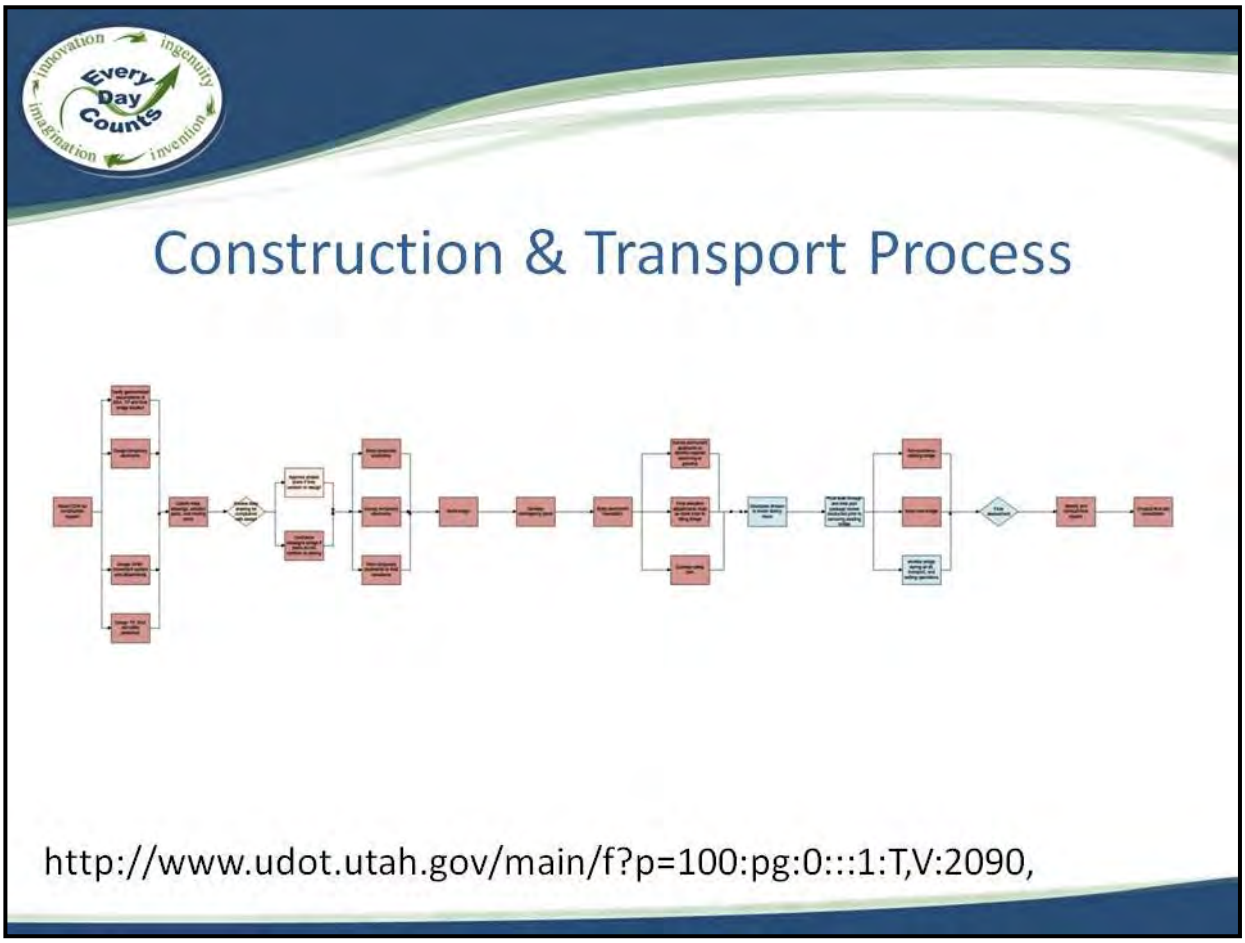


Slide 32:

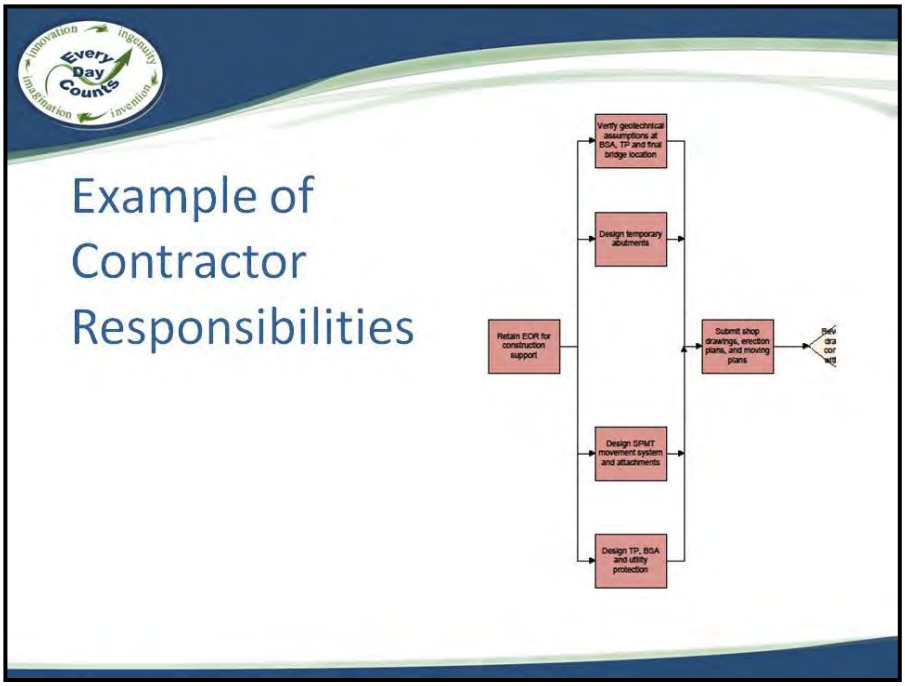
This is an enlargement of the previous flowchart to show some of UDOT's responsibilities.



Slide 33: This enlargement shows some of the Engineer of Record responsibilities.



Slide 34: Another flowchart in the manual shows the construction and transport process.



Slide 35:

This enlargement shows some of the contractor's responsibilities related to construction and transport.

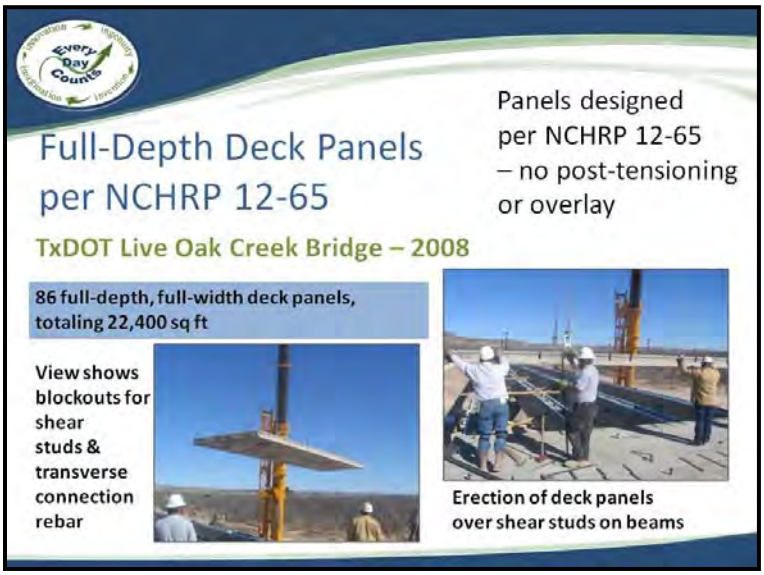
Slide 36:

The National Cooperative Highway Research Program (NCHRP) domestic scan program sponsored a scan on best practices in accelerated construction techniques. The 2009 final report on that scan can be downloaded from the TRB website.

No.	Title	Status
12-65	Full-Depth, Precast-Concrete Bridge Deck Panel Systems	Report 584
12-69	Design and Construction Guidelines for Long-Span Decked Precast, Prestressed Concrete Girder Bridges	Final Report on web
12-74	Development of a Precast Bent Cap System for Seismic Regions	Report 681
10-71	Cast-in-Place Concrete Connections for Precast Deck Systems	Web-Only Document 173

Slide 37:

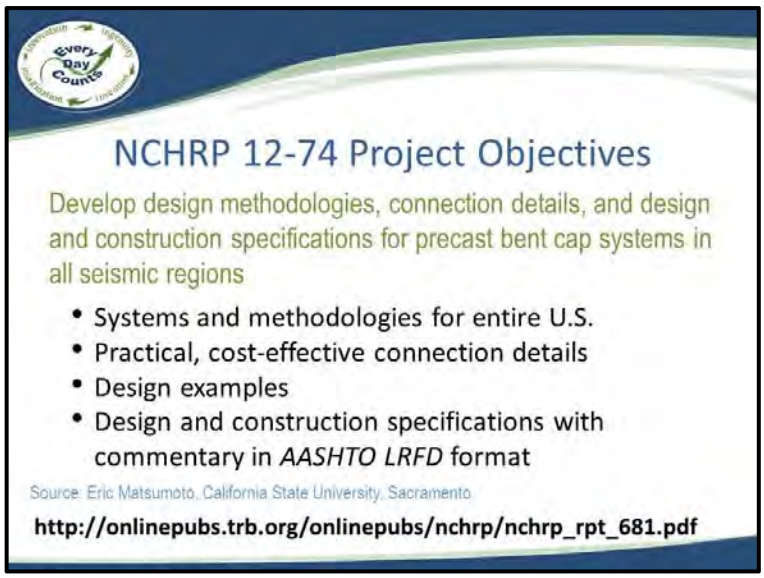
NCHRP has a number of recently completed or ongoing research projects related to ABC. Those include topics related to full-depth deck panels, long-span decked precast prestressed concrete girder bridges, precast bent cap connections for seismic regions, and connection details for full-depth precast concrete bridge decks. Each of these research projects includes design details and proposed design and construction specification language for consideration by the AASHTO Subcommittee on Bridges and Structures.



Slide 38:

Bridge owners use the details developed in the research projects.

As shown here, the Texas DOT built a bridge deck using the details from NCHRP 12-65.

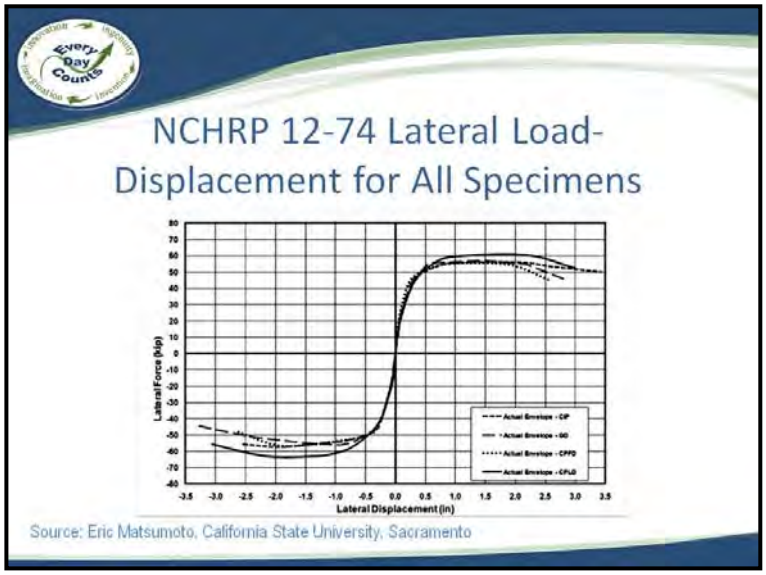


Slide 39:

NCHRP 12-74 is a recently completed research project that developed precast cap-to-column connection details. The final report includes design examples and proposed design and construction specification language with commentary in AASHTO LRFD format, for consideration by the AASHTO Subcommittee on Bridges and Structures to include in the LRFD design and construction specifications.

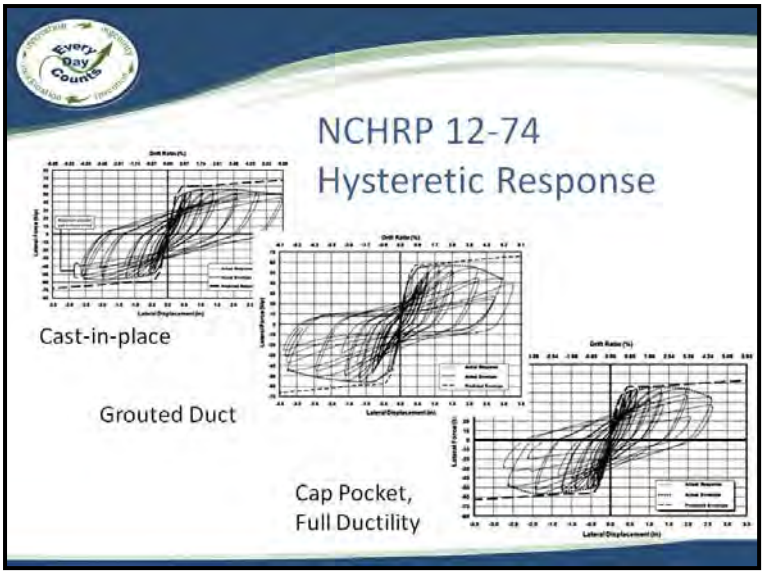
Slide 40:

The research project developed details for both a grouted duct connection and a cap pocket connection. These were selected because they were the most commonly used connections for precast caps as identified in the project's literature search.



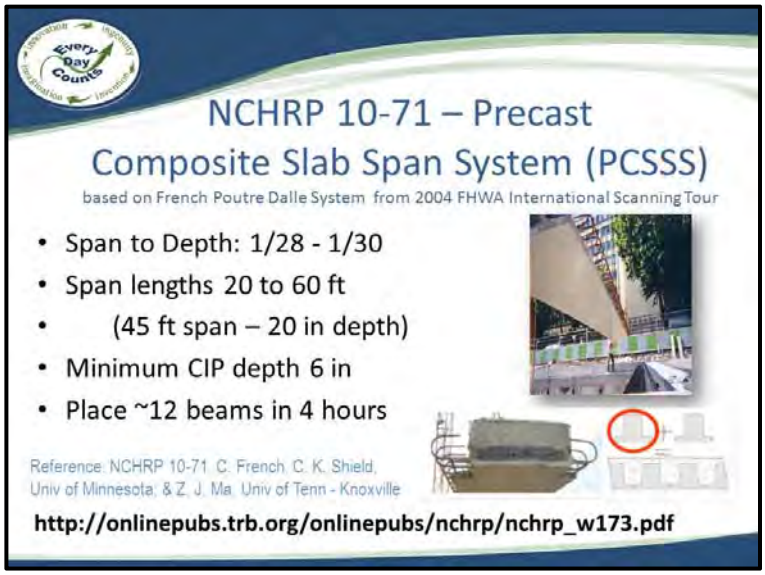
Slide 41:

The research tests showed excellent lateral load-displacement behavior, comparable to a conventional cast-in-place cap-to-column connection.



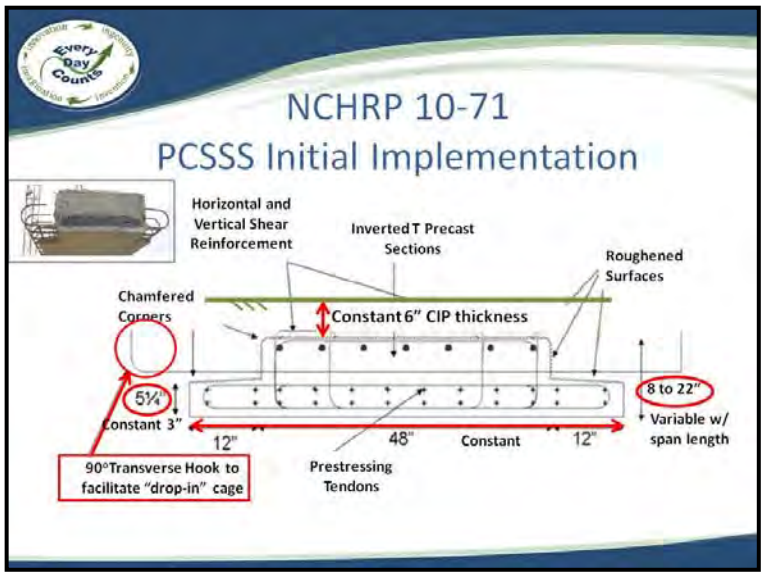
Slide 42:

The hysteretic response under seismic loading was also comparable to conventional cast-in-place construction.



Slide 43:

NCHRP 10-71 is an ongoing research project that is developing connection details for the precast composite slab span system that is based on the Poutre Dalle system seen in France on the 2004 prefabricated bridges international scan.

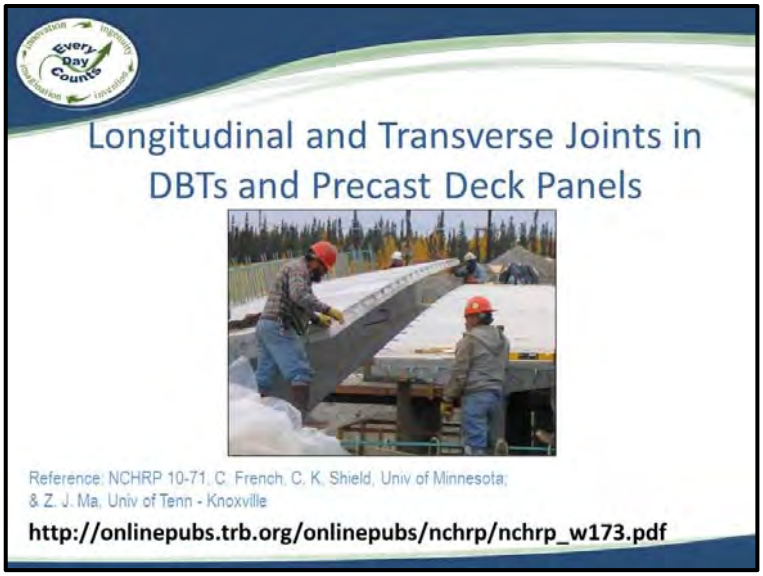


Slide 44:

The research team evaluated various reinforcement patterns and other details in their development of connection details that perform well.

Slide 45:

These are construction photos of a bridge in Iowa that was constructed with the details developed in the research project.



Slide 46:

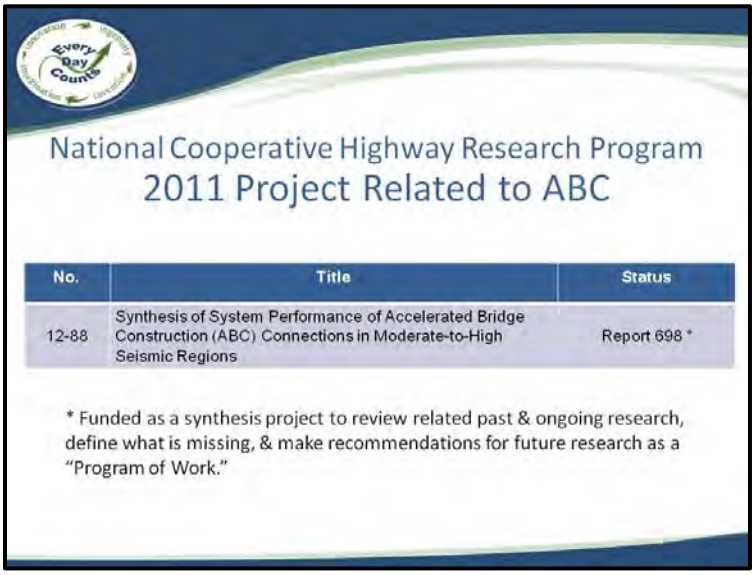
Also being developed in the NCHRP 10-71 project are connection details for longitudinal and transverse joints between decked bulb tees and between precast deck panels.

Slide 47:

In addition, closure pour materials for the joints were evaluated. Closure pour materials for a 7-day cure and an overnight cure were subjected to various durability tests to ensure good long-term performance.

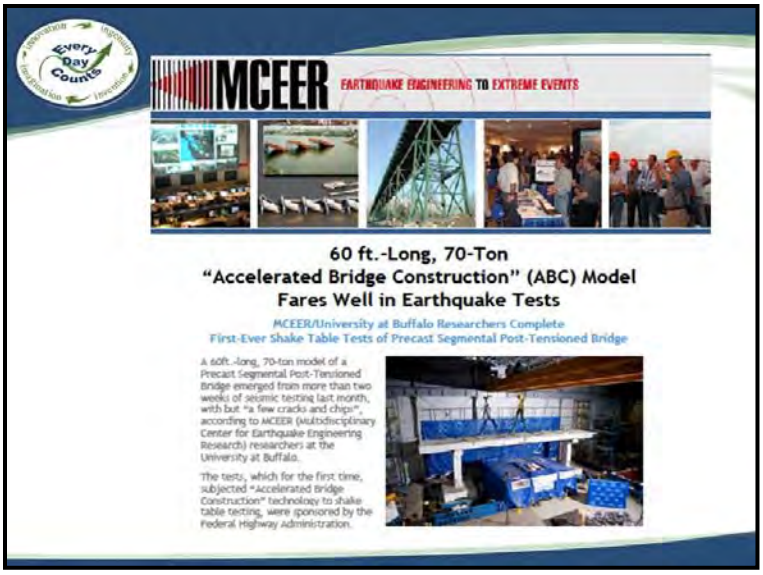
Slide 48:

NCHRP also has several research projects that facilitate the use of ABC. Three relatively recent projects included evaluation of self-consolidating concrete for precast elements, evaluation and repair procedures for precast prestressed concrete girders with longitudinal cracking in the web, and LRFD design specifications for shallow foundations. An ongoing research project is evaluating the use of high-strength, high-performance lightweight concrete for bridge girders and decks.



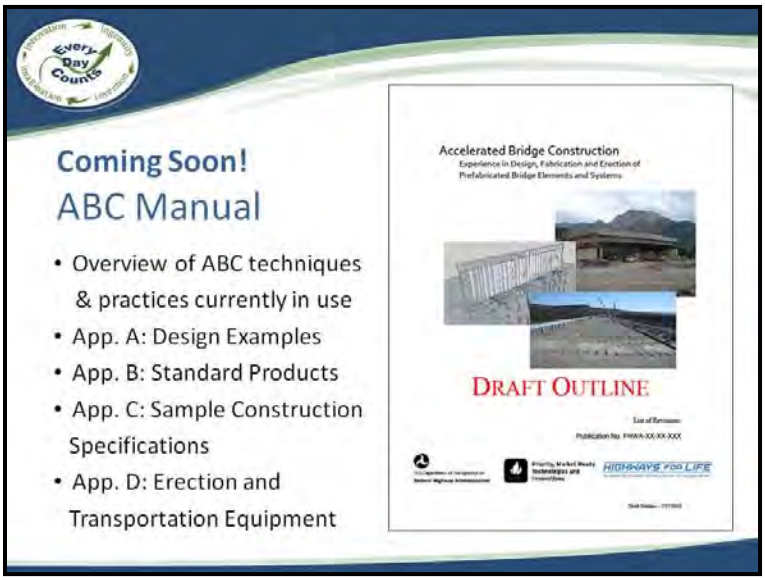
Slide 49:

An upcoming research project that has been funded as a synthesis project will determine additional ABC connection details that need to be tested for use in moderate-to-high seismic regions.



Slide 50:

The extreme events research facility MCEER at the University of Buffalo recently conducted the first-ever shake table test of a precast segmental post-tensioned bridge. The FHWA-sponsored tests proved adequate system performance under seismic loading.



Slide 51:

A resource that will be available in 2011 is the FHWA-sponsored ABC Manual. This manual will provide an overview of ABC techniques and practices currently in use around the country. Appendices will include design examples and sample construction specifications.

Slide 52:

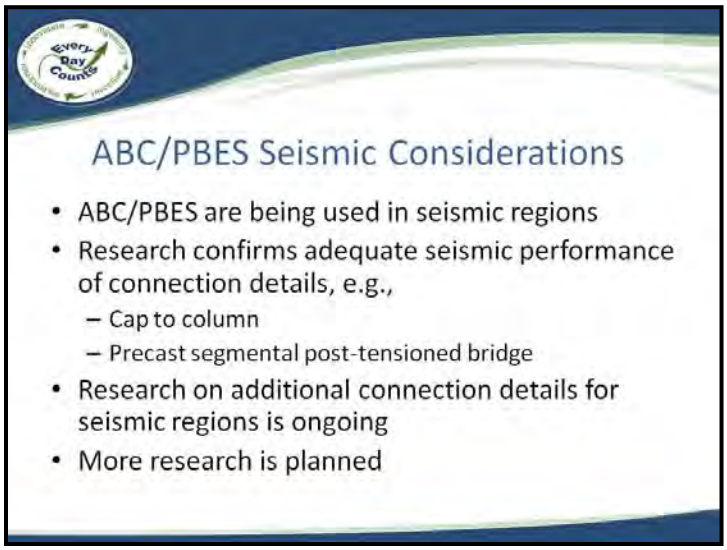
A resource that will also be available in 2011 is the Strategic Highway Research Program 2 (SHRP2) final report for Research Project R04, “Innovative Bridge Designs for Rapid Renewal.” The project’s objective is to develop standardized approaches to designing, constructing, and reusing (including future widening) complete bridge systems that address rapid renewal needs and efficiently integrate modern construction equipment.

Slide 53:

One would expect that economy could be achieved by developing national ABC/PBES shapes. However, a number of issues should be considered. First, many state DOTs have developed their own ABC/PBES shapes and their construction industries have geared their operations to build bridges with those shapes. Similarly, prefabrication plants have bought forms for those shapes, and local contractors have developed their processes to use them.

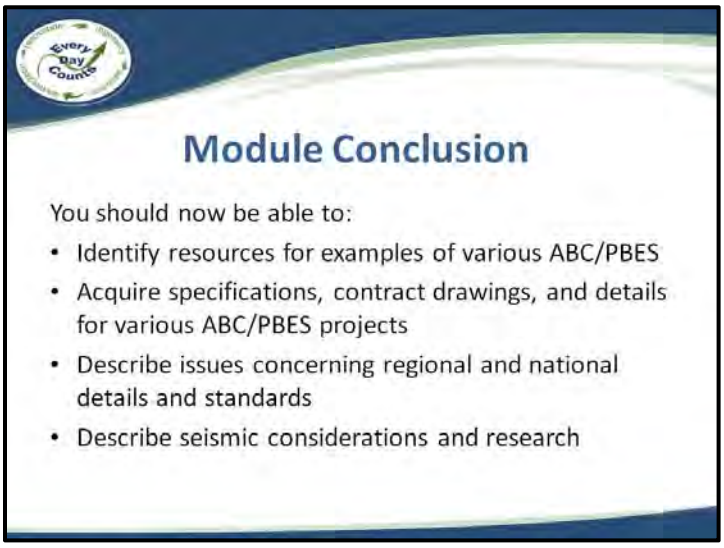
Slide 54:

Also, there are initiatives at the county level to use specific shapes. For over 40 years counties in Alabama have been using precast bridge superstructure and substructure standards developed by the Alabama DOT for its low-volume roads. Regional initiatives include the PCINE Technical Committee's development of the Northeast Extreme Tee (NEXT) beam, which is now being used by several northeastern States. Also, PCI has created a team to develop standards for spliced U-beams and curved U-beams for use in southeastern States.



Slide 55:

Seismic issues should also be considered for ABC/PBES projects. ABC/PBES details are being used in seismic regions. Research now confirms the adequate seismic performance of some ABC/PBES connection details, for example, cap-to-column details and total bridge system details as discussed earlier in this module. Research on additional connection details for seismic regions is ongoing, and more research is planned.



Slide 56:

Participants should now be able to:

- Identify resources for examples of various ABC/PBES
- Acquire specifications, contract drawings, and details for various ABC/PBES projects
- Describe issues concerning regional and national details and standards
- Describe seismic considerations and research

Slide 57:

Thank you for your attention. Questions?

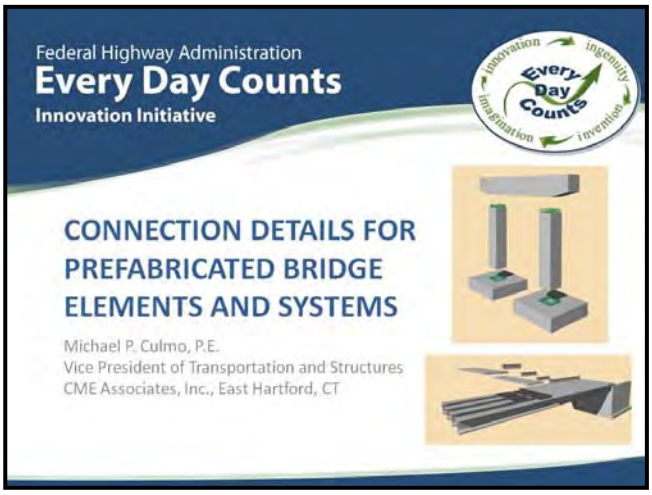
Module 6: CONNECTION DETAILS and PBES DESIGN EXAMPLE

MODULE LEARNING OUTCOMES

After completing this Module, you will be able to:

- identify resources for examples of various ABC/PBES projects
- acquire specifications, plans, and details for various completed ABC/PBES projects
- describe issues concerning regional versus national details/standards
- describe seismic considerations and research

MODULE SLIDES & NOTES



Slide 1:

Introduction

The Federal Highway Administration (FHWA) has undertaken a program called Highways for LIFE. The word "LIFE" in this program title is an acronym for:

L = Long lasting
I = Innovative
F = Fast construction
E = Efficient and safe

The thrust of this program is to change the way we design and build our highways. A former Deputy Secretary for the US Department of Transportation put it best when he stated:

"Change the way we build highways. We need to build them faster, have them last longer, have them be safer and at a lesser cost. Be BOLD and AUDACIOUS in your thinking."

The Highways for LIFE program motto is: "Get In, Get Out, and Stay Out". The first two portions of the motto are self-explanatory. The "Stay Out" portion refers to the inherent lasting quality of prefabricated components that are produced in the controlled environment of a fabrication site. Just because something can get built fast does not mean that we need to sacrifice quality. In fact, the exact opposite is true. We can build highways faster and better.

The focus of this Manual is on connections used in prefabricated bridge construction. Prefabrication is not a new concept. The vast majority of bridges built today employ some form of prefabrication. Steel and pretensioned concrete beams are two of the most common prefabricated components. Using prefabrication, large portions of the structure are manufactured off site before construction begins. There are many benefits to the use of prefabricated components; however, this Manual will focus on prefabrication as a means of accelerating bridge construction.

Numerous agencies have experimented with rapid construction techniques when bridges needed to be constructed quickly. There have been many successes, and a few failures. The next logical step in the evolution of this process is to make accelerated construction more commonplace and effective.

This type of evolution is not unprecedented. Forty years ago, parking garage structures were constructed primarily with cast-in-place concrete (either all concrete or concrete on steel framing). Today, in most parts of the country, total precast concrete parking structures are the norm and construction times for these structures have been dramatically reduced as a result. The fact that structures using prefabricated elements and systems are common in a competitive construction market also indicates the economies of this type of construction.

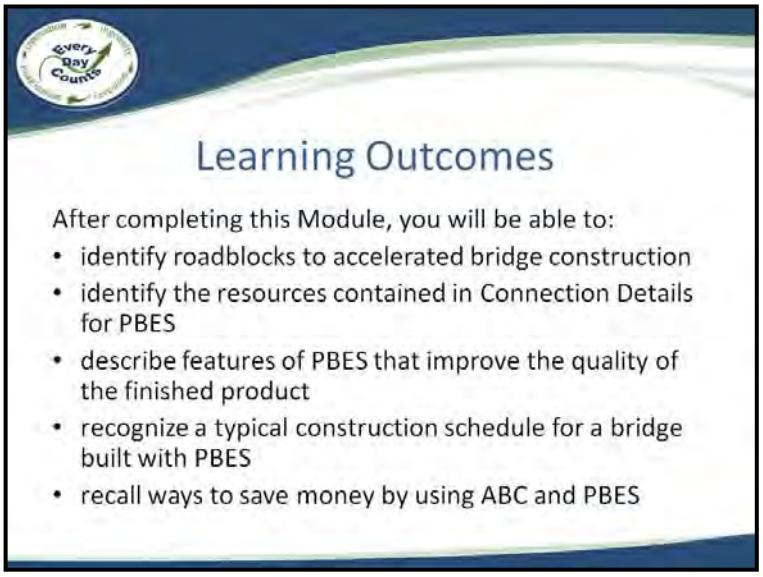
Accelerated Construction Technology Transfer Program (ACTT) The FHWA has sponsored numerous three-day workshops under their Accelerated Construction Technology Transfer Program (ACTT). During each workshop, a team of national experts visited a state highway agency to brainstorm on a particular project proposed for accelerated construction techniques. Each workshop provided the state agency with a wealth of information to be used as the building blocks for a successful accelerated construction project. During these workshops, the following were identified as common needs for successfully implementing accelerated bridge construction:

- Quality details
- Long-term performance and durability
- Design methodologies and training
- Construction methodologies

Slide 2:

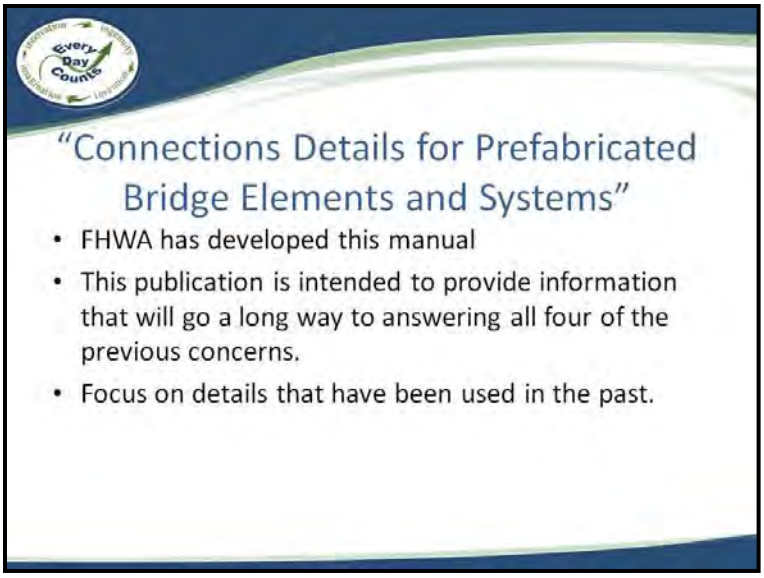
After completing this Module, you will be able to:

- identify roadblocks to accelerated bridge construction
- identify the resources contained in *Connection Details for PBES*
- describe features of PBES that improve the quality of the finished product
- recognize a typical construction schedule for a bridge built with PBES
- recall ways to save money by using PBES



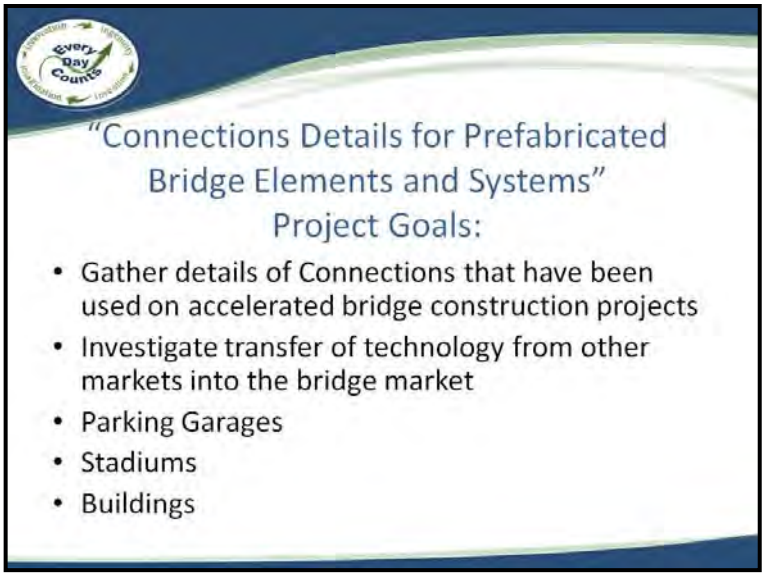
Slide 3:

FHWA has polled transportation agencies in the past to determine the roadblocks to using ABC. The responses are as shown.



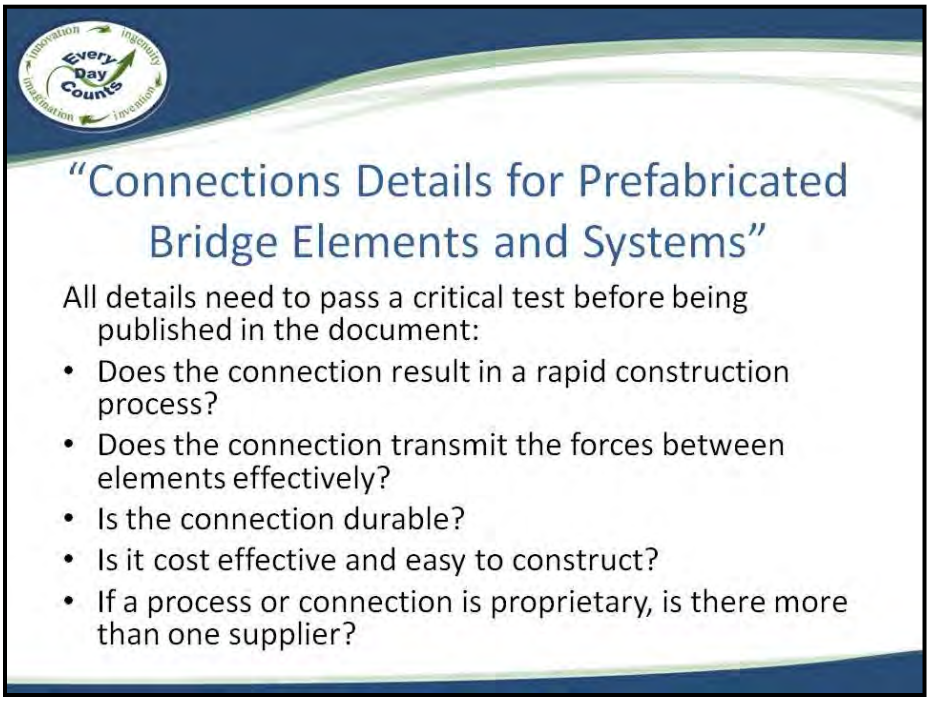
Slide 4:

In response to the concerns from agencies, FHWA developed a manual that focused on connection details that have been successfully used in the past.

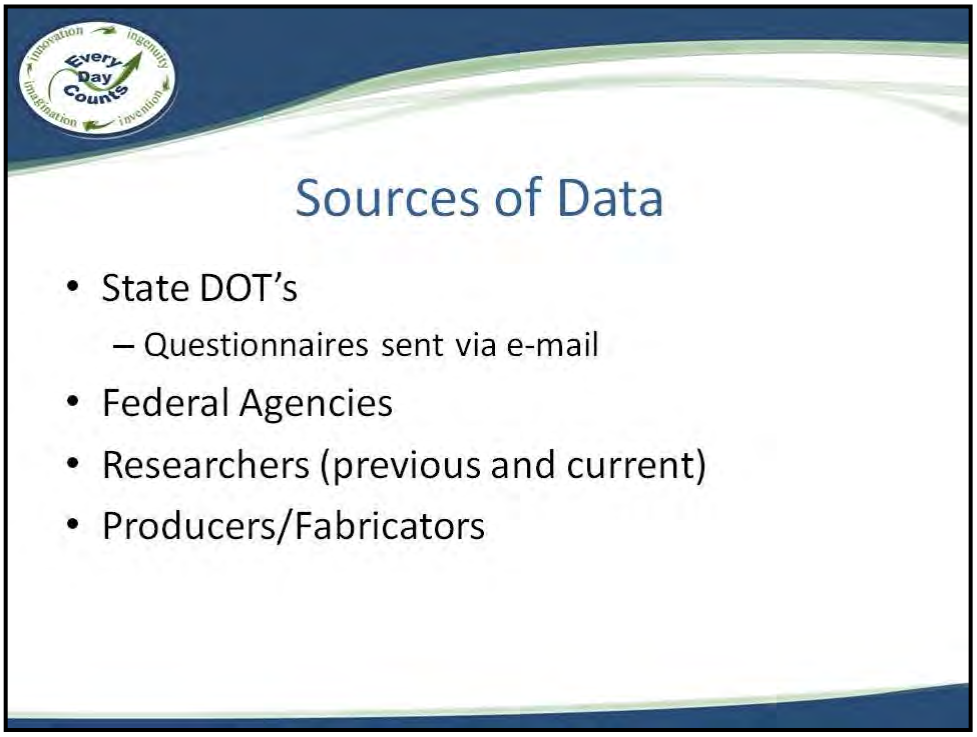


Slide 5:

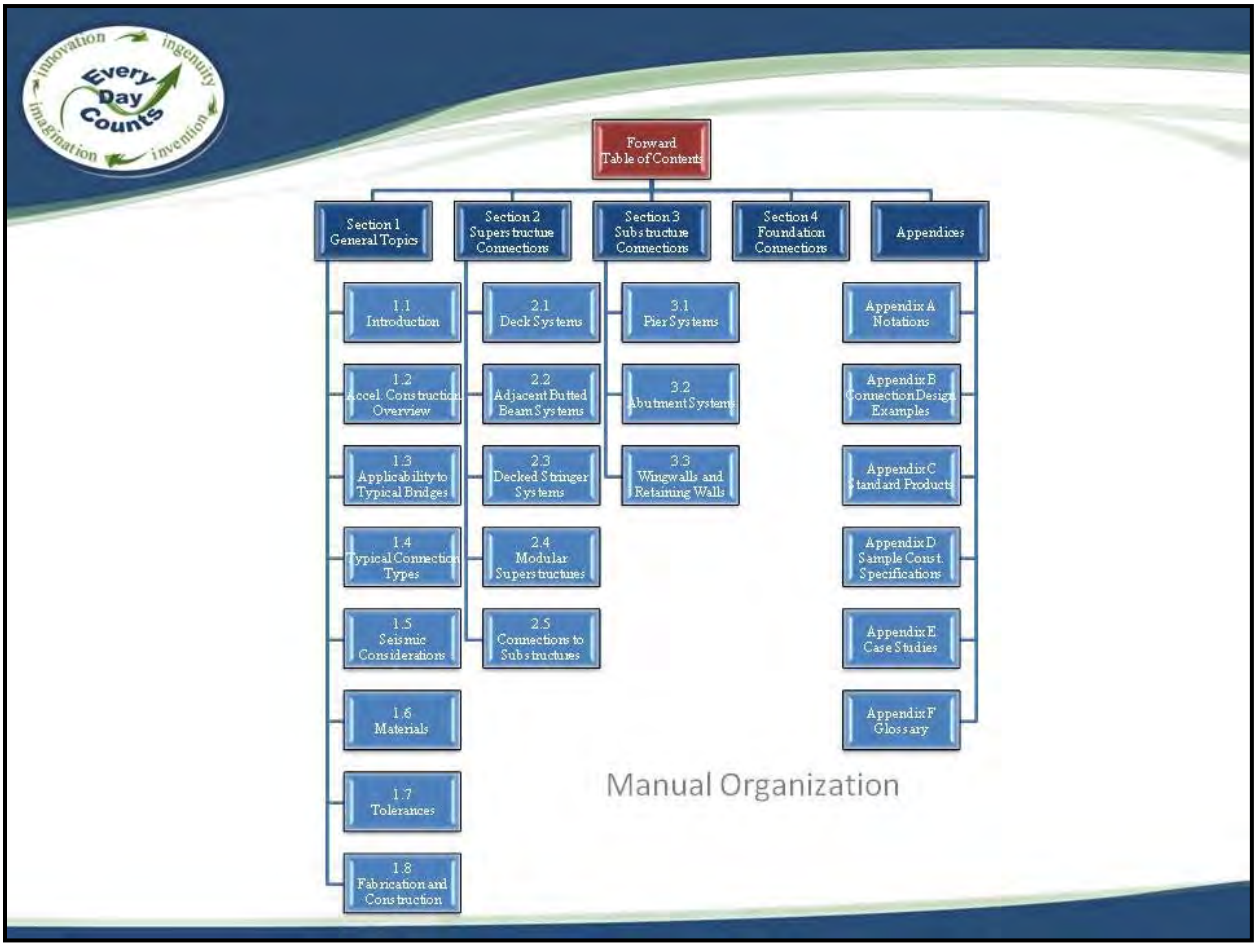
The details were gathered from transportation agencies and other industries, which turned out to be a key component of the work. Accelerated construction is also used in vertical construction. Many of the details used in this industry are transferable to bridge construction.



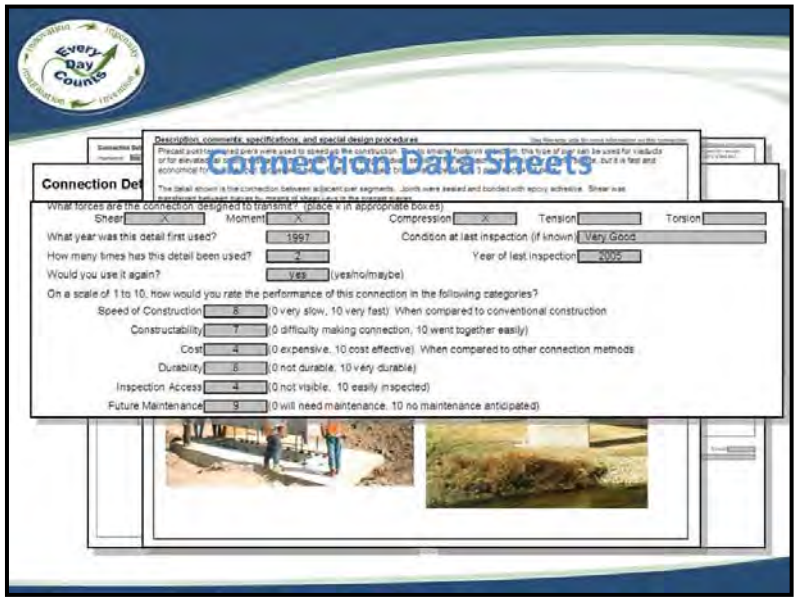
Slide 6: It is imperative that all detail pass these critical test in order to ensure proper performance and a 75 year service life.



Slide 7: The connection details were gathered from the following sources.



Slide 8: The manual is organized so that users can easily find details. The sections are divided by parts of the bridge that are defined in AASHTO. Superstructure, Substructure and Foundations.

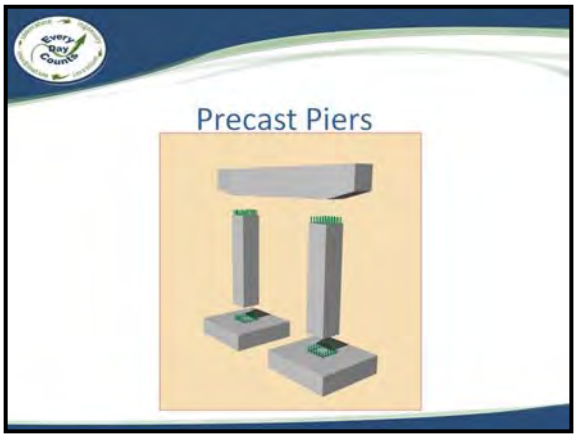


Slide 9:

Detail data sheets were developed that are similar to materials cut sheets. Users can gather enough information to complete a structure type study. Contact information and detail performance are included. Users can contact the agency that submitted the details and find out more information as their project proceeds.

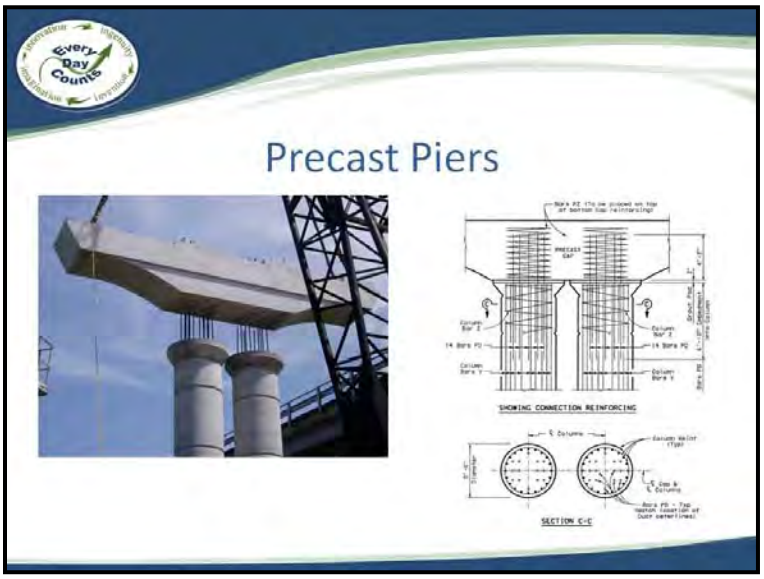
Slide 10:
Samples of details included in the manual:
Precast cantilever abutment connections

Slide 11:
Samples of details included in the Manual:
Precast integral abutment connections



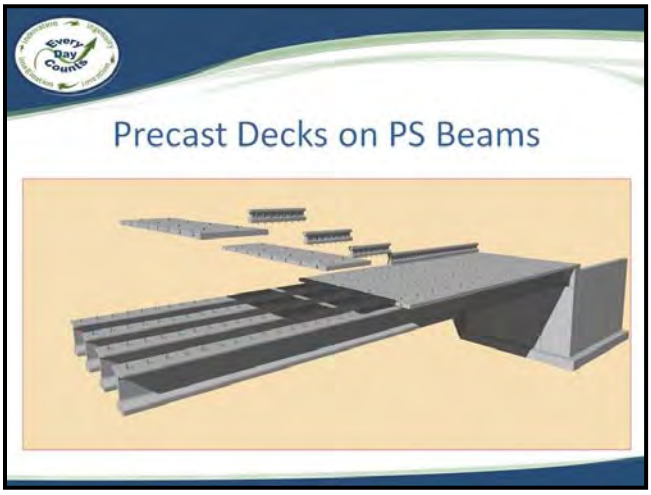
Slide 12:

Samples of details included in the manual: Precast pier bent connections



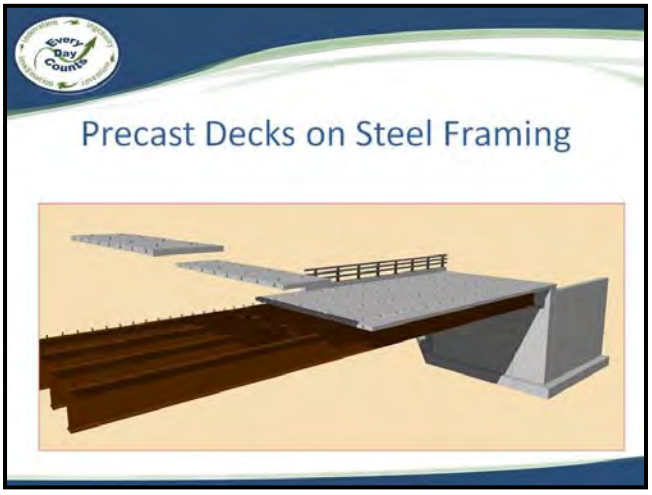
Slide 13:

Samples of details included in the manual: Precast pier cap connections



Slide 14:

Samples of details included in the manual:
Precast deck connections on concrete beams

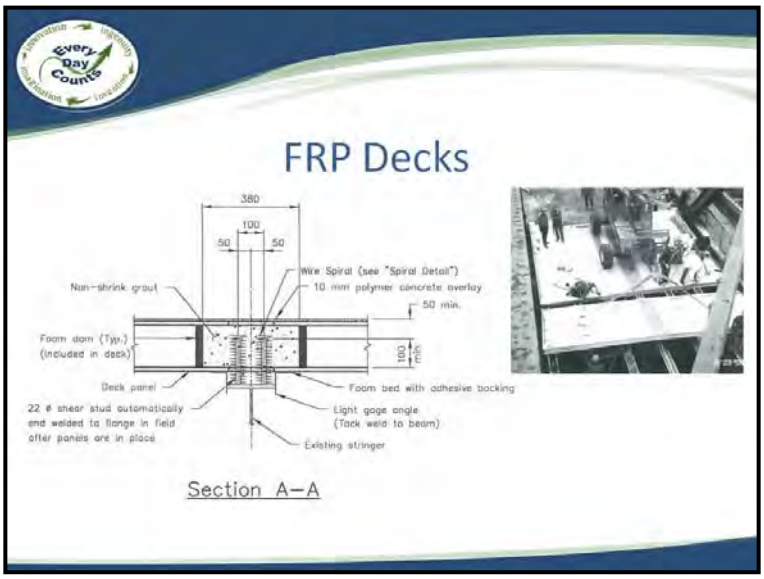


Slide 15:

Samples of details included in the manual:
Precast deck connections on steel beams

Slide 16:

Samples of details included in the manual: Precast deck connections on steel beams

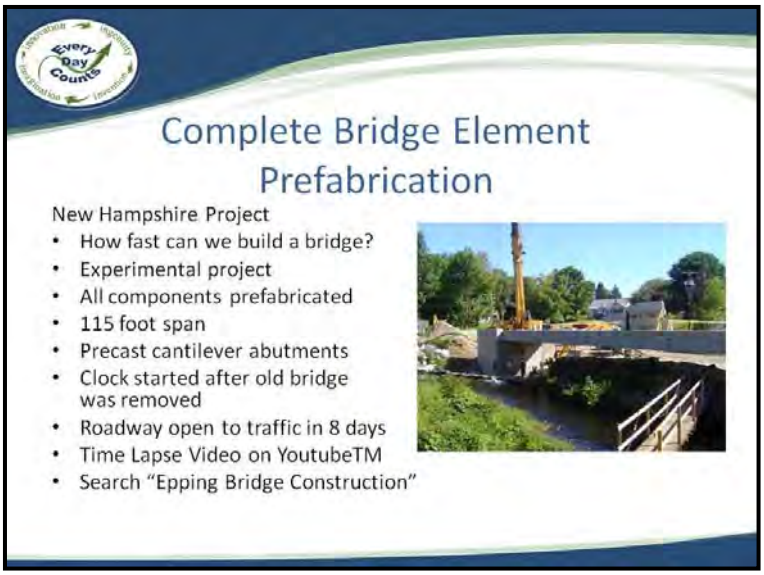


Slide 17:

Samples of details included in the manual: FRP deck connections on steel beams

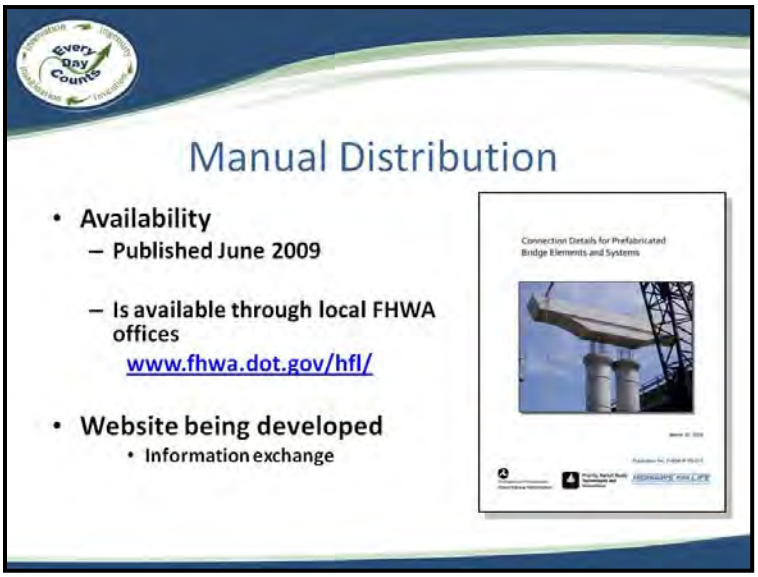
Slide 18:

Everything shown in this graphic can be prefabricated and connected



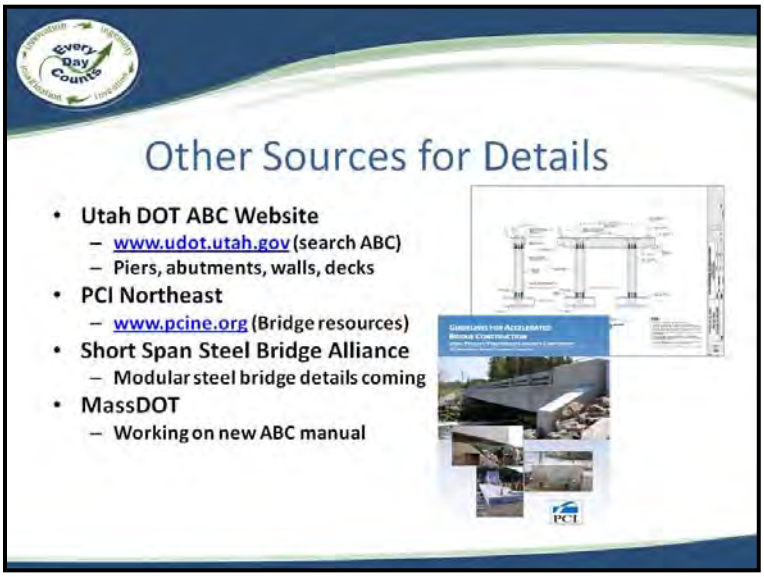
Slide 19:

This is an example of a totally prefabricated bridge in Epping, NH. All details used in this project are included in the manual.



Slide 20:

The manual is complete and available for use. A web-site is under development that will include the details in the manual. Other details will be added to the website as they become available.



Slide 21:

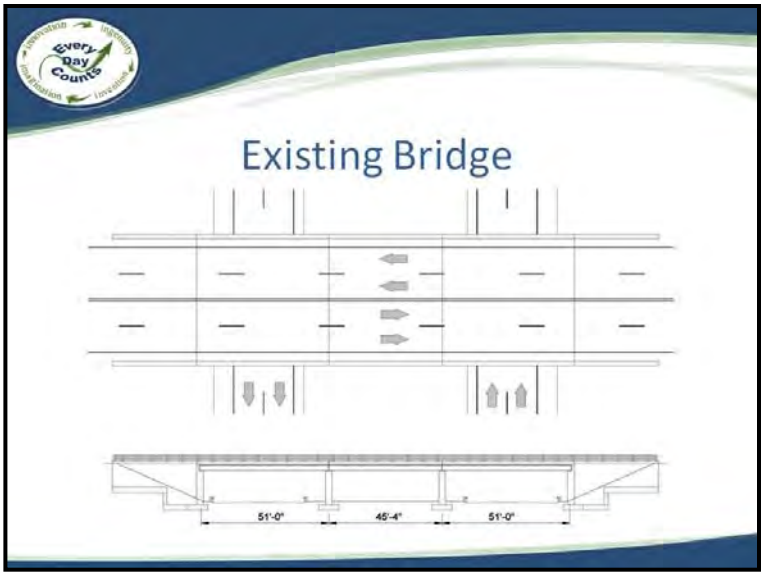
There are other sources of details for ABC connections.

Slide 22:

This is an example of how to use the FHWA manual to prepare a structure type study for an ABC project.

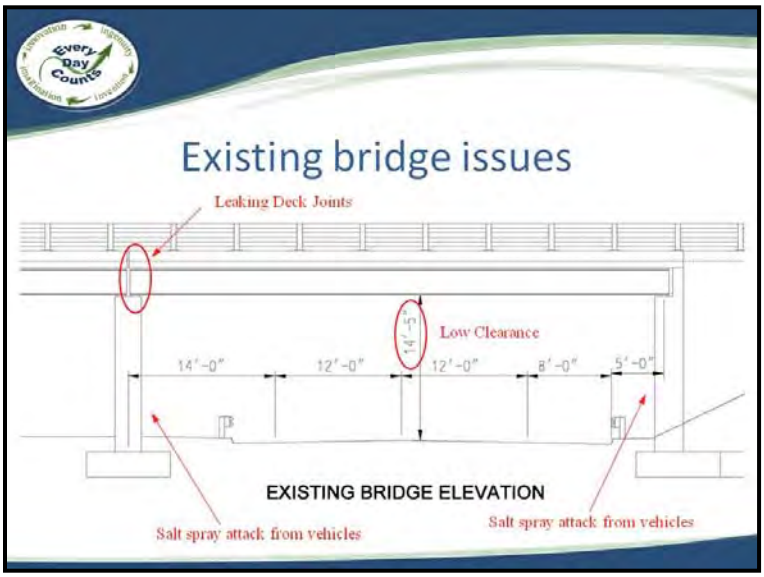
Slide 23:

This hypothetical bridge was chose to represent typical deficient highway overpasses throughout the country.



Slide 24:

The existing bridge layout is as shown.

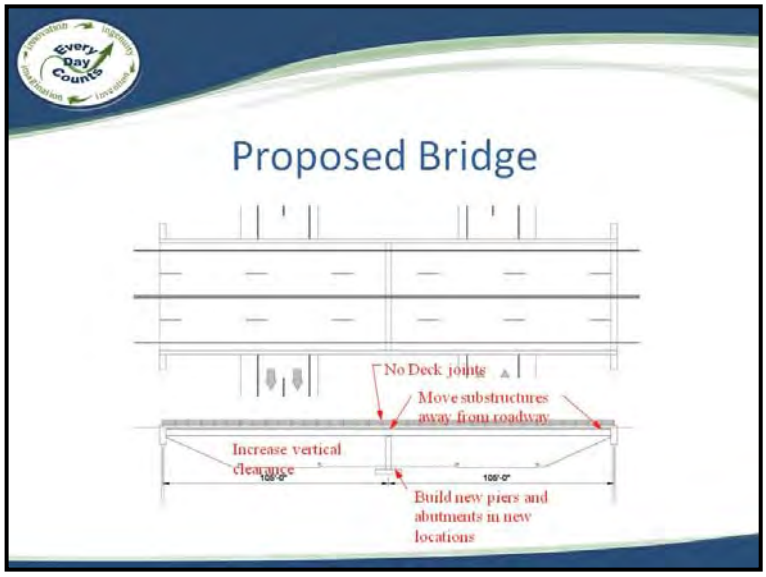


Slide 25:

Major issues include deterioration of substructures caused by leaking joints and spray attack from passing vehicles. The clearance is also substandard.

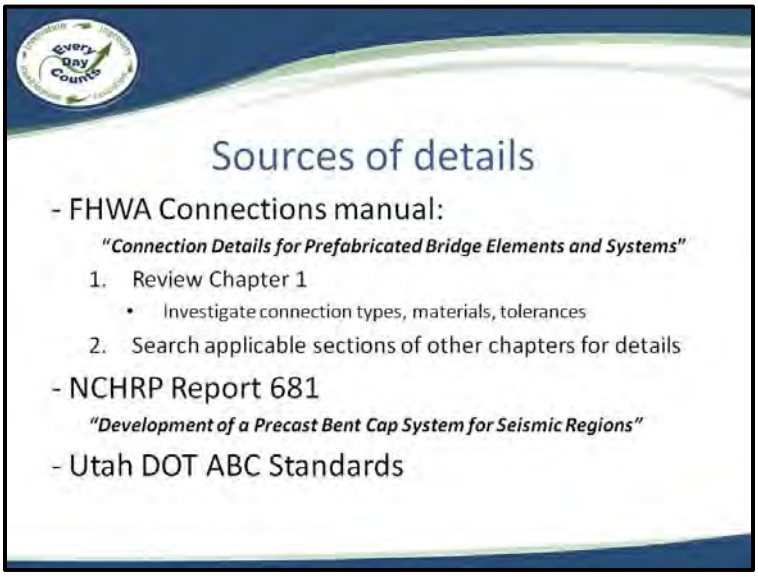
Slide 26:

The proposed bridge is a conventional composite stringer bridge with the following criteria.



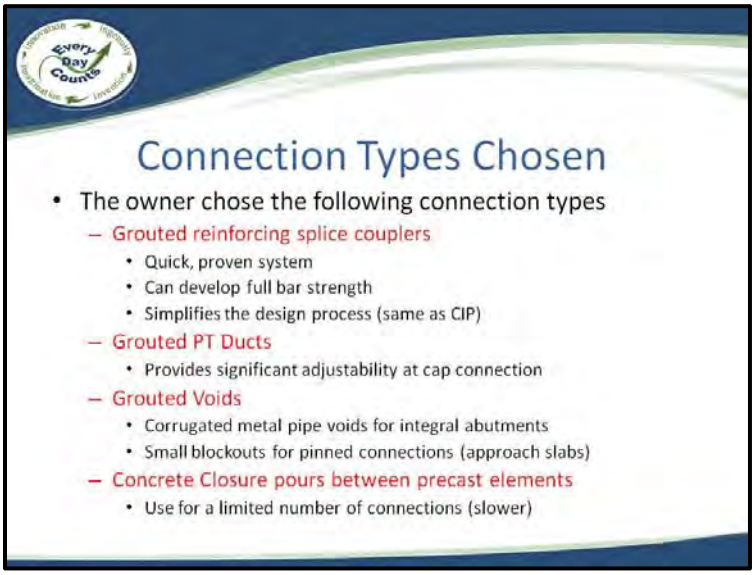
Slide 27:

The layout was chosen to improve the geometry of the roadway under the bridge and eliminate the problems at the site. The new substructures are located at different location to facilitate construction. The new substructures can be built at the same time the existing substructures are demolished, thus saving time.



Slide 28:

Before the connections are chosen from the manual, designers should review chapter 1 to become familiar with ABC concepts.



Slide 29:

The designer, in this case, chose three different types of connections for the bridge.

Slide 30:

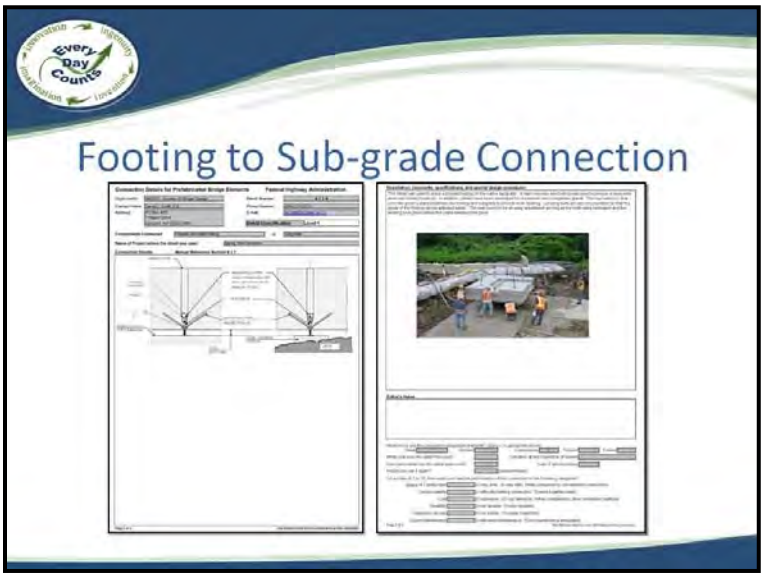
Grouted reinforcing splice couplers are an example of a connection that migrated from the vertical construction industry.

Slide 31:

The couplers can be used where ever a construction joint would normally be placed in a conventional bridge. This facilitates the design of the bridge because it can be designed as a cast-in-place structure. The couplers replace the normal lap splices. The only design change is the depth of the reinforcing cage in order to get proper cover over the couplers.

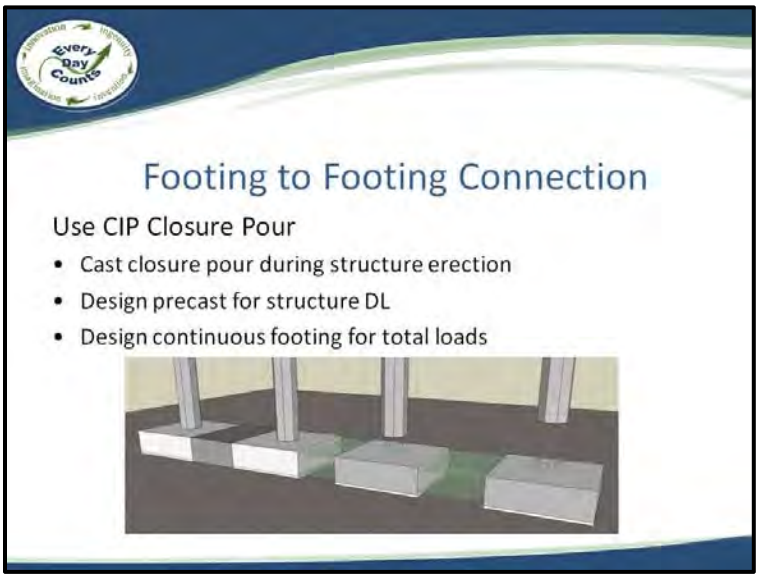
Slide 32:

The NCHRP study was for high seismic regions, however the connections are good for all locations.



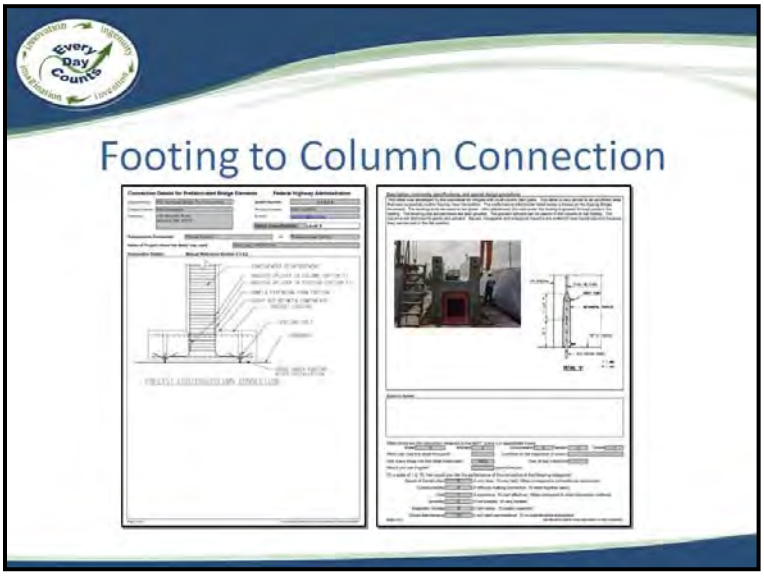
Slide 33:

The connection of the footings to the sub-grade is made with a simple grout pour. Flowable fill can also be used. The data sheet from the manual is shown.



Slide 34:

The connection of the footings is a simple closure pour. The closure pour can be placed as the remainder of the bridge is erected. No need to wait for concrete to cure.

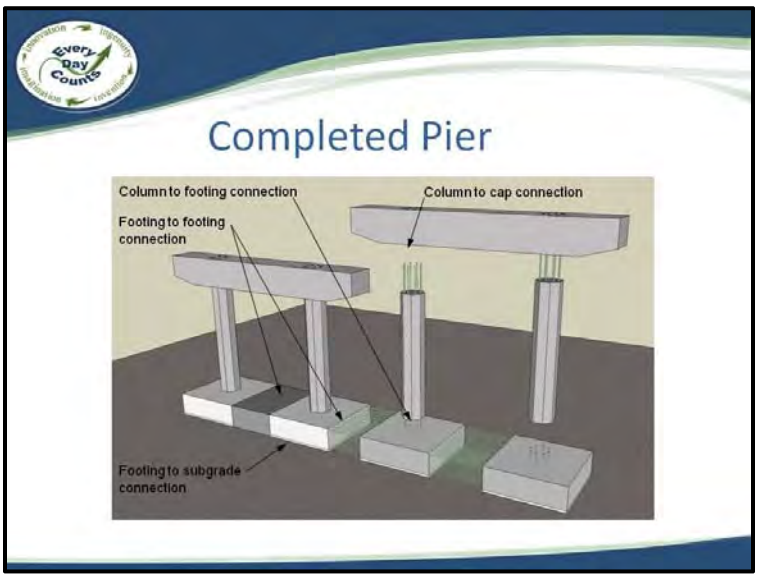


Slide 35:

The connection of the footings to the column is made with grouted couplers. The data sheet from the manual is shown.

Slide 36:

The connection of the columns to the pier cap is made with grouted PT ducts.

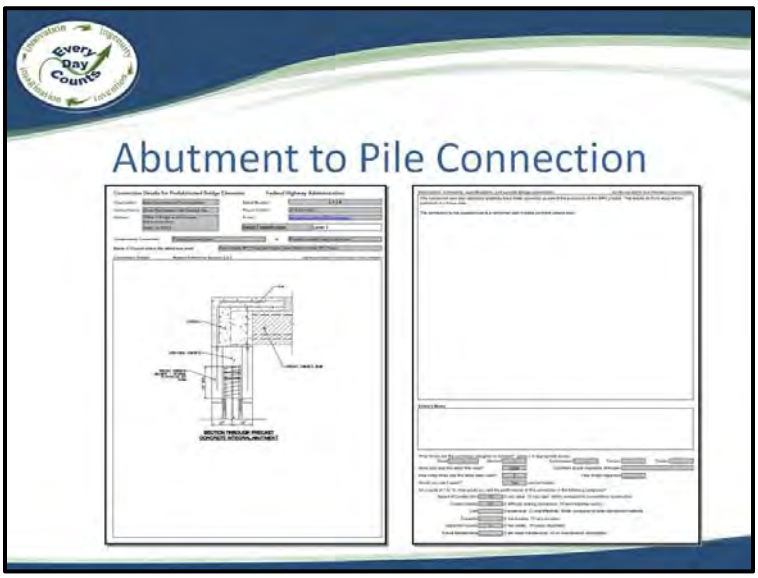


Slide 37:

This is a graphic showing the pier connections chosen.

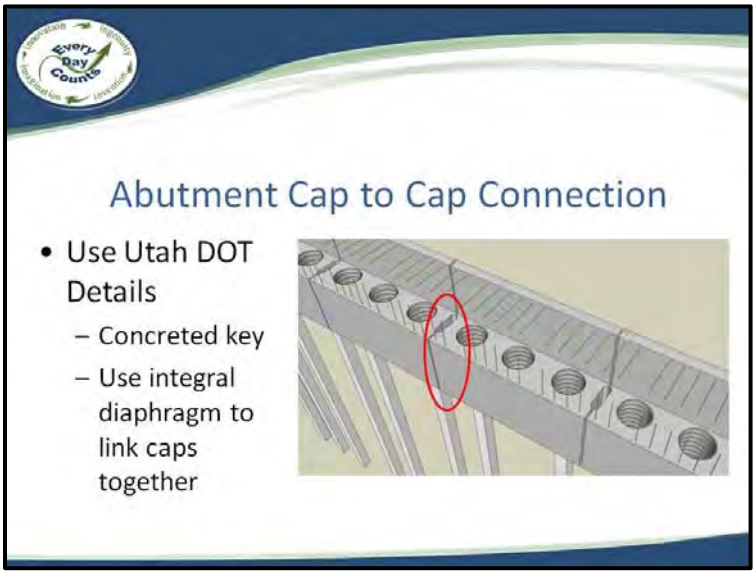
Slide 38:

Corrugated metal pipes are an inexpensive and structurally sound connection. The voids can be used to reduce element weight as well.



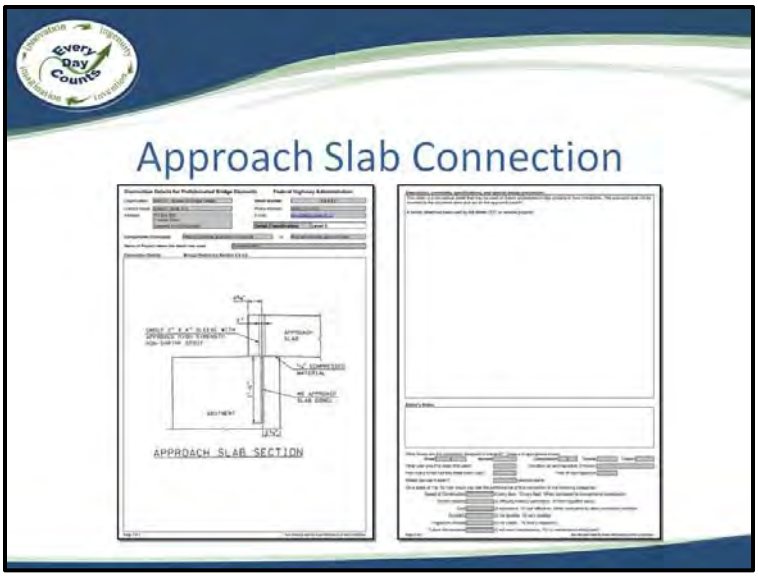
Slide 39:

The connection of the piles to the abutment cap is made with a simple grouted void. The data sheet from the manual is shown.



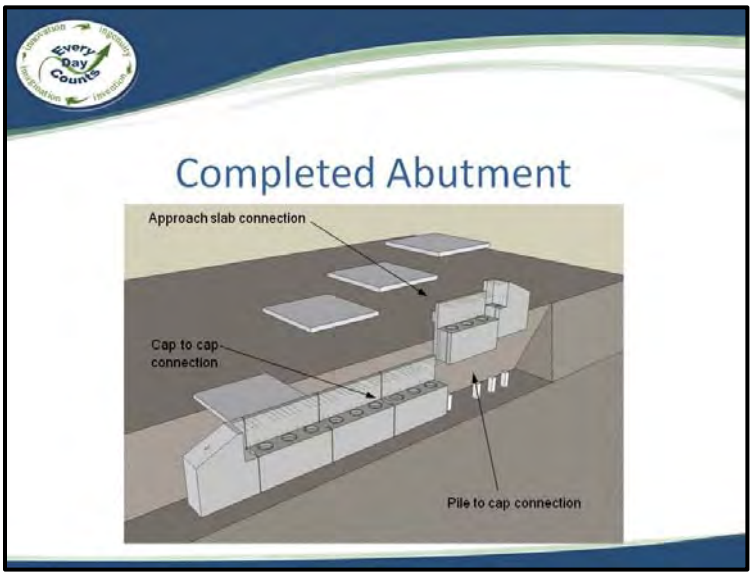
Slide 40:

The abutment cap to cap is made with a simple concreted shear key combined with the integral diaphragm that is case after the superstructure is in place. 2+ Piles per cap element are recommended.



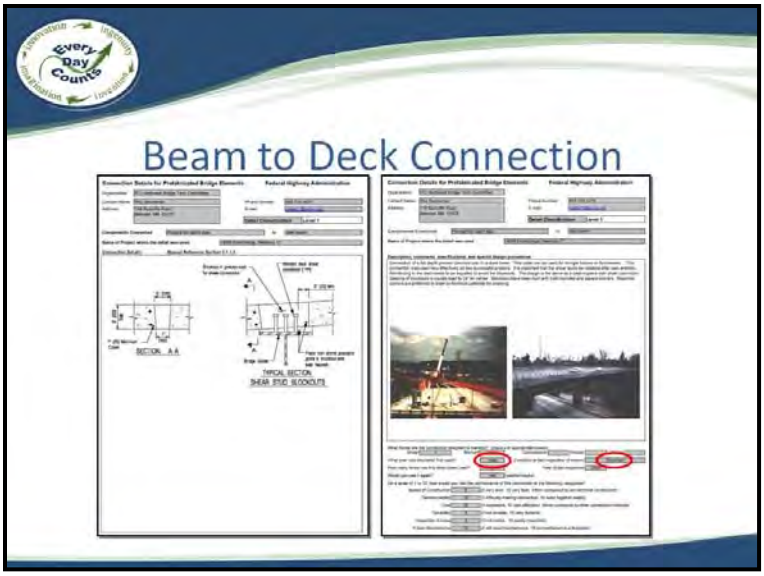
Slide 41:

The connection of the approach slab to the abutment cap is made with a simple grouted void. The data sheet from the manual is shown. The connection of the backwall to the abutment stem is made with grouted couplers.



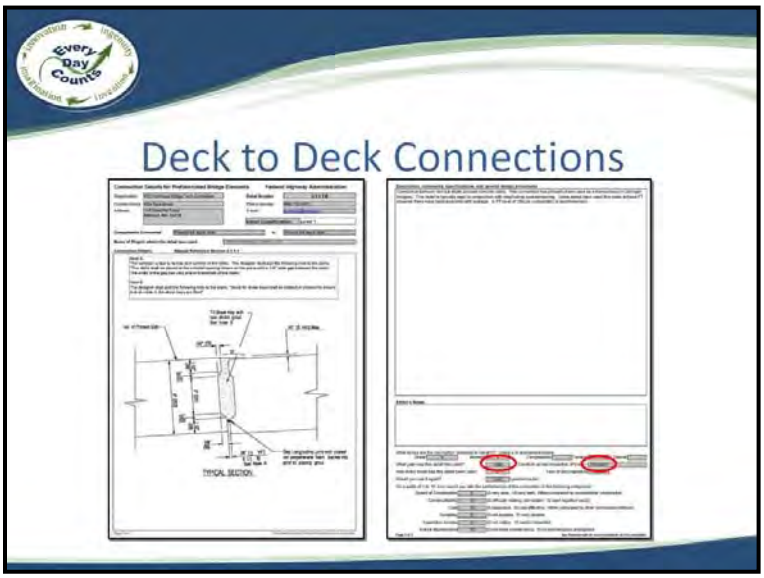
Slide 42

This is a graphic showing the abutment connections chosen.



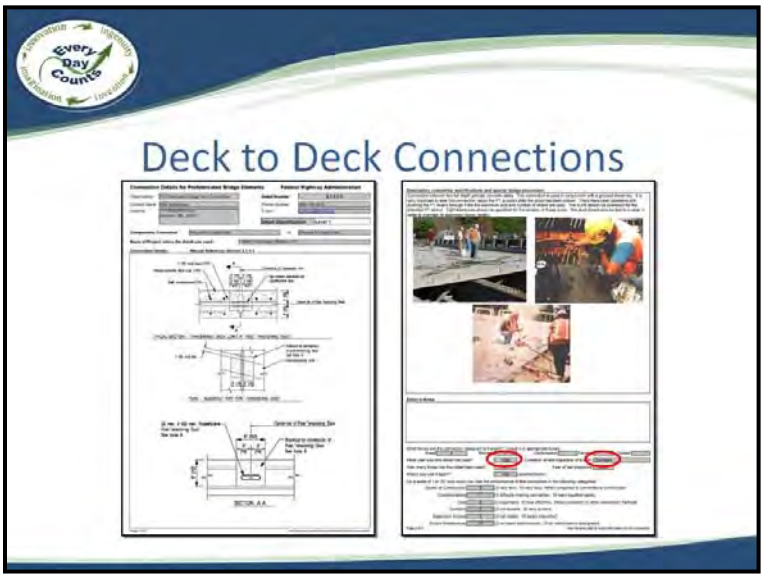
Slide 43:

The connection of the precast deck to the steel beam is made with a simple grouted void. The data sheet from the manual is shown. Note the age of this detail and its corresponding performance.



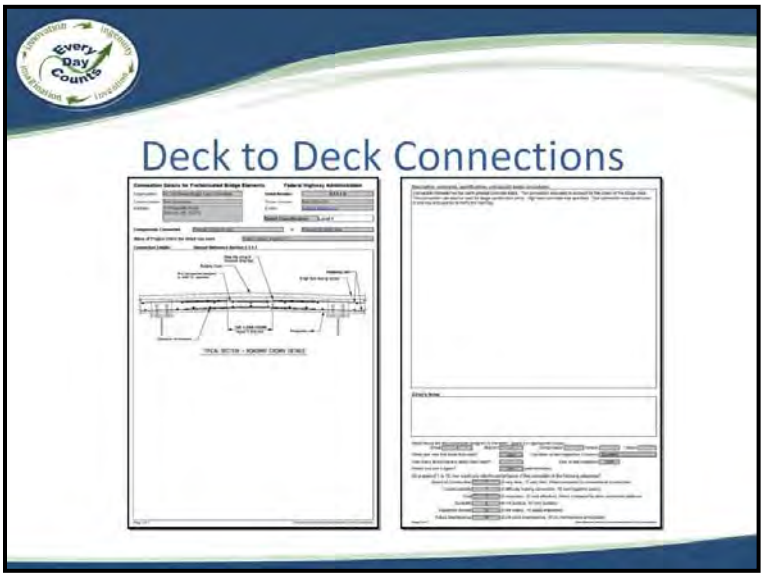
Slide 44:

The connection of the precast deck to the steel beam is made with a simple grouted void. The data sheet from the manual is shown. Note the age of this detail and its corresponding performance.



Slide 45:

The transverse connection of the precast deck is completed with longitudinal PT. The data sheet from the manual is shown. Note the age of this detail and its corresponding performance.

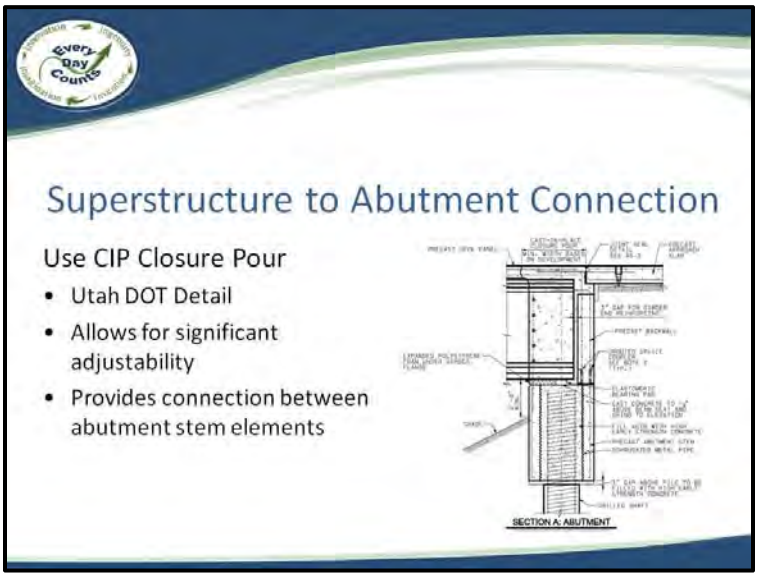


Slide 46:

A connection of the precast deck to deck is made with a closure pour at the roadway crown. This is done to reduce the handling size of the elements and account for the deck geometry. It is not required on every bridge. The data sheet from the manual is shown.

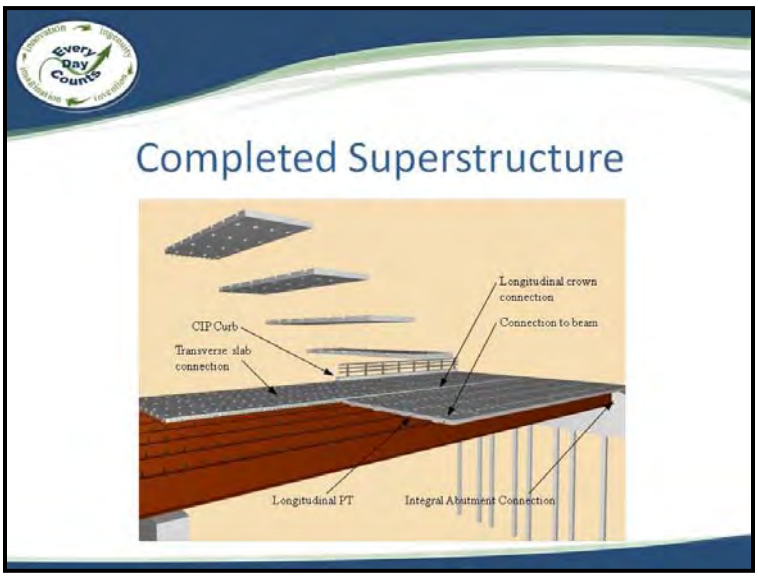
Slide 47:

This is a graphic showing the deck connections chosen.



Slide 48:

This detail shows the integral abutment elements and connections. This detail is not included in the FHWA manual. It was taken from the PCI Northeast Website.

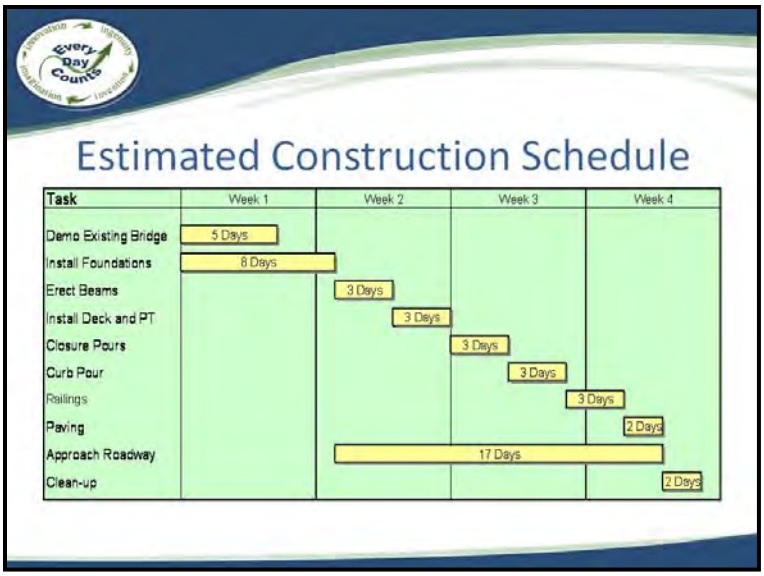


Slide 49:

This is a graphic showing the superstructure connections chosen.

Slide 50:

This is a graphic showing the entire bridge.



Slide 51:

The schedule shown is based on real-world experience on ABC projects. This should be considered a minimum timeframe for a typical prefabricated element project.

Slide 52:

The costs shown are relative. ABC can cost more than conventional construction for the structural elements, however there are other non-structure savings that can be realized, including the cost of a temporary bridge.

Slide 53:

There are other non-structure related cost savings that can also be realized.

Slide 54:

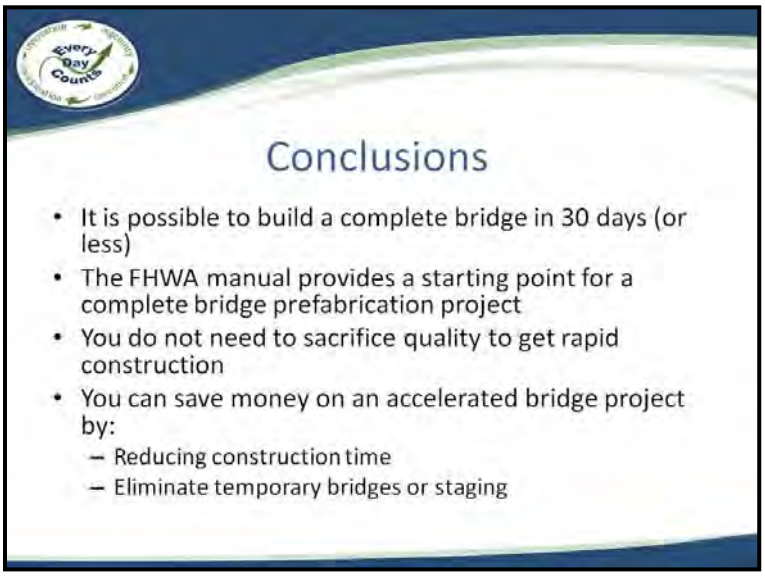
The FHWA manual demonstrates that the details chosen can be exposed to harsh environments with great success.

Slide 55:

Based on the information discussed in this presentation, it is possible to get high quality, low overall project costs and rapid construction.

Slide 56:

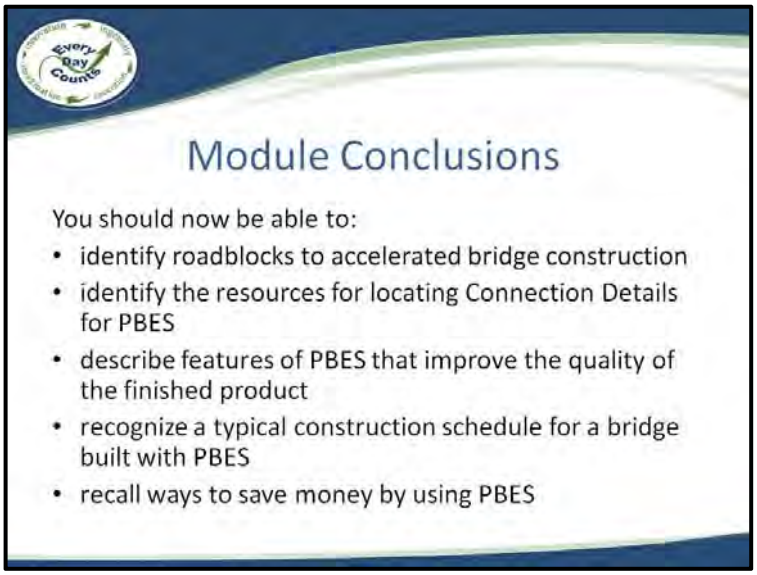
In conclusion: It is possible to replace a bridge in 30 days using prefabricated bridge elements. The FHWA manual is a great starting point for planning an ABC project. ABC does not necessarily mean higher overall project costs.



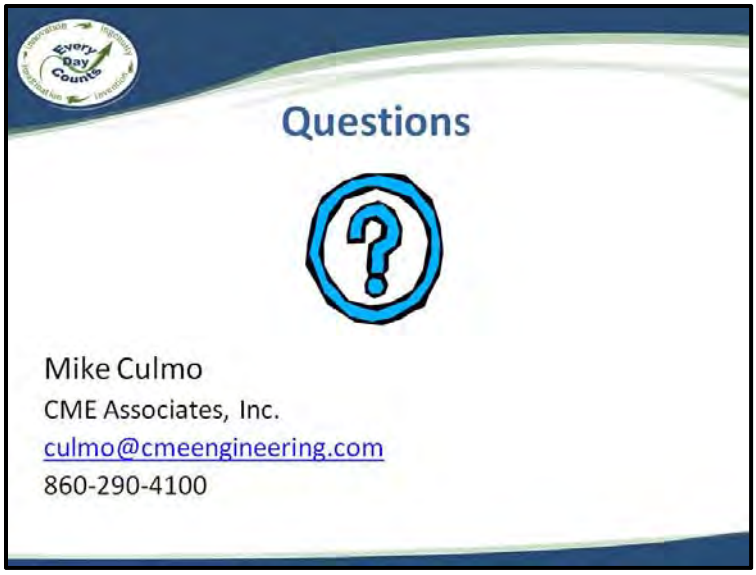
Slide 57:

You should now be able to:

- identify roadblocks to accelerated bridge construction
- identify the resources contained in Connection Details for PBES
- describe features of PBES that improve the quality of the finished product
- recognize a typical construction schedule for a bridge built with PBES
- recall ways to save money by using PBES



Slide 58:



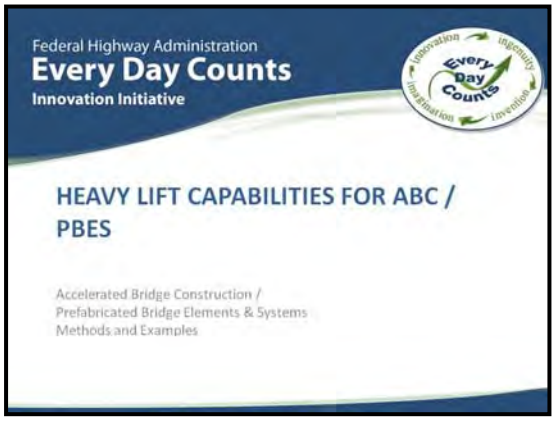
Module 7: EFFORTS and CAPABILITIES to SUPPORT PBES DEPLOYMENT

MODULE LEARNING OUTCOMES

By the end of this Module, you will be able to:

- recognize varying structural placement methods
- identify alternative placement methods
- recall the advantages for using prefabricated bridge placement methods
- identify projects that have successfully used structural placement methods

MODULE SLIDES & NOTES



Slide 1:

- Self-Propelled Modular Transporters (SPMTs)
- Longitudinal launching
- Horizontal sliding or skidding
- Other heavy lifting equipment and methods

EXAMPLE OF SUCCESSFUL PBES ADOPTION:

Utah DOT ABC History as of 2009

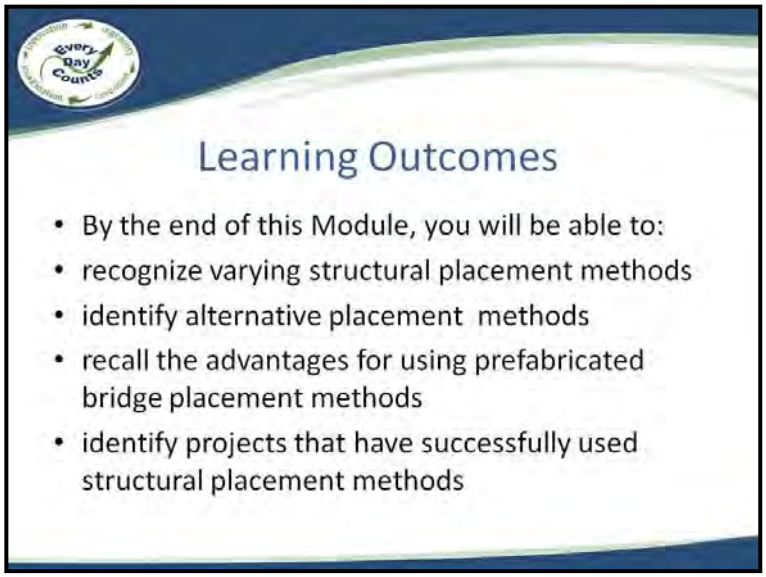
The Utah Department of Transportation (UDOT) has 32 projects, including 124 bridges total, completed or under construction that utilized ABC:

- Self-Propelled Modular Transports: 4 projects/13 Bridges
- Half Thickness Precast Deck Panels: 5 Projects/74 Bridges
- Full Depth Precast Deck Panels: 15 Projects/21 Bridges
- Precast Voided slabs: 1 Project/2 Bridges
- Approach Slab Panels: 10 Projects/15 Bridges
- Precast Sleeper Slabs 10 Projects/15 Bridges
- Precast Abutments: 3 Projects/5 Bridges
- Precast Bent Caps: 2 Projects/2 Bridges
- Precast using Sliding: 1 Project/1 Bridge
- Precast Box Culvert: 3 Projects/7 Bridges
- Heavy Lift Cranes: 3 Projects/4 Bridges

Slide 2:

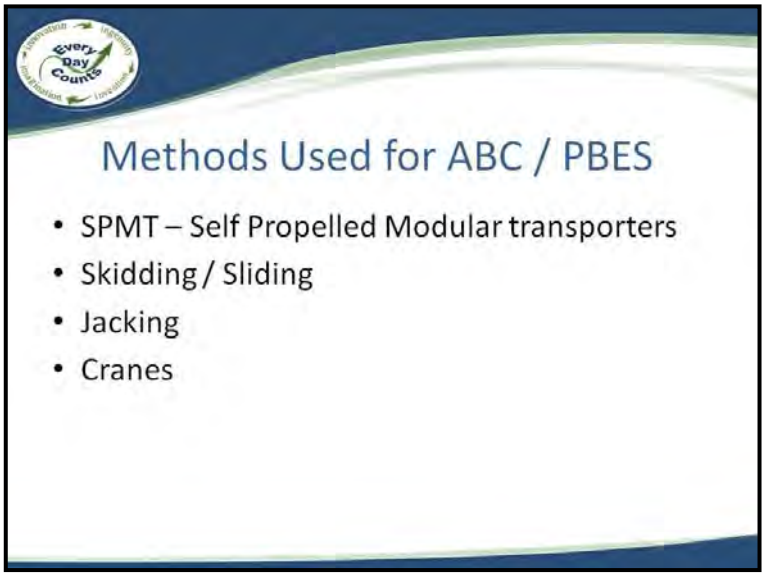
By the end of this Module, you will be able to:

- recognize varying structural placement methods
- identify alternative placement methods
- recall the advantages for using prefabricated bridge placement methods
- identify projects that have successfully used structural placement methods



Slide 3:

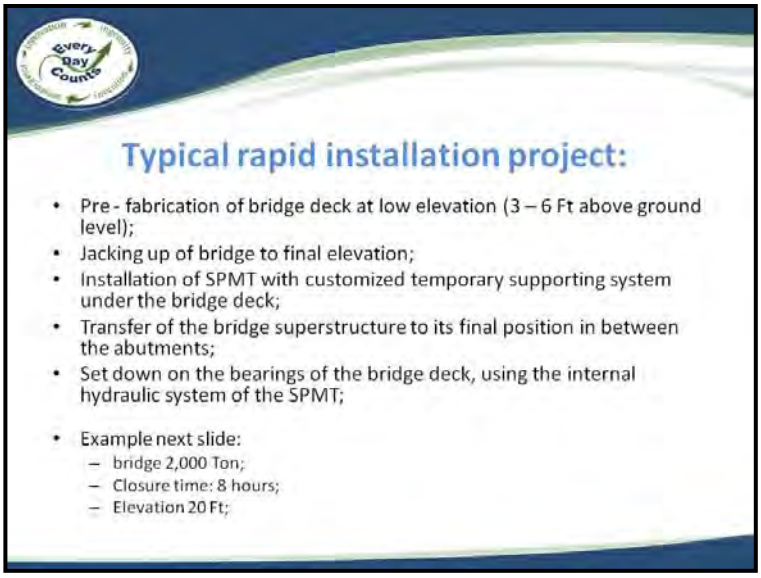
There are various methods that can be used for Accelerated Bridge Construction and Prefabricated Bridge Element Systems. Predominately SPMTs, than skidding/sliding, jacking and cranes. We will detail each application.



Slide 4:

Slide 5:

Brief animation showing typical movements of SPMTs



Slide 6:

Slide 7:

Video showing typical SPMT bridge move

Slide 8:

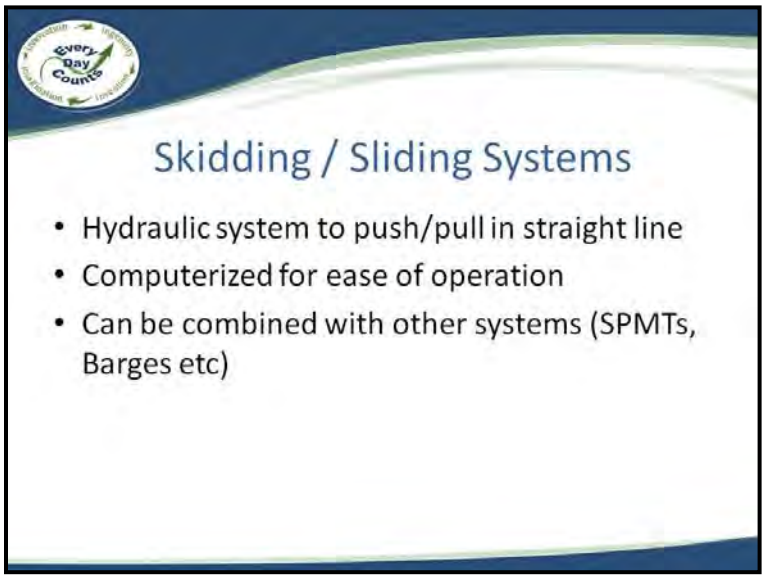
Bridges are built offsite but near bridge location

Slide 9:

Old spans can be moved out as new spans are coming in. Removal and / or installation can literally take just a few hours.

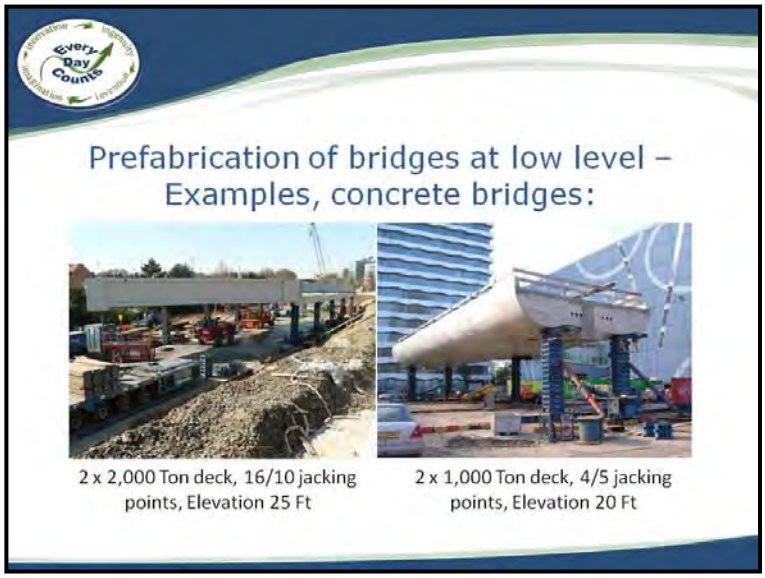
Slide 10:

There are various methods that can be used to support bridge spans on the SPMTs. These systems are pre-engineered with the contractor to insure proper support and location.



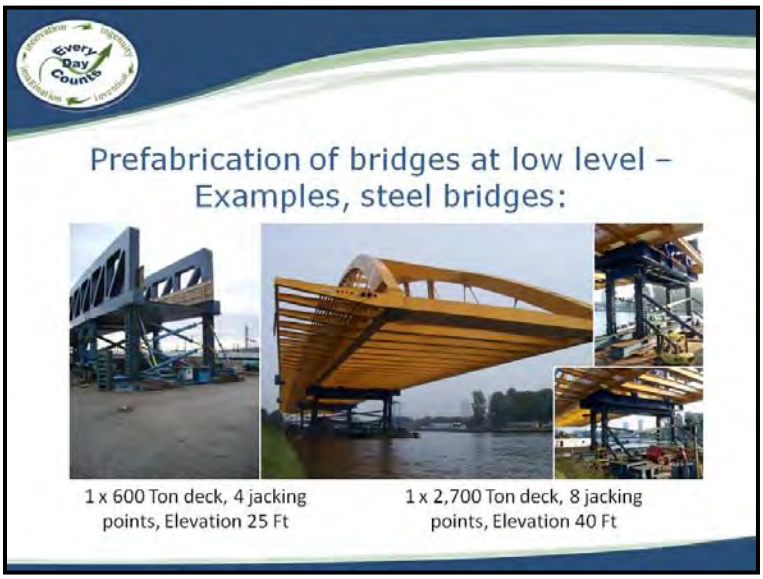
Slide 11:

Slide 12:



Slide 13:

Bridges can be built low to the ground and when ready. be jacked up to appropriate height for the SPMT and supports.



Slide 14:

Slide 15:

Using any combination of SPMTs, skidding systems and jacks with barges allow for launching applications over water.

Slide 16:

Slide 17:

Cranes are the conventional way. Cranes can also be used where there are limits to other uses.

Slide 18:

Slide 19:

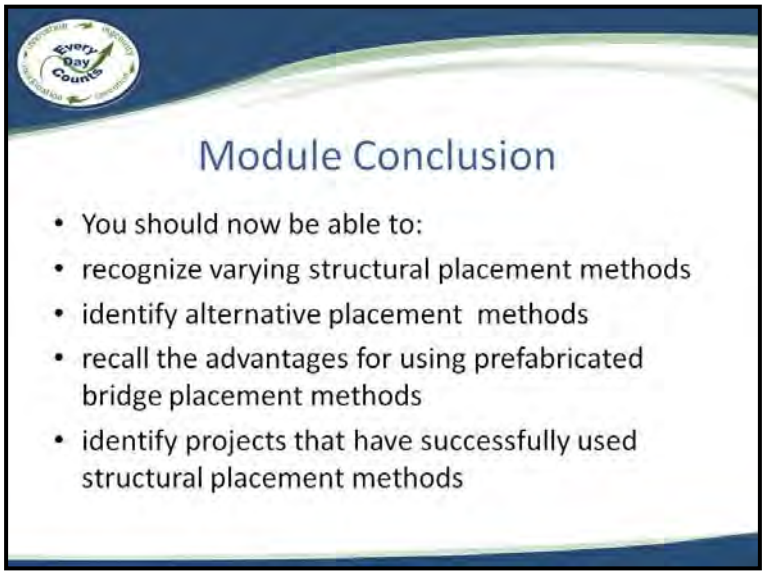
Towers, strandjacks or winches can be used in very unusual applications.

Slide 20:

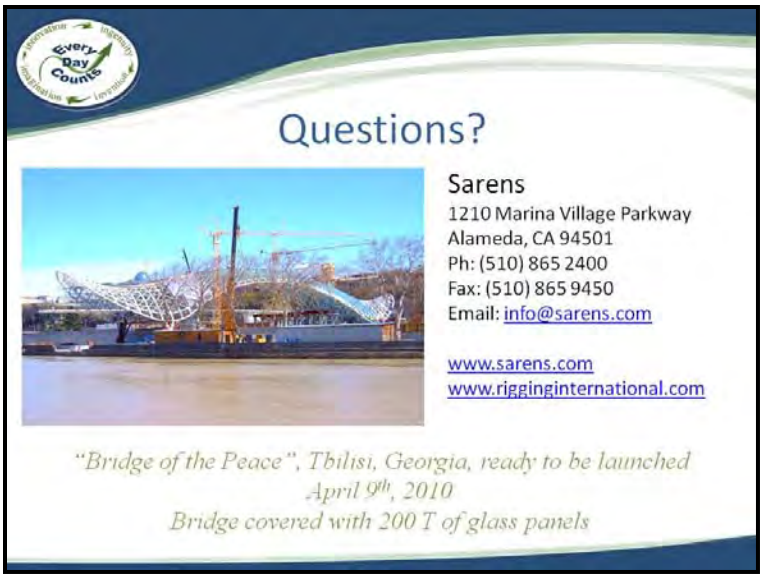
Slide 21:

You should now be able to:

- recognize varying structural placement methods
- identify alternative placement methods
- recall the advantages for using prefabricated bridge placement methods
- identify projects that have successfully used structural placement methods



Slide 22:


Questions?
Sarens
1210 Marina Village Parkway
Alameda, CA 94501
Ph: (510) 865 2400
Fax: (510) 865 9450
Email: info@sarens.com
www.sarens.com
www.rigginginternational.com
"Bridge of the Peace", Tbilisi, Georgia, ready to be launched
April 9th, 2010
Bridge covered with 200 T of glass panels

Slide 23:

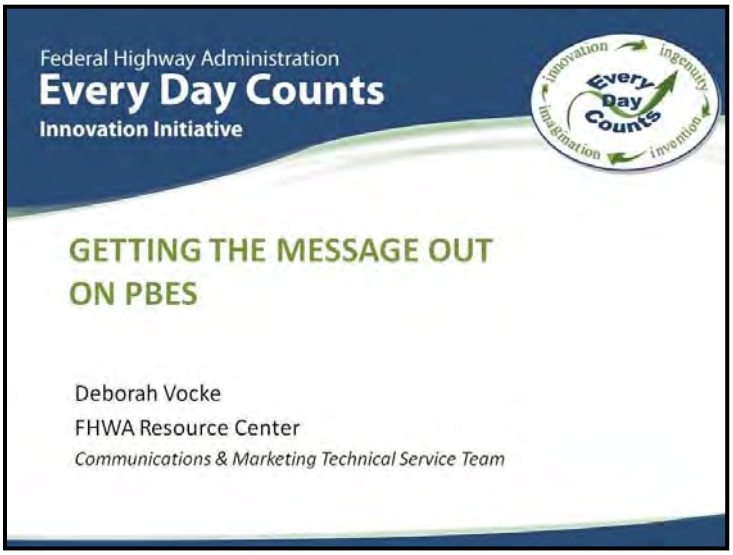
GETTING THE MESSAGE OUT ON PBES

MODULE LEARNING OUTCOMES

By the end of this Module, you will be able to:

- Identify existing target audience members & groups
- Identify techniques for communicating ABC/PBES advantages
- Identify venues for promoting ABC/PBES
- Understand protocols and how to aid FHWA in participating in appropriate events (booth space, speaking, presentations) to promote PBES
- Locate available resources & marketing materials

MODULE SLIDES & NOTES



Slide 1:

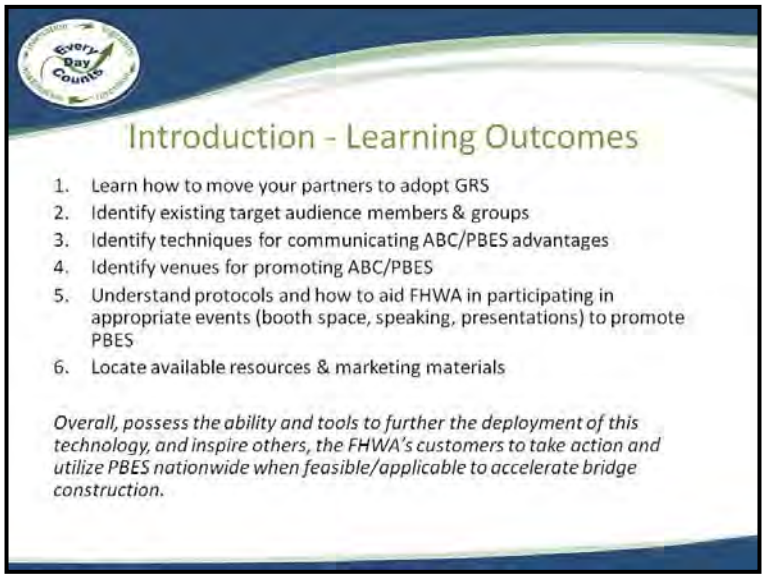
Slide 2:

AGENDA: Introduction; Available Communication & Marketing Pieces; Effective Outreach

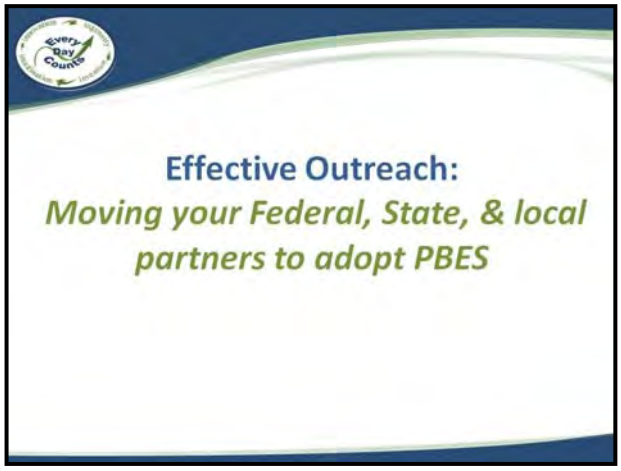
Slide 3:

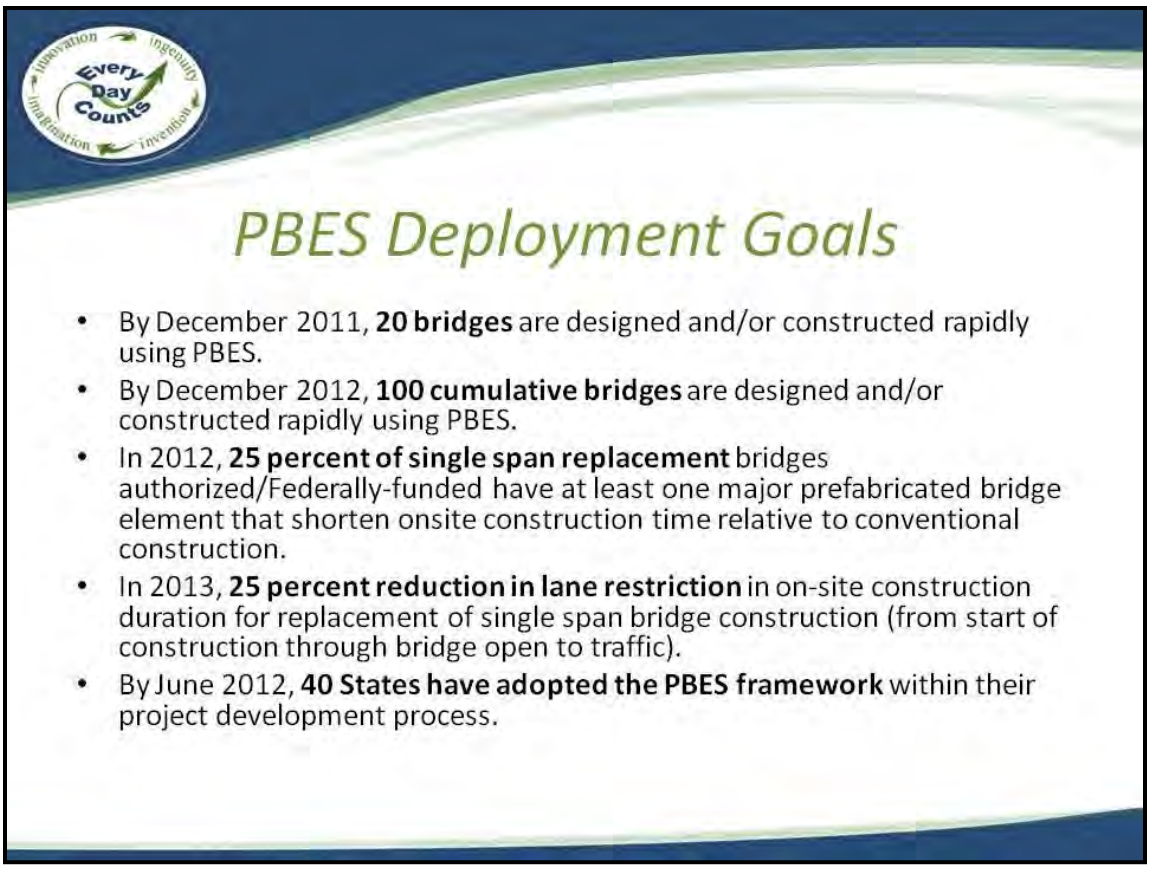
Upon completion of this Module, participants will:

- Be able to locate resources & materials available for supporting PBES marketing and communications activities
- identify techniques and venues for promoting ABC/PBES technology
- Identify existing groups with target audience members & appropriate venues for promoting PBES
- Understand protocols and how to aid FHWA in participating in appropriate events (booth space, speaking, presentations) to promote PBES
- Possess the ability and tools to further the deployment of this technology, and inspire others, the FHWA's customers to take action and utilize PBES nationwide when feasible/applicable to accelerate bridge construction.



Slide 4:





Slide 5:

First, we need to recognize the agency has set some very aggressive deployment goals.

EDC PBES DEPLOYMENT GOALS:

- By December 2011, to accelerate bridge construction, **20 bridges** are designed and/or constructed rapidly using PBES.
- By December 2012, to accelerate bridge construction, **100 cumulative bridges** are designed and/or constructed rapidly using PBES.
- In 2012, **25 percent of single span replacement bridges** authorized/Federally-funded have at least one major prefabricated bridge element that shorten onsite construction time relative to conventional construction.
- In 2013, **25 percent reduction in lane restriction** in on-site construction duration for replacement of single span bridge construction (from start of construction through bridge open to traffic).
- By June 2012, **40 States have adopted the PBES framework** within their project development process.

Slide 6:

Effective Outreach: ***Moving your State partners to adopt PBES***

Assembling Your Team
This process offers significant advantages over traditionally-used cast-in-place construction, resulting in:

- Reduced on-site construction time
- Minimized traffic disruption – months to days
- Reduced Environmental impact
- Improved work zone & worker safety
- Lower initial and Life-Cycle Costs
- Improved product quality – controlled environment, cure times, easier access, etc.

However, at the State, local, and tribal government levels, the senior Bridge Engineer, must work early on with the planners, the design engineer, and ultimately with Construction and Maintenance personnel to proceed with the installation of the PBES on bridge projects. It is imperative to bring the right people to the table—to achieve success.

The first step in deploying PBES is to form a team. You cannot do this alone. How do you bring together the right people to do the job? It's highly recommended that you establish some kind of implementation team consisting of a core group of stakeholders with a shared interest in PBES. Who are the best people to approach? Are they people in safety, pavements, maintenance, policy and standards? Which individuals or organizations do you already have a working relationship with? Who can you reach out to for help? And are these the right people and groups?

You do not have to start from scratch building a team, when it's a coalition or partnership. These may already exist. Consider the 8 partners listed on this slide as a starting point. Consider other key stakeholders in your State.

The team you choose will help lead the effort to implement PBES. Most of these individuals and entities, especially LTAPs, have already established coalitions and partnerships within your State. LTAPs often have extensive mailing lists, quarterly newsletters, technical support, pilot locations, training videos and Web-conferencing support.

Meet with your new implementation team as soon as possible and begin to put a PBES implementation plan in place for your State.

Face-to-face team meetings are essential with all key parties in the State. Consultation meetings with decision-makers in the safety and pavement disciplines -- along with contractors and State bridge associations – help promote understanding and begin the process of encouraging and persuading partners and stakeholders to implement PBES. This team will form the foundation for hosting meeting and training and eventually full implementation of PBES.

Slide 7:

You should consider starting with your own Division staff. Who in your office can help? Next, there may be a State bridge champion who has already been selected. Next, you can consider contractors and state and local association leaders. Once you've put your team together, start meeting to establish your vision, goals and objectives, as well as how you're going to operate.

Your first major project can be a demonstration project, with the ultimate goal of attaining a State standard and full implementation.

Slide 8:

Slide 9:

To date, PBES has been implemented on many Interstates and on Federal Land's projects. The intent of the EDC program, is that the rate of PBES deployment will improve nationwide, to accelerate bridge construction.

The FHWA PBES Implementation Team developed the following list of target audience members:

- State Transportation Agencies
- Local Transportation Agencies
- Metropolitan Planning Organizations
- Users
- FHWA Division Offices
- Federal Lands Highway Divisions
- Industry *(Consultants, Fabricators, Suppliers, Contractors, Producers, & Trade/Professional Organizations)*
- Educators *(Academia, NHI, LTAP, TTAP)*
- Researchers *(Better ways to build bridges through research)*

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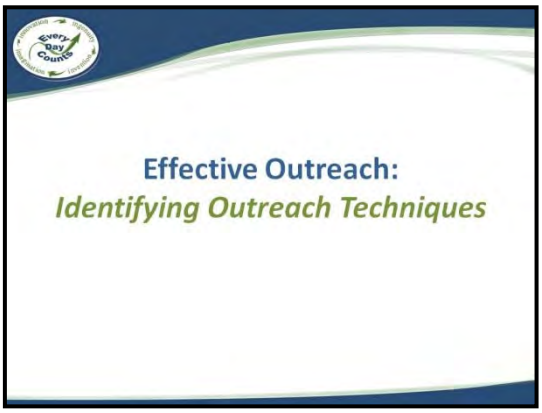

Slide 11:

So, HOW DO PEOPLE MAKE DECISIONS?

First, Awareness begins. Awareness of a problem, awareness of a potential solution. Awareness begins with education.

While piquing interest will, to some extent, depend on your ability to persuade, when people **talk to their social circle**, the idea may get support or get rejected depending on this critical step. If you can influence this step, you'll be more successful at persuasion.

Individual decision-making is often based not on facts and reason, but on the **decision-maker's personal reflection—their desires to meet individual needs** and pursue certain interests. Interests are often the activities we pursue to meet our needs. You may have an interest in having a new gymnasium built in your community because of your need to be physically active to maintain good health.

Organizations go through a similar decision-making process as individuals. They make decisions **based on organizational needs and interests**. For State DOTs and other transportation organizations, interests can be the solution to a problem, such as deploying the GRS to reduce construction time in work zones, crashes and/or congestion. Organizations will base their decision to deploy GRS on whether it meets such agency needs as safety, mobility and costs. Your partners will want to know if GRS will help them pursue their interests in accelerating bridge construction. For these reasons, your ability to help your stakeholders understand how the GRS can meet their needs and fulfill their interests is critical.

That's why building and maintaining positive working relationships and to communicate effectively through persuasion is so important. Keep in mind that emotions will play an important role in the decision-making process, as will technical information.

Slide 12:

There are multiple ways to reach the target audience, ranging from a simple, informal one-on-one conversation, to a formal meeting, or a presentation at a structured event like a conference of workshop, or through staffing an exhibit at a trade show. You could also consider arranging a visit for interested folks to other States or counties or a Federal lands project to see up close and personal how it works in a demonstration

You should also consider documenting your success through an article in one of the agencies newsletters or magazines to share your experiences with other States and divisions considering deployment with similar issues and conditions.

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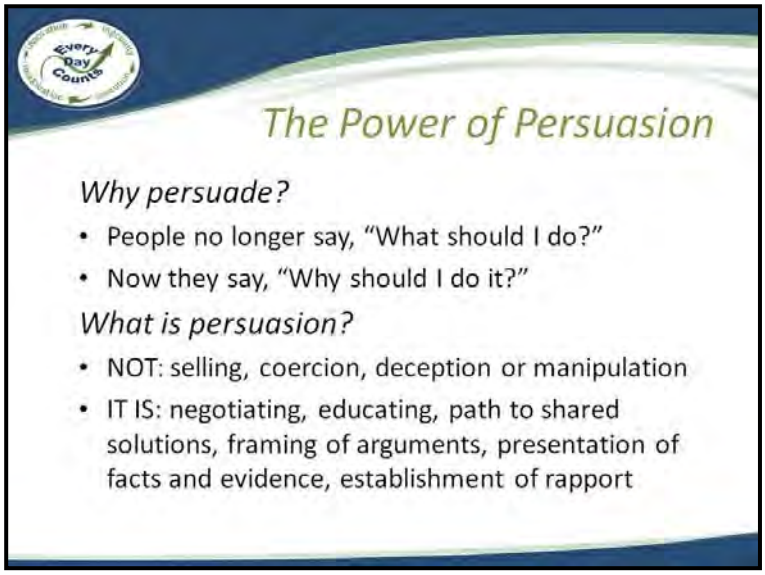

The Power of Persuasion:

Why persuade? An important element in successful persuasion of a target audience is to address the question: "Why should I do this?" What's in it for me and my agency? This is where persuasion comes in.

What is persuasion? Persuasion is not about selling, coercion or even manipulation. Persuasion is about moving your stakeholders down a path to a shared solution that PBES is in all of our best interests. You have to be willing and able to educate, frame arguments, present facts and evidence, and establish positive working relationships with your team and other stakeholders. This requires relationship building and being an effective communicator.

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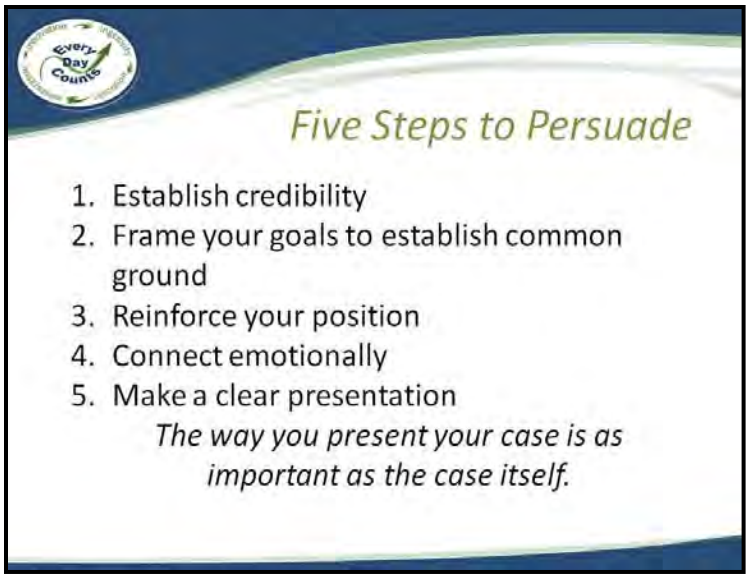

FIVE STEPS TO PERSUADE
Establish credibility requires you to prove yourself trustworthy and knowledgeable. People are taking a risk when they allow themselves to be persuaded. You lessen that risk for them by being credible. Connecting emotionally is all about relationship building and being sensitive to your stakeholders' underlying needs and interests. Let's examine the five steps in more detail.

How you succeed with PBES deployment will, to some extent, depend on current and past relationships with your stakeholders. Do you have a sound track record? Some questions to consider as you establish credibility:

- How will others perceive my knowledge about this situation?
- Do people respect and trust me when it comes to this area and others?
- Do people see me as helpful or as divisive?
- Do people feel like they can connect with me or do they see me like I'm not in sync?

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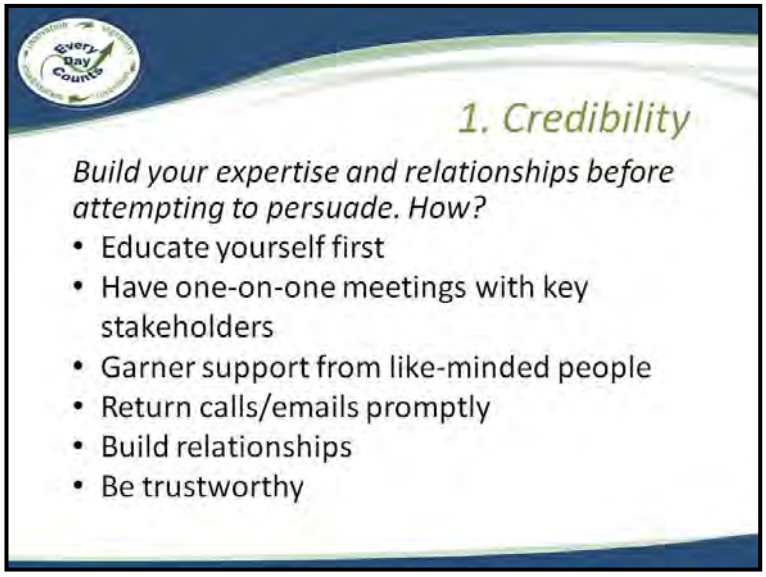


CREDIBILITY

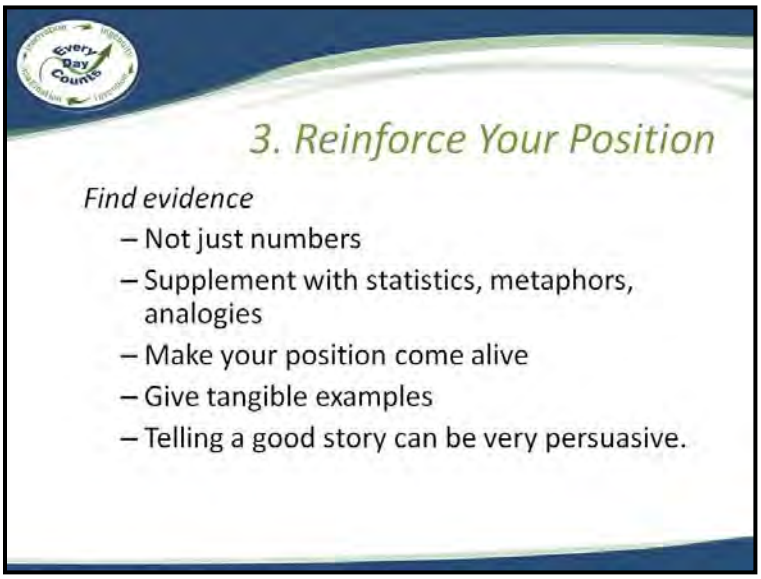
Relationship-building is a critical early component of getting your State to endorse and fully implement PBES. Consider these six items as you build your credibility.

Slide 16:

ESTABLISH COMMON GROUND Most States and FHWA have common goals. These shared goals should be articulated. For example, Aren't we all trying to make our roads safer, more efficient, and last longer for the lowest possible cost to the taxpayer? You can outlined these shared goals to show that going down the path to deploying PBES is beneficial to everyone. You also must explain "What is in this for me," or WIFM. These goes to the heart of helping your State meet its needs and fulfill its interests as they relate to transportation.

Slide 17:

Reinforcing Your Position: When working with your stakeholders, you have to go beyond just providing technical data. You have to make that data come alive. One of the best ways to do this is to be a good storyteller. Don't be afraid to talk about technical details using meaningful, relevant statistics, metaphors and analogies. For example, using an analogy might go something like this:
PBES is a form of accelerated bridge construction (ABC) that lowers cost, slashes construction time, improves durability, and increases safety—all at the same time.



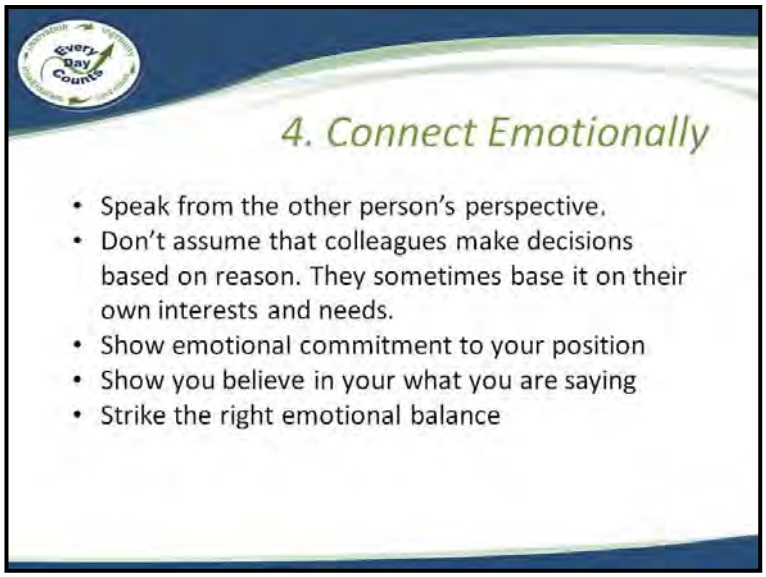
OR

PBES technology is an innovative approach to bridge construction that allows components to be:
1. Built off-site, outside traffic area(s)
2. Transported to the site
3. Installed rapidly

These kinds of communication tools make your presentations come alive and help your stakeholders visualize the technology while making an emotional connection. These techniques are part of effective communications -- and ultimately effective persuasion.

Slide 18:

CONNECT EMOTIONALLY
Persuasion requires delicately balancing technical data with people's emotions. You might wonder what could possibly be so emotional about PBES. It's not the technology itself that's emotional, it's how PBES can meet the needs and fulfill the interests of the stakeholder and his or her agency. No matter how technical you sound, you have to make an emotional connection to your stakeholders. You have to show them that you care about and believe in what you're doing. You have to understand their needs and how PBES can help meet those needs.



Slide 19:

ROADBLOCKS TO ACCEPTANCE
Roadblocks to deployment and implementation can include conflicting budgetary priorities, equipment shortfalls, or other more tangible issues. However, despite your best efforts, you could run into roadblocks to acceptance based on intangibles. These roadblocks can vary widely, depending on many circumstances. Your stakeholders can have differing or conflicting interests and needs, ambivalence, skepticism, personal prejudices and dislike or even negative impressions of you.

Who we are shouldn't impact how people accept what we say, but it does. The listener's impression of us doesn't change logic, but it does influence reaction. 10+10 will always be 20. But people don't just make decisions based on their logic, they use their heart, their memories, their physical characteristics, their feelings and their values, interests and needs. Take the facts about seat belts, for example. They save lives. Your stakeholder may say, "So what?" Maybe I'm not concerned with that fact. Facts are only valuable when everyone agrees with them and agrees to act accordingly. Remember, don't assume facts alone will be sufficient. You must appeal to the emotions of your partners and stakeholders to be persuasive and to avoid roadblocks.

Slide 20 :

Slide 21:

IDENTIFYING VENUES FOR OUTREACH

Look at meeting invitations and schedules and determine if PBES is an applicable topic for inclusion on the agenda.
Look at Regional or National events happening in your State and ask whether PBES is an appropriate topic for the audience gathered.

Look at the subject matter being covered and see if FHWA has a place on the agenda to discuss PBES. In addition, look at planned events for exhibiting opportunities.
Following a project in your State, provide a write up for use in agency newsletters or magazines to share Best Practices and experiences with other States. While prefabricated elements have been used in bridges for more than half a century, the current prefabricated bridges initiative focuses on newer systems such as full-depth deck panels and whole superstructure and substructure systems that are fabricated offsite or near-site and then quickly installed at the site.

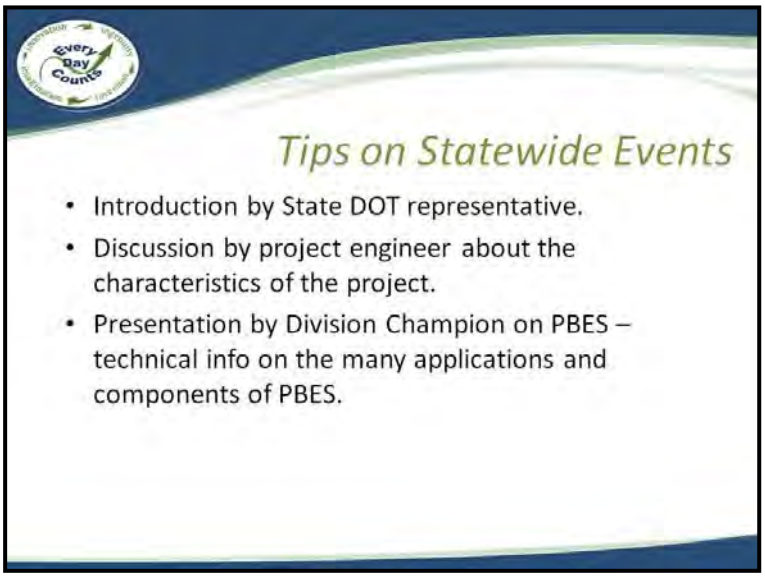
Slide 22:

Learning about PBES in the classroom or on paper is often not enough to fully grasp the technology's potential. You and your partners can benefit from getting out into the field to see the PBES application for yourselves.

Hosting a demonstration project or workshop is one of the most effective ways to get started. A workshop or open house, combined with a product demonstration in the field, helps create knowledgeable customers, raises interest and continues the process of encouraging and persuading stakeholders to implement the PBES. Onsite review of the project and the opportunity to answer questions can overcome resistance.

Slide 23:

Slide 24:



There are many ways to host a workshop, a demo, a formal meeting, and no one size fits all. These are some tips on what you can do to plan and carrying out a PBES-oriented event. These venues are also good places to gather contact information for additional communications and marketing efforts. Consider developing an e-mail database of PBES stakeholders, partners and key individuals in your state. With this database, you can regularly communicate electronically with these stakeholders.

During the early part of the event, consider allowing the roadway owner to give a broad overview of the project, such as bridge age, traffic volume, land and shoulder widths, safety performance and maintenance history. Then demonstrate how using PBES can accelerate the completion on a the project to replace it.

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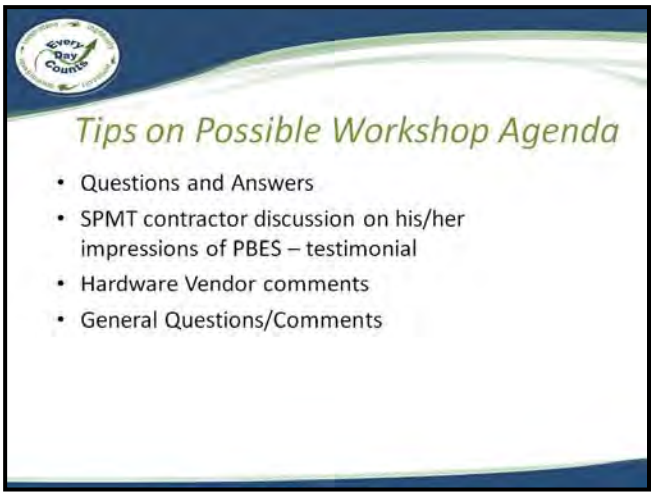

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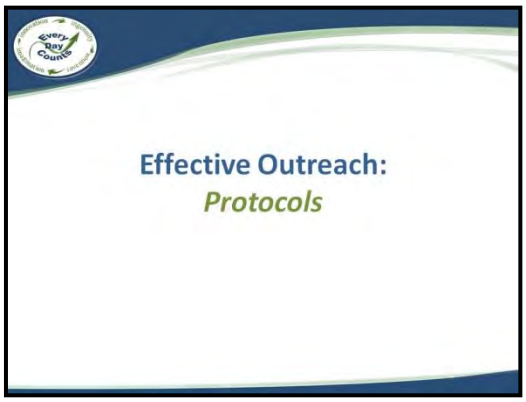


Slide 27:

Protocols
The Office of Public Affairs and The Administrator's Office must be consulted and coordinated with regarding any external outreach activities undertaken for EDC. Deborah and Stephanie can advise you how to facilitate this requirement.

For assistance on FHWA protocols and how to aid FHWA in participating in appropriate events
contact Marketing & Communication Team members (Deborah Vocke or Stephanie Roth) .

They are also available to help you:

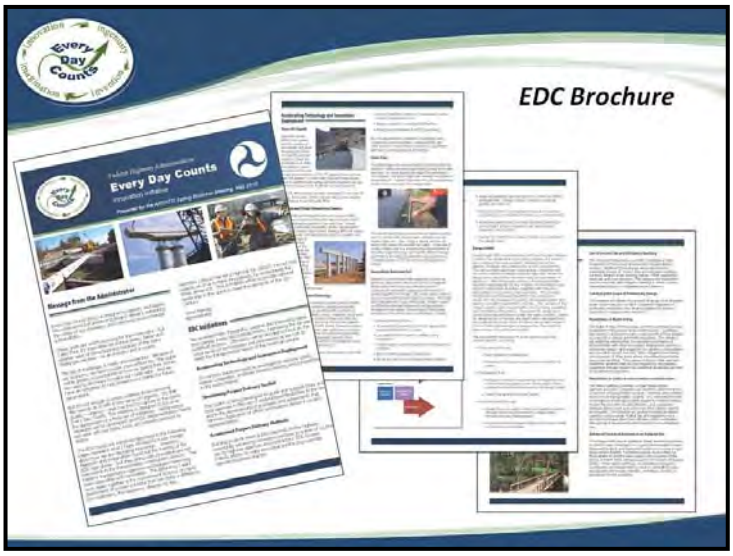
- Secure Materials (Presentations, brochures, technical)
- Secure Booth Space at events
- Arrange for Speakers for meetings or large conferences
  Request Presentations (large scale, informal)
- Article (Writing, editing. and placement)
- Photography/videotaping

Slide 28:

Slide 29:

AVAILABLE MARKETING MATERIALS

- EDC Brochure
- PBES Orientation Brochure
- PBES 2-page Flyer (technical)
- PBES Table Top Exhibit
- On-line Resources



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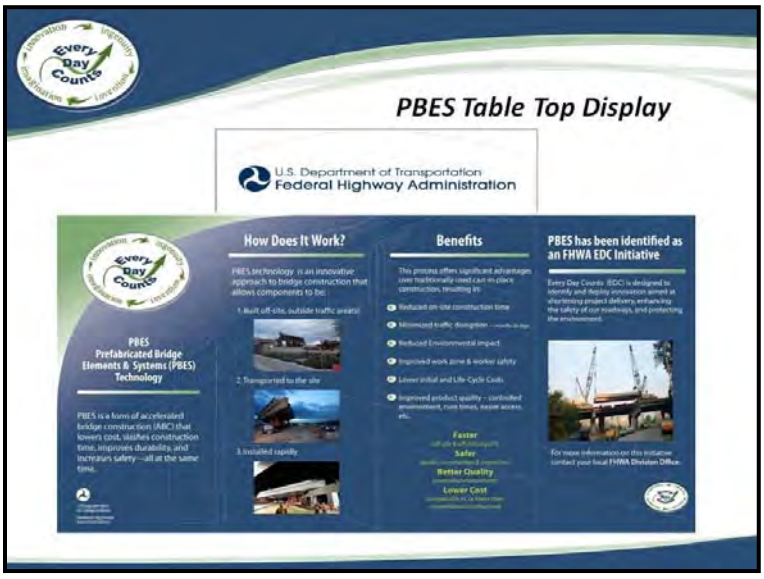

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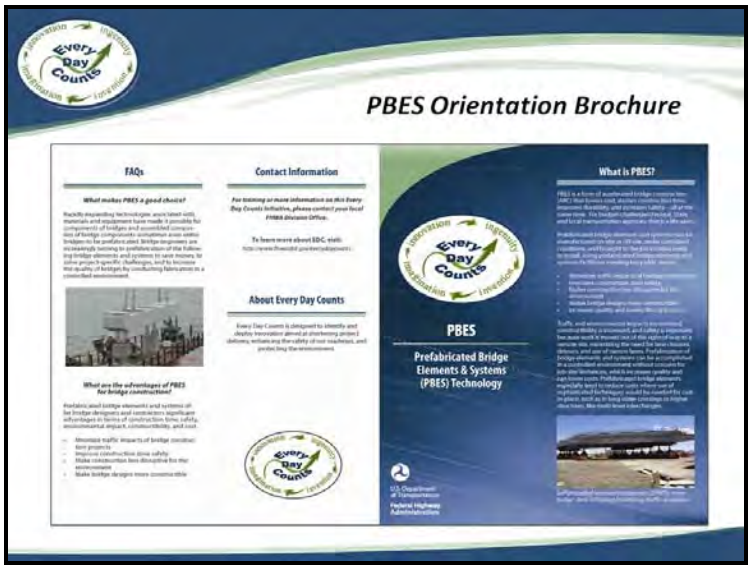

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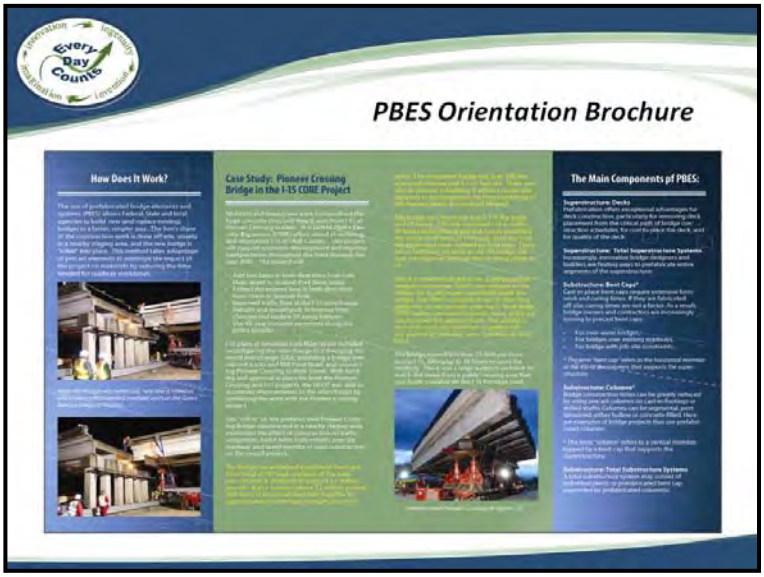

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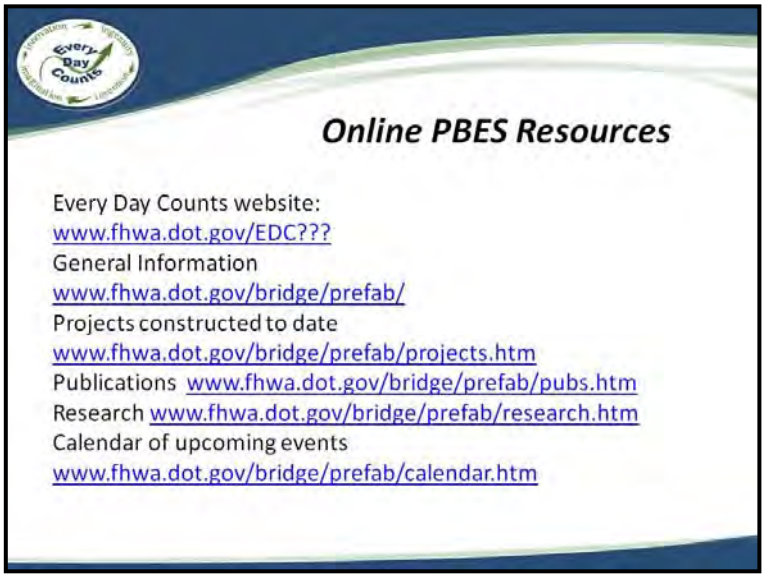

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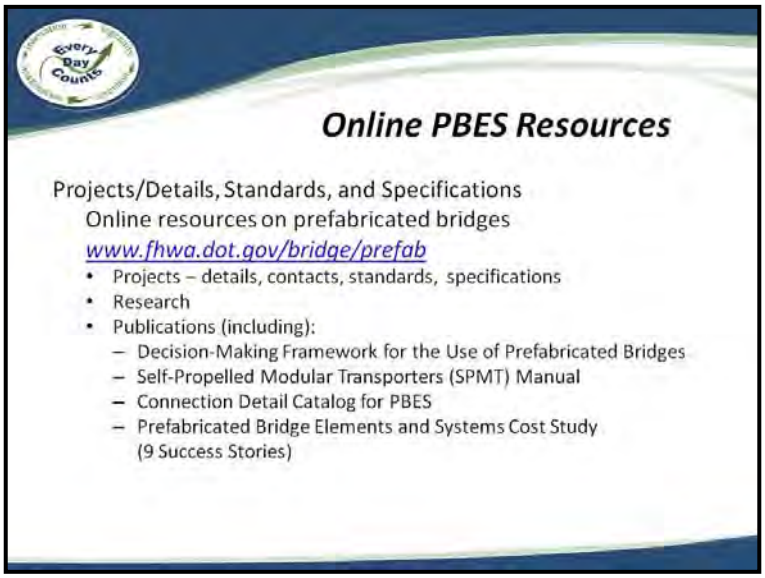

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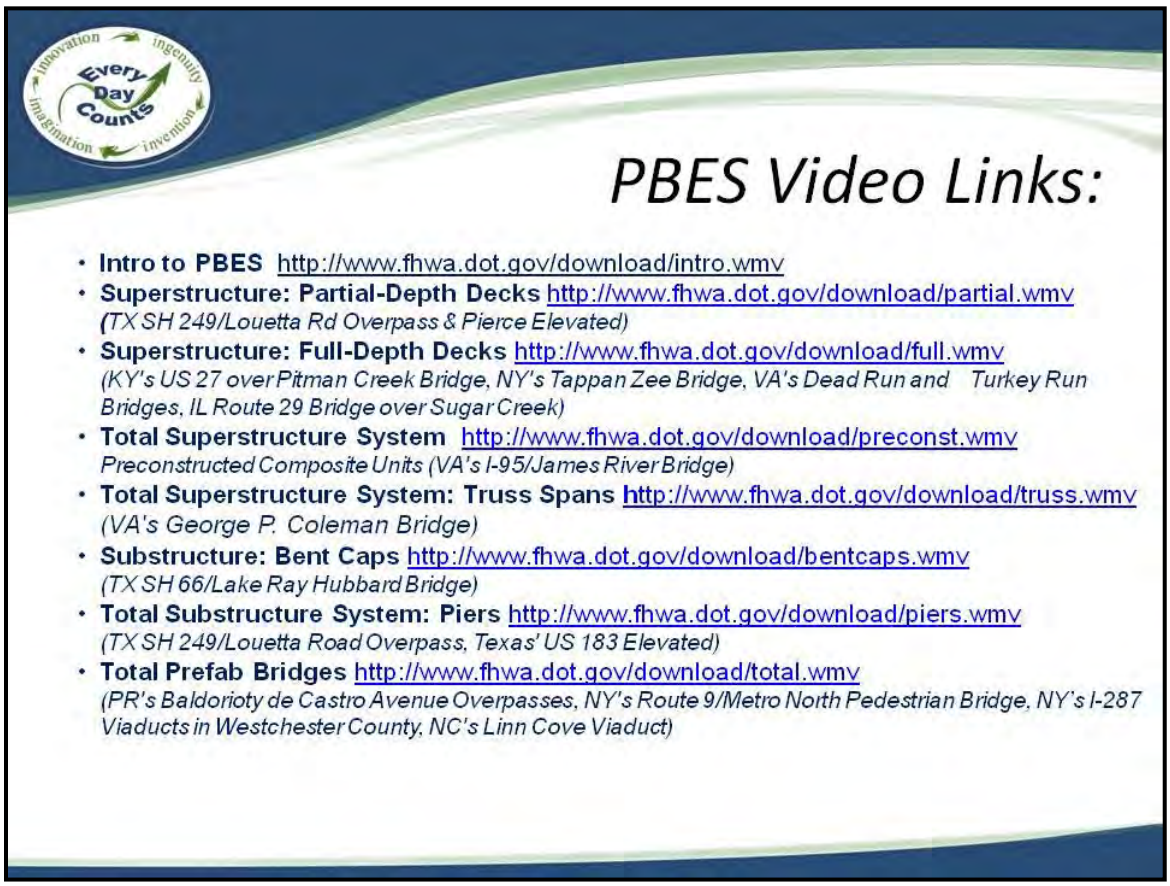

Slide 36:

PBES Video Links:

Other Videos

- **Graves Avenue Prefabricated Bridge Project** http://www.fhwa.dot.gov/bridge/prefab/gravesave.cfm
- **Time lapsed video showing the moving of a complete bridge superstructure carrying Graves Avenue over I-4 near DeLand, Florida.** http://www.fhwa.dot.gov/bridge/prefab/gravesave.cfm The bridge was moved into place in less than 1-hour while traffic was temporary slowed using a gang of highway patrol "rolling road block" to interrupt traffic flow for less than 30 minutes. Courtesy of Florida DOT.
- **Nemo Bridge** http://www.fhwa.dot.gov/bridge/prefab/videos.cfm
- **Sarens Video** http://www.sarens.com
- **UDOT Crews successfully move bridge in Layton** http://www.youtube.com/watch?v=7ezy0Gk5QT0
- **I-80 Bridge Replacement Animation** http://www.youtube.com/watch?v=OaE4U_E-z8g

Slide 37:

Online Outreach Resources

Public Roads Magazine (TFHRC)
http://www.fhwa.dot.gov/publications/publicroads/index.cfm
Public Roads -- Author Instructions (TFHRC)
http://www.fhwa.dot.gov/publications/publicroads/author.cfm
FOCUS Magazine (Office of Infrastructure)
http://www.fhwa.dot.gov/publications/focus/
Centered on Service newsletter (FHWA Resource Center)
http://www.fhwa.dot.gov/resourcecenter/success/cos.cfm

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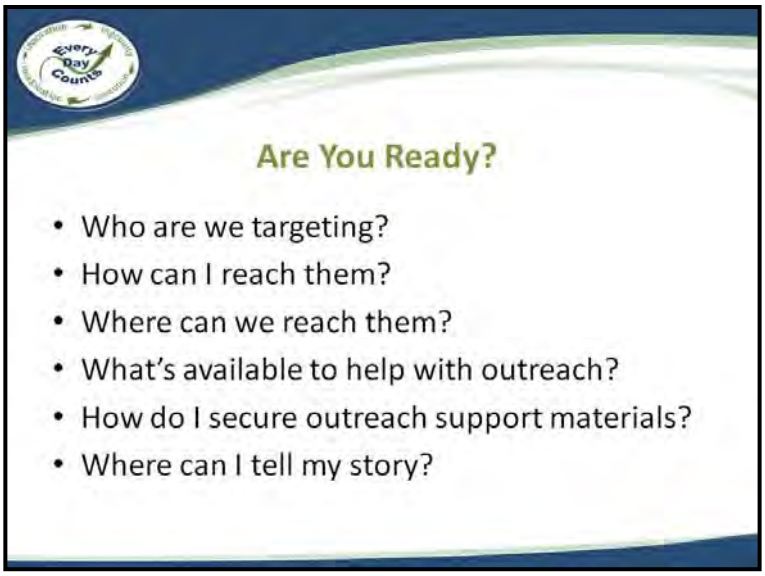

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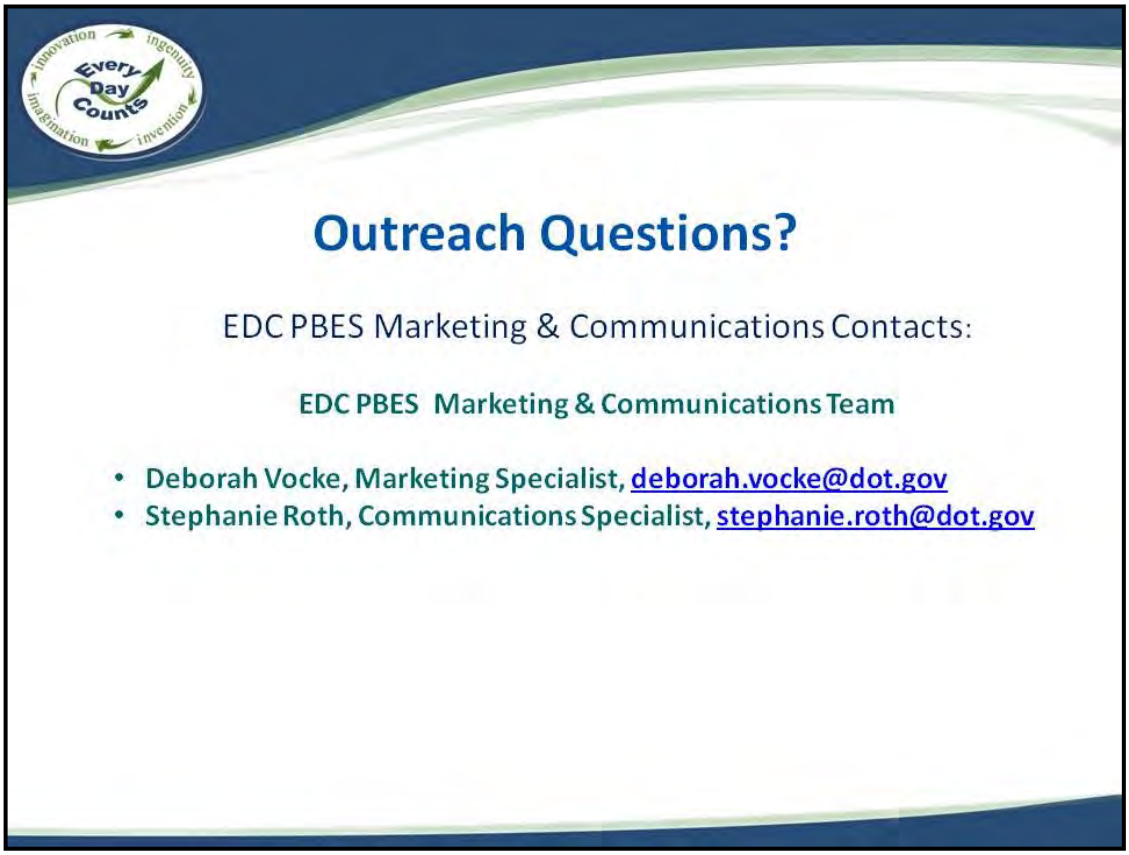


Slide 40:

Module 8 : Concrete Industry Efforts & Capabilities to Support PBES Deployment

MODULE LEARNING OUTCOMES

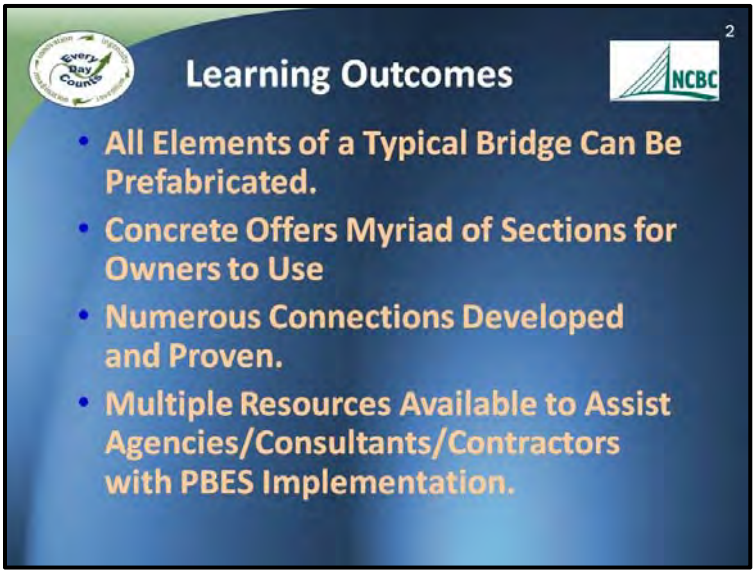
By the end of this Module, you will be able to:

- Identify Prefabricated Concrete Bridge Elements
- Recognize Standard Sections and Details
- Understand connections between Prefabricated Concrete Elements
- Assuring excellent quality of concrete elements
- Conclusions

MODULE SLIDES & NOTES

Slide 1:

This Module will discuss your concrete choices for PBES.



Slide 2:

This Module will discuss your concrete choices for PBES.

Slide 3:

These are the members of the National Concrete Bridge Council. Resources to help State DOTs, FHWA Division Offices, Consultants, Professors, and Contractors with the design and construction of prefabricated bridge elements and systems are available from these organizations.

American Coal Ash Association (ACAA):

Contact = Tom Adams, thadams@acaa-usa.org, http://www.acaa-usa.org/

American Segmental Bridge Institute (ASBI):

Contact = Randy Cox, wrcox@asbi-assoc.org, http://www.asbi-assoc.org/index.cfm

Concrete Reinforcing Steel Institute (CRSI):

Contact = Neal Anderson, nanderson@crsi.org, http://www.crsi.org/

Expanded Shale, Clay, and Slate Institute (ESCSI):

Contact = Reid Castrodale, rcastrodale@staalite.com, http://www.escsi.org/Default.aspx

National Ready Mix Concrete Association (NRMCA):

Contact = Lionel Lemay, LLemay@nrmca.org, http://www.nrmca.org/

Portland Cement Association (PCA):

Contact = Sue Lane, SLane@cement.org, http://www.cement.org/bridges/br_abc.asp

Precast/Prestressed Concrete Institute (PCI):

Contact = William Nickas, WNickas@pci.org, http://www.pci.org/intro.cfm

Post-Tensioning Institute (PTI):

Contact = Ted Neff, TedNeff@post-tensioning.org, http://www.post-tensioning.org/

Slag Cement Association (SCA):

Contact = Tony Fiorato, tony@slagcement.org, http://www.slagcement.org/

Silica Fume Association (SFA):

Contact = Tony Kojundic, tony.kojundic@elkem.com, http://www.silicafume.org/

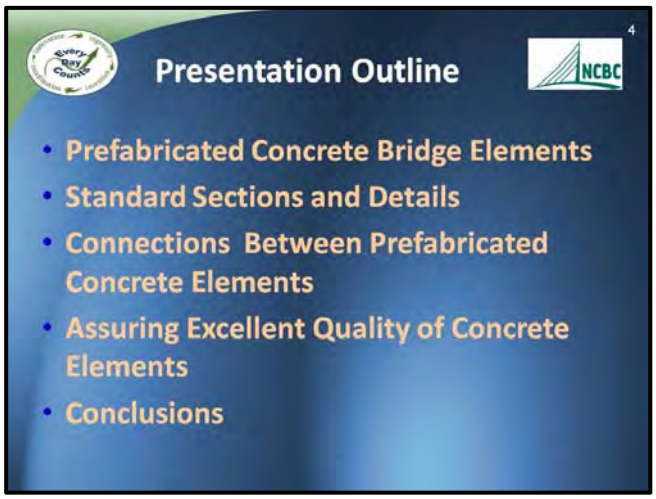
Wire Reinforcement Institute (WRI):

Contact = Todd Hawkinson,
todd@hawkinsonassociates.com,
http://www.wirereinforcementinstitute.org/

Slide 4:

This module will cover 5 major topics:

1. The Concrete Elements in PBES;
2. What Standard Sections and Details are available to Owners, Designers, and Contractors;
3. Viable Options for Connecting the Elements;
4. Making Sure that Owners, Consultants, and Contractors Have the Best Quality Concrete Elements;
5. Some Summary Thoughts;

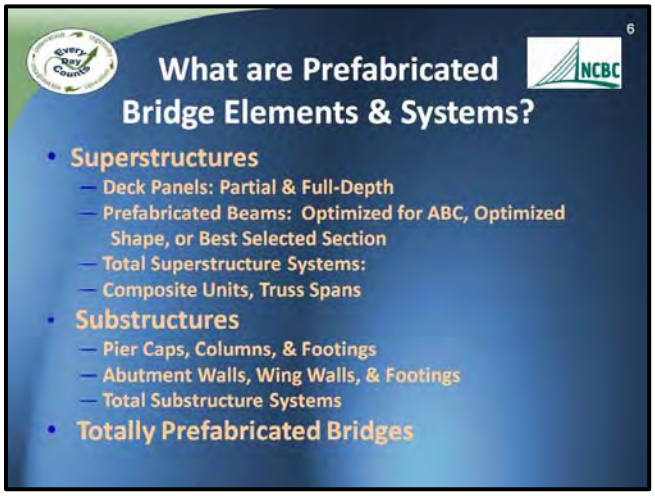


Slide 5:

Let's first discuss the Concrete Elements that make up PBES. These have all been used successfully on State DOT bridge projects.

Slide 6:

While prefabricated elements such as precast, prestressed concrete beams have been used in bridges for more than half a century, the current prefabricated bridges initiative also includes newer systems, such as full-depth deck panels and whole superstructure and substructure systems that are fabricated offsite or near-site and then quickly installed at the site.



PBES Superstructures include:

- ***Precast, Prestressed Deck Panels***— These can partial depth panels (Sub-deck panels) which function as stay-in-place forms as the remaining cast-in-

place portion of the deck is constructed or be full depth precast deck panels.

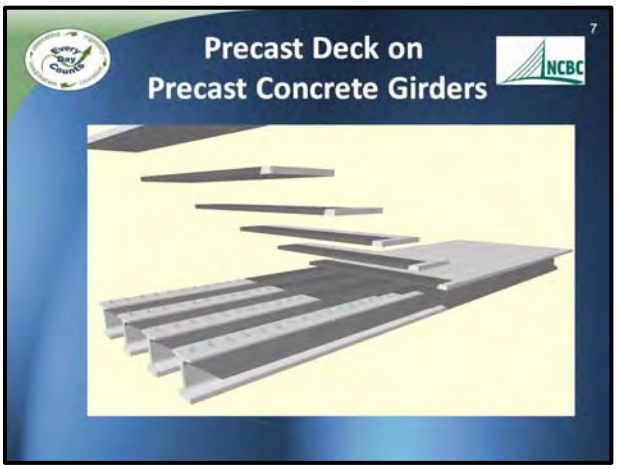
- ***Many shapes of Prefabricated Beams***—When coupled with High-Strength High Performance Concrete, these beams can span longer distances (possibly eliminating the need for an additional pier), can be of reduced depth (improving underclearances), or a fewer number of these beams can be used for a given cross-section and span length.
- ***Total Superstructures Fabricated Off-site and moved into place***—These can include the beams and deck already fabricated, sometimes coming with a sidewalk or bridge rails.
- ***Prefabricated Decks can be Precast and Pre-attached to Steel Beams –***These form Composite Units;

PBES Substructures Include:

- Precast Concrete Pier Caps, Columns or Piers, and Footings;
- Precast Concrete Abutments, Wing Walls, and Footings;
- Total Substructure Systems—Precast Pier Caps, Columns, Abutments, Wing Walls, and Footings or Prestressed Concrete Piles

PBES Totally Prefabricated Bridges:

- Precast Concrete Deck;
- Prestressed Concrete Beams;
- Precast Concrete Pier Caps;
- Precast Concrete Columns/Piers;
- Precast Abutment;
- Precast Wing Walls;
- Precast Footing and/or Prestressed Concrete Piles



Slide 7:

This slide shows Precast Deck Panels on Precast Prestressed Concrete Girders.

Slide 8:

This slide shows prefabricated concrete deck panels on top of concrete girders.

The MP200 Bridge is on US-6 between Spanish Fork and Price, Utah. This 93-foot long bridge was completed in June 2009. Prefabricated AASHTO Type VI Prestressed Concrete Beams were used; their 28-day compressive strength was 7500 psi. The abutment, deck, and parapets were all constructed with 4000 psi concrete.

Slide 9:

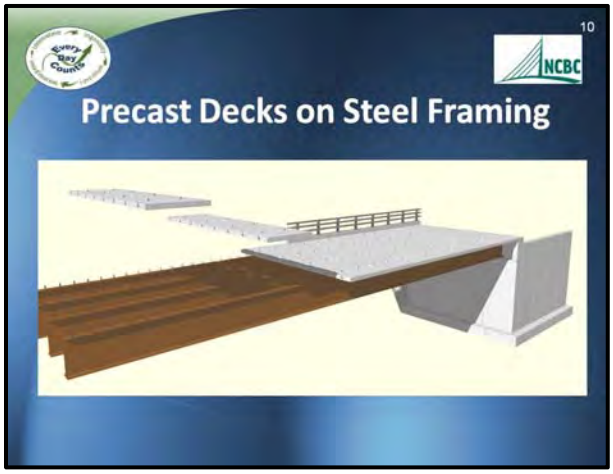
The Beaver Creek Bridge also was constructed with prefabricated deck panels on prefabricated concrete beams.

The Beaver Creek Bridge used precast, prestressed AASHTO Type IV concrete beams, with a compressive strength of 6000 psi. This 88-foot-2-in long bridge is located on US-6 between Spanish Fork and Price, Utah, and in addition to crossing the Beaver Creek also provides a wildlife passage. The deck, parapet, approach slabs and abutment are all constructed with 400 psi concrete. The precast concrete substructure was assembled onsite. The bridge was completed in October 2009.

Note that the reinforcement for this bridge was two mats (upper and lower) of Glass Fiber Reinforced Polymer (GFRP) rebar. The deck panels were post-tensioned longitudinally with steel strands.

Slide 10:

Precast Concrete Deck Panels can also be used with Steel Girders.



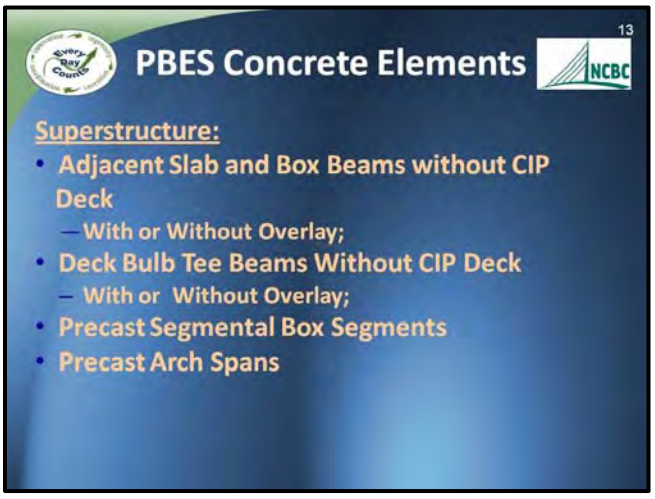
Slide 11:

The Eagle Canyon Bridge was a deck replacement project consisting of prefabricated concrete deck panels placed on top of the existing steel girders.

This bridge is located on I-70 between Salina, Utah and Green River, Colorado. It has a span of 484-feet-6-1/2-inches.

Slide 12:

The Eagle Canyon bridge was constructed with full depth, full width concrete deck panels. The concrete strength of the deck panels and parapet was 4000 psi.



Slide 13:

There are a plethora of options when it comes to prefabricated concrete beams/girders. Many standard shapes already exist across the U.S. In some instances, regional beam shapes are in use. The following slides will show many of these options.

Slide 14:

The Florida Department of Transportation's (FDOT) Graves Avenue over Interstate Four (I-4) Bridge Replacement Project was the first use of Self-Propelled Modular Transporters (SPMTs) to move bridge spans that crossed a U.S. Interstate highway.

Information about this project:

- Precast Prestressed 78-inch Deep Florida Bulb-Tee Girders in Replacement Superstructure;
- 8-inch Cast-in-Place Reinforced Concrete Deck in Replacement Bridge;
- Existing Spans Removed By SPMTs;
- New Girders and Deck Pre-Assembled Adjacent to Bridge Site;
- SPMTs Moved New Girders and Deck into Place;
- Each new span installed in few hours overnight;
- I-4 closed two partial nights for installations;

Old Bridge:

- 215-ft long, 30-ft wide
- 4 spans: 37'–70.5'–70.5'–37'
- AASHTO Type III beams
- 250 tons per 70.5-ft span
- Two 6-axle SPMTs

New Bridge:

- 286-ft long, 59-ft wide
- 2 spans: 143'–143'
- Florida 78" Bulb-T beams
- 1,300 tons per span
- Eight 6-axle SPMTs

Costs:

- Supplemental Agreement for Change Order to existing contract – $570,000;

Benefits:

- Graves Avenue detour reduced from 12 to 8 months, in time for start of school;
- I-4 lane closures decreased from 32 nights to 4 nights;
- Delay-related user cost savings of $2.2M;

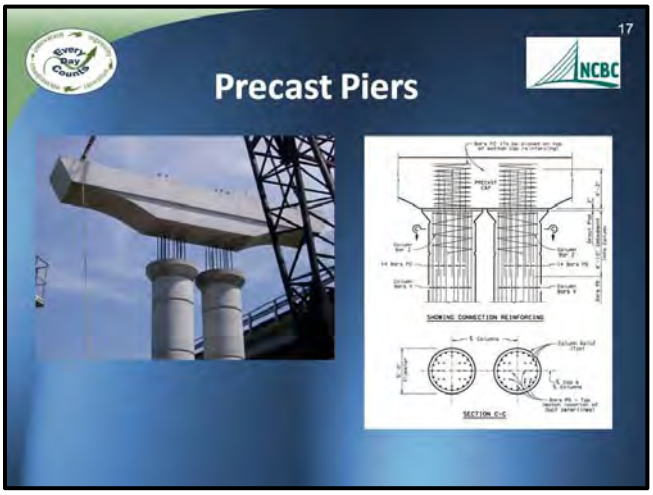
Slide 15:

This slide shows a prefabricated superstructure being transported to the bridge site using SPMTs. The superstructure consists of AASHTO Type IV Prestressed Concrete Beams (6000 psi compressive strength) with 4000 psi deck and parapets.

The Lambs Canyon Bridge is an 84-foot long bridge located on I-80 between Salt Lake City and Park City, Utah.

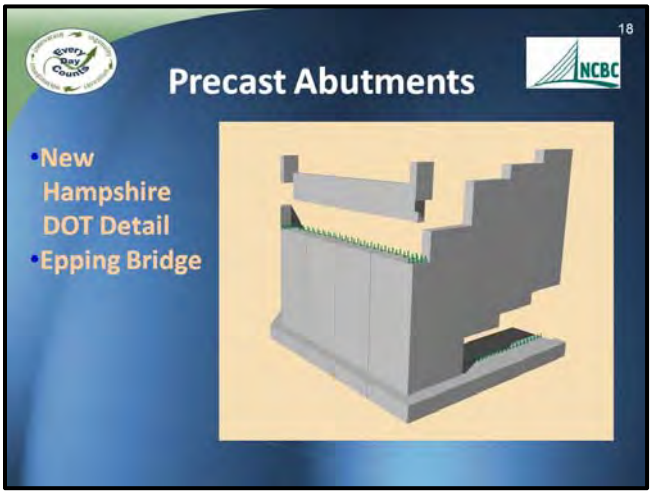
Slide 16:

There are also many options when it comes to precast concrete substructure elements. There are no national standard shapes yet for these elements, but many states have developed or are developing their own state standards and details for these elements.
The substructure can be constructed with all precast elements, or can be a combination of precast and cast-in-place (CIP) elements.



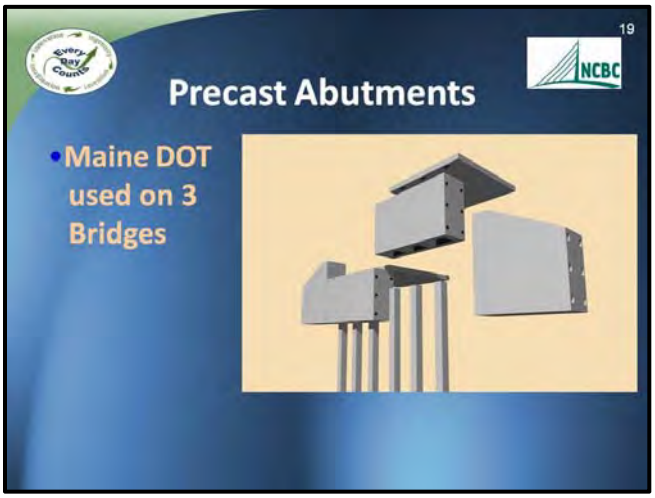
Slide 17:

Precast Pier Cap is shown, along with details.



Slide 18:

Precast abutments have also been used for PBES. This detail was used by New Hampshire DOT on their Epping bridge construction.



Slide 19:

Precast abutments can also be constructed by connecting prefabricated sections as shown.

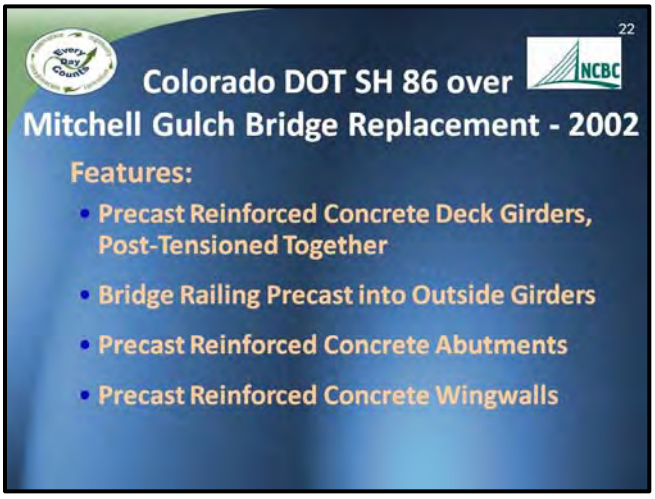
Maine DOT used this method on the construction of 3 bridges.

Slide 20:

Concrete Approach Slabs can also be prefabricated. This slide shows a prefabricated concrete approach slab being set in place for the Upton-Andover Dam Bridge Replacement in Maine. Maine DOT removed the old steel bridge and replaced it with a total precast concrete bridge, including approach slabs, with only 96 hours of roadway closure. The bridge replacement was done using conventional equipment, not SPMTs.

Slide 21:

As was seen in the previous slide with Maine DOT, a total precast concrete bridge can be fabricated and then constructed in a very short time.

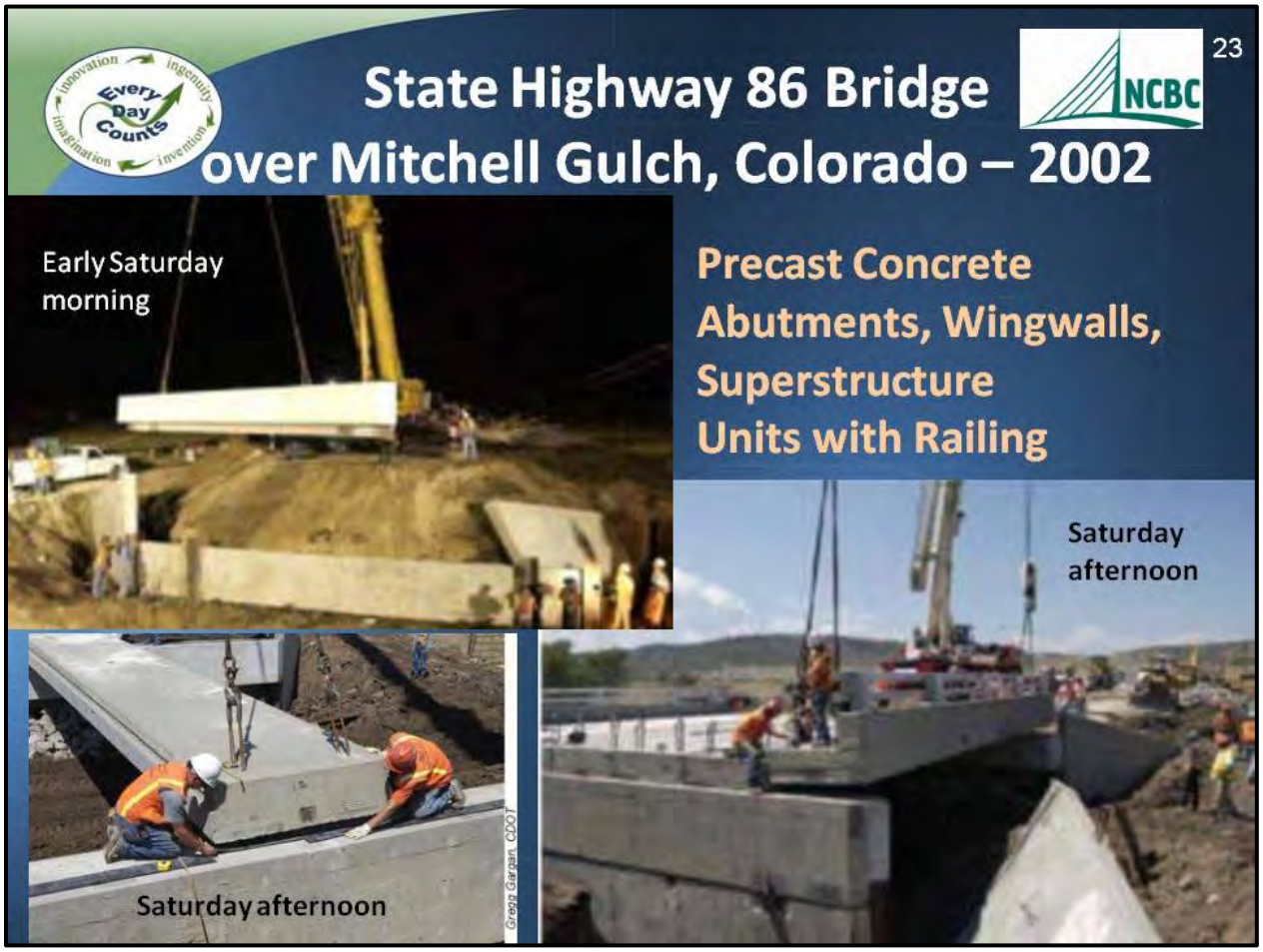


Slide 22:

Colorado DOT's State Highway 86 Bridge over Mitchell Gulch is located between Castle Rock and Franktown in Douglas County southeast of Denver, CO. The original timber bridge was built in 1953 and rated in 2002 as one of Colorado's ten worst bridges. The existing 40-ft long 2-span timber bridge was 26-ft wide with two 11-ft lanes and two 1.5-ft shoulders. The new 40-ft long concrete bridge, with 35-ft-clear single span, was 43-ft wide to accommodate two 12-ft lanes and two 8-ft shoulders.

Colorado DOT awarded the construction contract to Lawrence Construction Company to replace the deteriorated bridge with a conventional 3-cell cast-in-place concrete box culvert. However, the contractor was concerned about the steep downgrade of one of the approaches and a nearby curve, and how this would affect the safety of his construction crews. The contractor teamed with a local design firm,

Wilson & Company, to design and submit a value engineering change proposal to build the single-span totally prefabricated bridge over a weekend to improve the safety of his crew.



Slide 23:

Prior to the bridge closure, the contractor constructed a short detour to divert traffic for the weekend, and also drove 40-ft deep steel H piles at the abutments in the stream banks just outside the existing roadway width. The precast concrete abutments, wingwalls, and superstructure units were fabricated at Plum Creek Products Company in Littleton and shipped to the site just before being installed.

At 7 p.m. on a Friday in August 2002, the bridge was closed and traffic diverted to the detour. The existing timber bridge was demolished. Early Saturday morning, 44-ft wide precast abutments and 23-ft long precast wingwalls with embedded steel plates were erected with a crane and welded to the steel H piles and to each other prior to placing flowable fill behind the abutments. On Saturday afternoon, the eight 38'-4" long, 5'-4" wide, and 1'-6" deep precast superstructure units were erected, including the edge units complete with precast railing. The units were then transversely post-tensioned and grouted. Work stopped at 11 p.m. on Saturday and resumed Sunday morning at 7 a.m. to complete the earthwork and asphalt overlay.

The bridge was reopened to traffic at 5 p.m. on Sunday, 46 hours after closure of the existing bridge. Only 38 hours of construction work were required for the replacement.
The bridge is expected to see a 75-year service life due to the quality of its prefabricated components and the attention given to connection details.

Slide 24:

In 2003 the town of Epping's existing 28-ft wide 2-lane Mill Street Bridge over the Lamprey River consisted of two 30-ft long spans separated by a 60-ft long center pier causeway. The spans were deteriorated and required replacement. The low traffic volume crossing the bridge in combination with a short half-mile detour allowed complete closure of this bridge during its replacement.

The site was selected for the New Hampshire Department of Transportation's (NHDOT) first use of totally prefabricated cantilevered substructure construction. The location minimized the overall risk of using the precast abutment system that was newly developed by a team with members from the NHDOT, FHWA, University of New Hampshire, Precast/Prestressed Concrete Institute's Northeast Region Technical Committee, and local general bridge contractors and precasters.

In August 2004 the existing bridge was replaced with a 115-ft long and 28-ft wide 2-lane single-span pretensioned concrete adjacent box beam superstructure on full-height cantilevered precast concrete abutments founded on precast concrete spread footings. Thirty-two precast concrete segments were used to construct the bridge.

Slide 25:

The 32.4-ft wide 5,000 psi precast reinforced high performance self-consolidating concrete abutments consisted of 10 spread footing segments and 11 abutment wall and wingwall segments. All precast segments were fabricated at the J. P. Carrara & Sons plant in Middlebury, Vermont and shipped 170 miles to the jobsite. Spread footings provided significant speed and simplicity to bridge construction when soil conditions permitted their use as in this project and in many other New Hampshire bridge projects. The spread footings and other substructure components were fabricated in segments as determined by the contractor and precaster to facilitate shipping and handling, and were standardized to reduce fabrication costs. The precaster used a template in the plant fabrication to ensure adequate tolerances between the abutments, wingwalls, and footing segments. The contractor developed the assembly plan.

Following placement of the footings, a minimum 3-inch thick flowable grout bed was injected through grout tubes in the footings to provide a sound bearing surface for the roughened bottom surfaces of the footings. Proper grading was assured by using leveling screws cast in the corners of each footing segment. The abutment walls and wingwalls had splice sleeve connections to accommodate the reinforcing bars protruding from the tops of the footings. The walls were lowered into place, and the splice sleeves were then grouted to complete the bar splices. All horizontal joints were full-moment connections with grouted reinforcing bars, and vertical joints had grouted shear keys.

The erection of the abutments took 2 days, plus a third day to cure the grout and prepare for the backfill. Similar conventional cast-in-place abutments would have required 6 separate concrete placements and two months to construct.

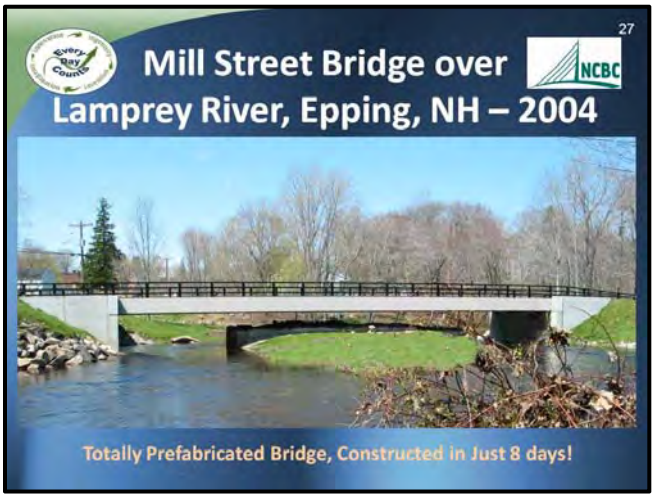
Slide 26:

The 115-ft long and 28-ft wide superstructure consisted of seven 4-ft wide adjacent box beams. The beams were fabricated with 8,000 psi pretensioned high performance concrete (HPC). The use of HPC in combination with 0.6-inch diameter pretensioned strands stretched the span of the 3-ft deep box beams to 115 ft, allowing the use of a single span.

Following erection of the beams, a precast concrete pilaster was set along the top of the stem wall on each side of the outside box beams to provide lateral load transfer between the superstructure and substructure and to improve aesthetics. Full-depth shear keys were then cast between each box beam, and the span was transversely post-tensioned in 6 locations to complete the connection between beams. A 3-bar aluminum railing was then installed. A waterproofing membrane was applied to the top surfaces of the box beams, followed by an asphalt overlay.

In spring 2006, the Lamprey River crested 1 to 2 ft above the bridge deck after heavy rains. Although the area has a significant flooding history, this level was the highest seen by Epping residents. The bridge showed no ill effects from the flood.

The bridge is expected to see a service life of at least 75 years due to the use of HPC, the quality of its prefabricated construction, the attention given to connection details, and an aggressive NHDOT maintenance and preservation program.

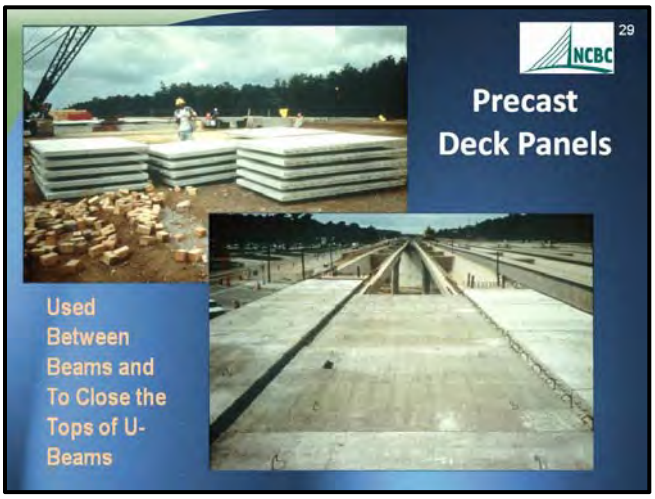


Slide 27:

This shows the completed Mill Street Bridge. The erection of the bridge, from start of footing placement to opening to traffic, required 8 days. The bridge was closed to traffic for a total of 2 months, compared to 5 months that would have been required for conventional construction.

Slide 28:

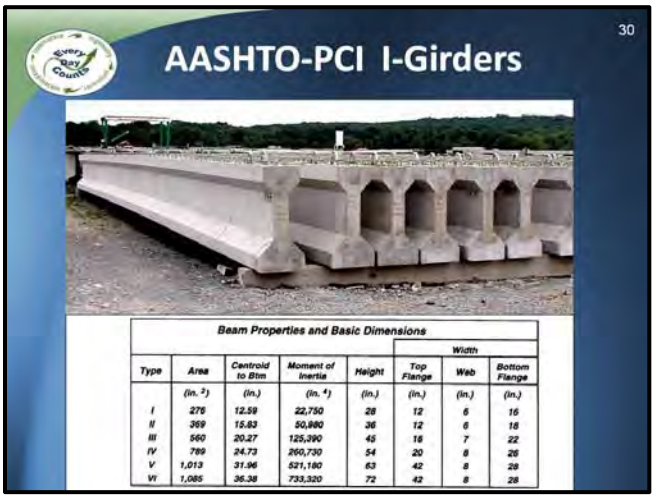
Many standard sections (shapes) and details already exist for precast concrete bridge elements.



Slide 29:

Precast concrete partial depth stay-in-place deck panels can be used between beams and to close the tops of the U-beams. About 85% of Texas bridges use these precast partial-depth deck panels as stay-in-place forms. Normally, about 3 ½ to 4 ½ in. of composite deck concrete will be cast on the panels. The prestressed concrete panels will provide the positive moment reinforcement for the deck.

Full-depth precast concrete deck panels are also available.

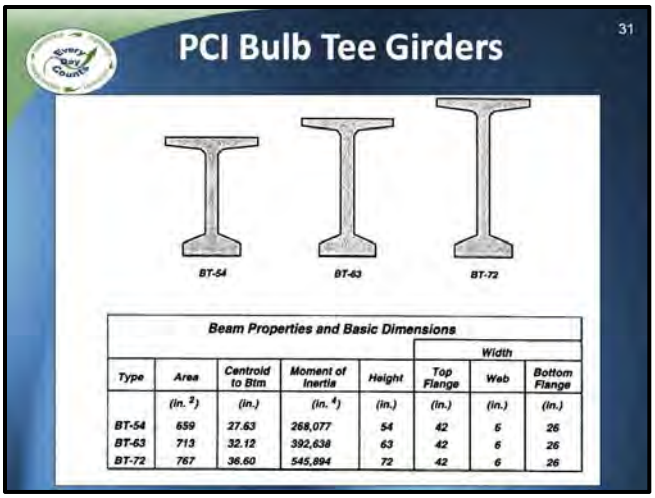


Beam Properties and Basic Dimensions

Type	Area	Centroid to Btm	Moment of Inertia	Height	Width: Top Flange	Width: Web	Width: Bottom Flange
	(in.^{2})	(in.)	(in.^{4})	(in.)	(in.)	(in.)	(in.)
I	276	12.59	22,750	28	12	6	16
II	369	15.83	50,980	36	12	6	18
III	560	20.27	125,390	45	16	7	22
IV	789	24.73	260,730	54	20	8	26
V	1,013	31.96	521,180	63	42	8	29
VI	1,085	36.38	733,320	72	42	8	28

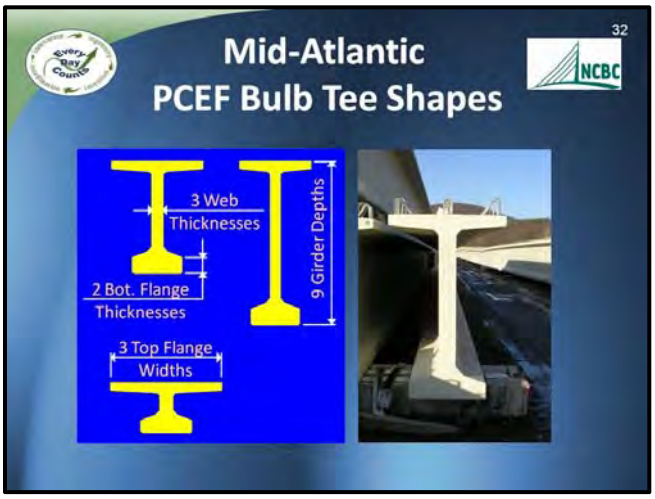
Slide 30:

Six different sizes of I-Girders have been standardized by AASHTO and the Precast/Prestressed Concrete Institute (PCI), and are available throughout the U.S.



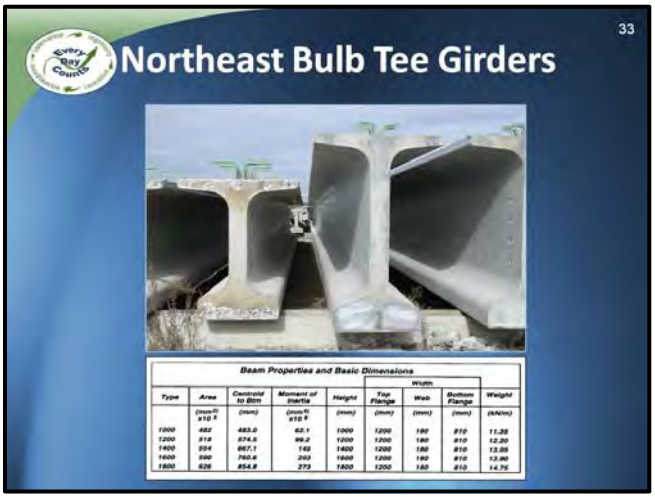
Slide 31:

There are also three standard sizes of Bulb-Tee Girders available throughout the U.S.



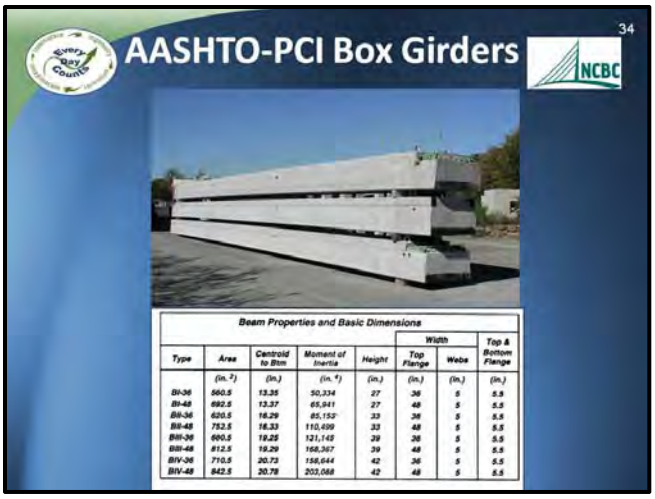
Slide 32:

The Mid-Atlantic states decided to modify the standard Bulb-Tee shape to create a new regional standard section—the PCEF Bulb-Tee. This work was done by the Prestressed Concrete Committee for Economic Fabrication (PCEF)—Mid-Atlantic, whose committee members include precasters, State DOT engineers, ready mix concrete producers, FHWA engineers, contractors, and consultants.



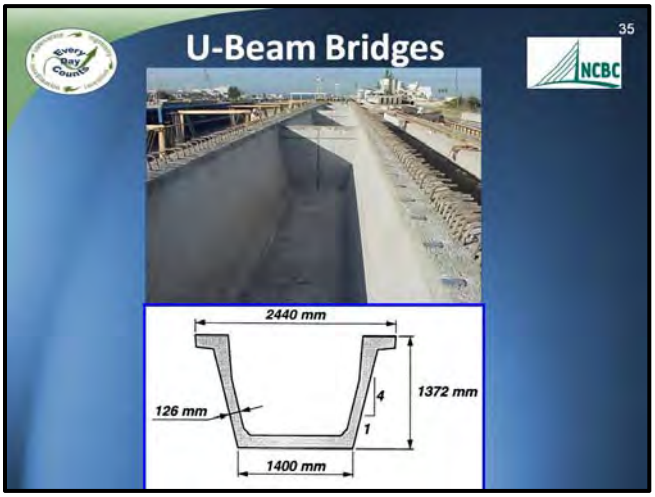
Slide 33:

The Northeast (or New England) states also decided to modify the standard Bulb-Tee shape to create a new regional standard section—the Northeast Bulb-Tee. This work was done by the PCI Northeast Technical Committee, whose committee members include precasters, State DOT engineers, ready mix concrete producers, FHWA engineers, contractors, and consultants. Section properties, details, load charts, and a design guide are available on the PCI Northeast website: http://www.pcine.org/index.cfm/resources/bridge/Northeast_Bulbtee.



Slide 34:

Eight different sizes of Box Beams have been standardized by AASHTO and PCI, and are available throughout the U.S.



Slide 35:

One of the special sections developed especially for aesthetic reasons is the open-topped trapezoidal box beam (or U-Beam). This is the Texas DOT version and one of the first used in a routine fashion for urban locations where visual impact is important. This section was developed to directly replace two Texas 54 in. deep I-Beams at 8-ft spacing.

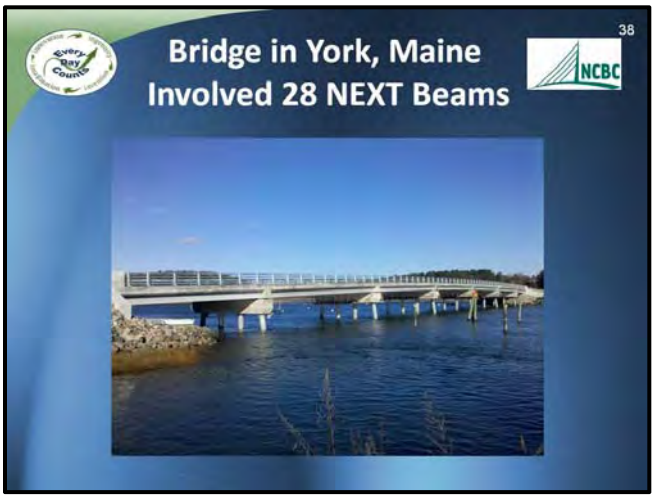
Slide 36:

The PCI Northeast Technical Committee has also published Guidelines for ABC Using precast/Prestressed Concrete Components. This helpful guide is available free on their website: http://www.pcine.org/index.cfm/resources/bridge/Accelerated_Bridge_Construction.

This group has also developed a new section optimized for ABC—it is called the Northeast Extreme Tee Beam or NEXT Beam. Standards for this beam are also available for free from the PCI Northeast website: http://www.pcine.org/index.cfm/resources/bridge/Northeast_Extreme_Tee_Beam

Slide 37:

This slide provides the details concerning the NEXT Beam. This beam was developed to facilitate ABC and to provide options for States with shallow bridges that have a lot of utilities. It works well in the 30-foot to 90-foot span range.



Slide 38:

The New Bridge over the York River in York, Maine is a 510-foot long, 7-span bridge with integral abutments. It was constructed with 28 NEXT Beams, either 55-feet or 80-feet long (depending on the span), in the superstructure. This bridge utilized the Type "F" NEXT Beam which has a partial top flange that serves as a stay-in-place form for the cast-in-place concrete topping. This particular bridge employed a 7-inch thick cast-in-place concrete topping.

Slide 39:

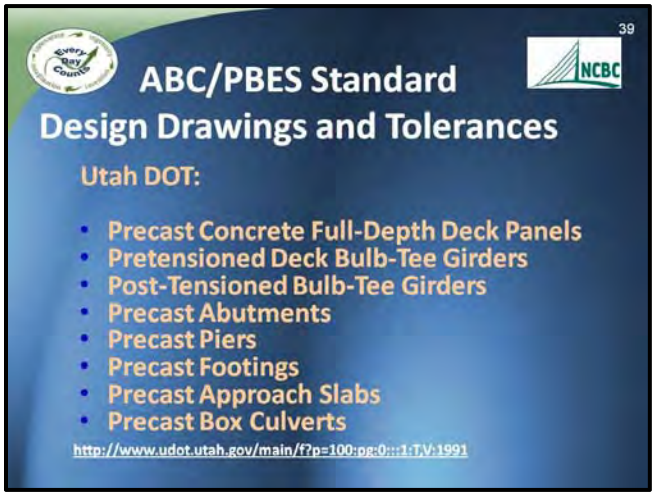
Utah DOT has standardized many precast concrete elements for use with ABC/PBES. These include precast concrete full-depth deck panels, abutments, piers, footings, approach slabs, and box culverts, as well as pretensioned concrete decked bulb-tee girders and post-tensioned bulb-tee girders.

Design Manuals and Tolerances are Available for:

- Full-Depth Precast Concrete Deck Panels
- Precast Concrete Bulb-Tee Girders
- Precast Substructure Elements (Piers, Integral Abutments, Semi-Integral Abutments, Cantilever Abutments, and Cantilever Walls)
- Precast Concrete Approach Slabs
- Precast Concrete Box Culvert

Standard Drawings are Available For:

- Full-Depth Precast Concrete Deck Panels
- Pretensioned Concrete Bulb-Tee Girders
- Pretensioned Deck Bulb-Tee Girders



- Post-Tensioned Bulb-Tee Girders
- Precast Integral Abutments
- Precast Cantilever Abutments
- Precast Piers and Footings
- Precast Approach Slabs
- Precast Box Culverts
- Tolerances for Precast Bent Caps, Abutments, Wall Elements, and Approach Slabs

Slide 40:

A previous module already discussed connections for PBES elements. That module highlighted Grouted Reinforcing Splice Couplers and Grouted Voids. Those are very valid options for connections. This section will highlight two other options for deck connections, Grouted Post-Tensioning and Cast-in-Place Ultra High Performance Concrete.

Slide 41:

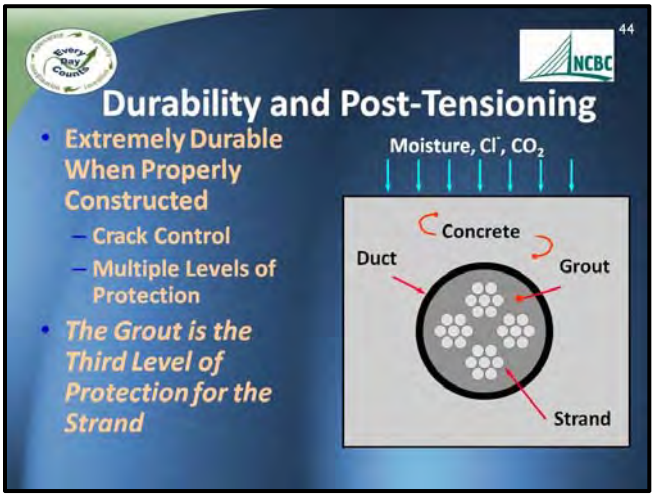
A great resource is the *Connection Details Manual for Prefabricated Bridge Elements and Systems*. It includes connection details used across the US. Sample construction specifications and case studies are also included.

Slide 42:

As was noted earlier, a previous module already discussed connections for PBES elements. That module highlighted Grouted Reinforcing Splice Couplers and Grouted Voids. Those are very valid options for connections. This section will highlight two other options for deck connections, Grouted Post-Tensioning and Cast-in-Place (CIP) Ultra High Performance Concrete (UHPC).

Slide 43:

Let's discuss one of the options, Post-Tensioning for Deck Connections.



Slide 44:

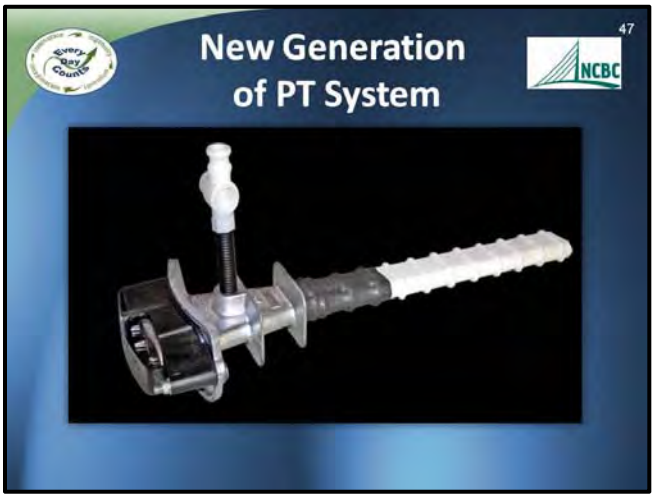
Post-tensioning produces compression of the concrete and eliminates or reduces cracking. The prestressing steel is protected by multiple levels of protection. Proper grouting is extremely important to obtaining a durable post-tensioned bridge.

Slide 45:

Modern post-tensioning systems provide a multi-layer level of protection for steel post-tensioning tendons. This begins with a high quality concrete such as high performance concrete, with proper curing and cover. The next layer is a non-corrosive (non-metallic) post-tensioning duct with watertight connections. The next level is permanent protection of the post-tensioning anchorage. A permanent grout cap is the next level of protection, so that no water or other materials can enter the member. The final layer is a high quality grout (high performance grout), typically employing anti-bleed and thixotropic admixtures.

Slide 46:

Field performance and research indicated that galvanized metal ducts offered little corrosion protection. Plastic ducts provide an added layer of protection. Plastic Ducts are also air and watertight.

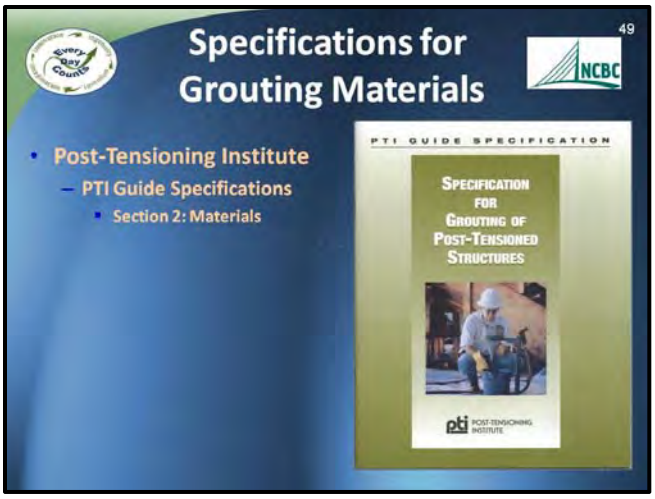


Slide 47:

New Post-Tensioning system: galvanized anchor, plastic duct, heat shrink connection, permanent plastic grout cap, positive grout cut-off valve.

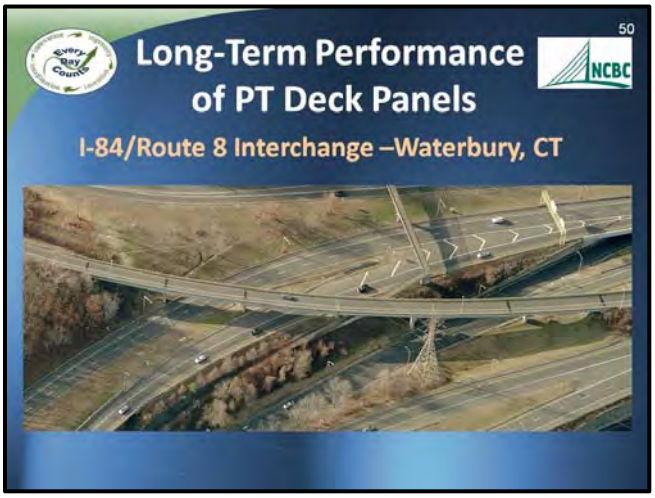
Slide 48:

Permanent grout caps are used so that no air, water, or other material can enter the grout.



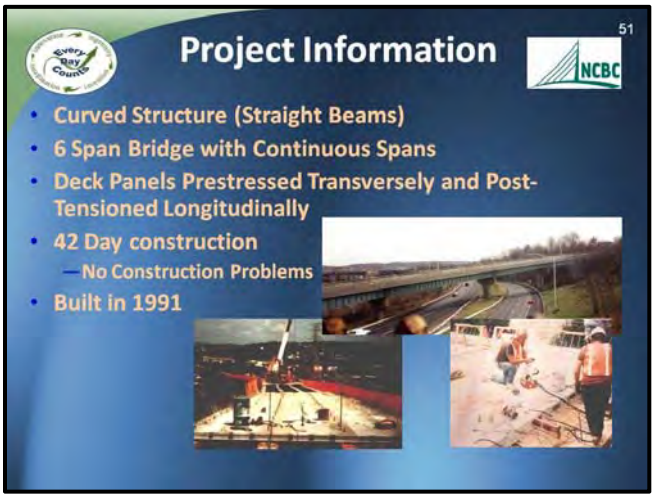
Slide 49:

Post-Tensioning Institute (PTI) specifications establish requirements for post-tensioning grouts used in aggressive and non-aggressive environments.



Slide 50:

This slide shows the I-84/Route 8 Interchange in Waterbury, Connecticut. It is an example of good long-term performance of deck panels that have been post-tensioned together. This structure was built in 1991.



Slide 51:

This slide provides information about the I-84/Route 8 Interchange. Note that precast prestressed concrete deck panels were used which were pretensioned transversely and post-tensioned longitudinally.

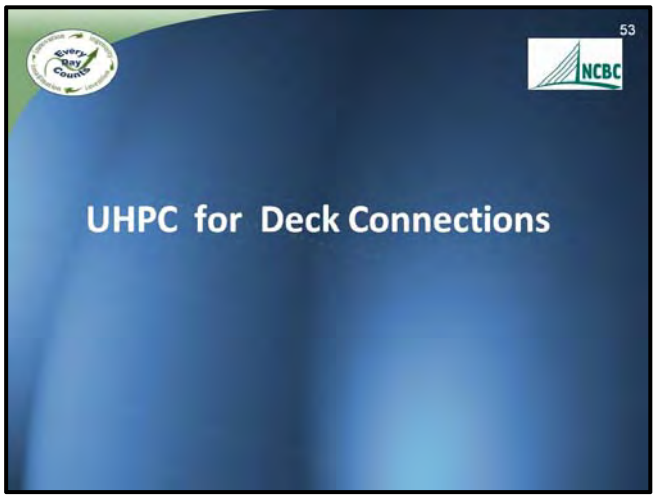
Slide 52:

The photos show the underside of the I-84/Route 8 Interchange in 2011 after 20 years of service in Connecticut, which is subject to harsh winters. The left photo displays the underside of the whole superstructure, while the right photo reveals a close-up of the post-tensioned deck panels. The photos exhibit:

- Excellent condition of the post-tensioned deck panels after 20 years of service.
- No leakage through the joints

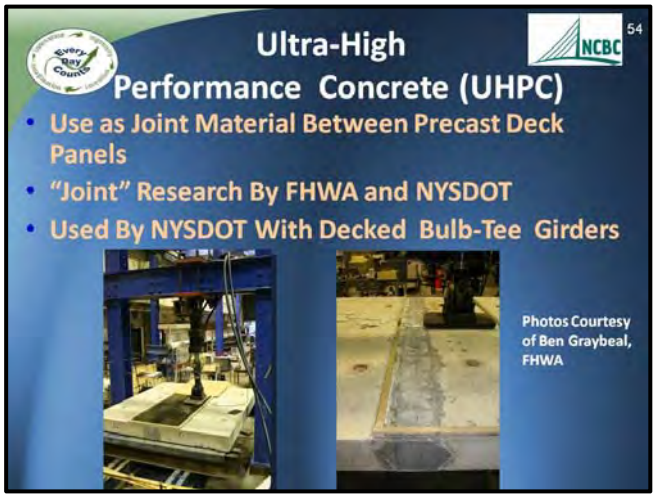
Note that the deck was constructed with membrane waterproofing and an asphalt wearing surface.

Slide 53:



Now let's discuss another option, cast-in-place Ultra High Performance Concrete (UHPC) for deck connections.

Slide 54:



The Federal Highway Administration (FHWA) has tested cast-in-place UHPC as a joint material between precast deck panels. This research was conducted at the FHWA's Structures Laboratory at the Turner-Fairbank Highway Research Center, and was a "joint" research study (pun intended) with New York State Department of Transportation (NYSDOT).

The left photo shows the fatigue load being applied on top of the slab, with ponded water on the slab and over the joint. This was done to see if any water would leak through the joint during fatigue loading—none did. The right photo reveals a close-up of the UHPC joint. After successful performance of the joint, NYSDOT used UHPC in joints between deck bulb-tee girders.

Slide 55:

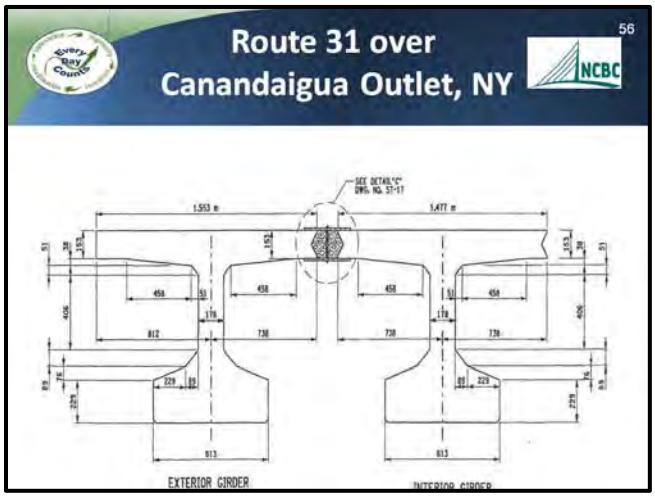
NYSDOT first used cast-in-place UHPC as the joint material between precast deck bulb-tee girders on the Route 31 Bridge over Canandaigua Outlet.

Some facts about the bridge:

- 85'-0" (25.91 m) Span;
- 42'-9" (13.03 m) width;
- 15° skew
- 3'-5" (1.04 m) deep Deck Bulb-Tee girder;
- 5'-4" (1.63 m) Deck Bulb-Tee spacing.

Slide 56:

This slide shows a drawing of the UHPC joint between the deck bulb-tee girders.



Slide 57:

This slide exhibits the deck bulb-tees in place, as well as a close up of the joint, prior to placement of the UHPC.

Slide 58:

Cast-in-place UHPC is then placed in the joints.

Slide 59:

This slide shows the finished deck of the bridge.

Slide 60:

The performance of the bridge is dependent on the performance of its elements. It is worth it in the long run to construct with excellent quality concrete elements.

Slide 61:

The National Ready Mixed Concrete Association (NRMCA) has a number of certification programs to help ensure that personnel are knowledgeable and able to perform all aspects of mixing and placing ready-mixed concrete.

Slide 62:

The Concrete Reinforcing Steel Institute's (CRSI) fusion-bonded epoxy coating applicator plant certification is a voluntary industry-sponsored program — extremely effective at improving the quality of epoxy-coated rebar.

A certified plant and its employees are trained, equipped, and capable of producing high quality epoxy-coated reinforcing bars. The plants are randomly inspected, a minimum of once a year, by an independent third party. The purpose of CRSI's plant certification program is to:

- Help plants produce and deliver high quality material
- Improve plant operations
- Recognize excellence

The certification program is based on meeting ASTM standard specifications for epoxy-coated reinforcing bar. Components of the CRSI certification program are more stringent than ASTM. Areas evaluated in the program include:

- Quality control policies and procedures
- Handling and storage practices
- Surface preparation
- Curing
- Holiday testing
- Thickness measurement
- Adhesion testing

Slide 63:

For more than 40 years, the Precast/Prestressed Concrete Institute (PCI) has certified manufacturers of precast/prestressed concrete products. The certification program also addresses plant personnel. This assures owners, specifiers, and designers that precast concrete products are manufactured by companies that subscribe to nationally accepted standards, have comprehensive quality systems in place and are audited to ensure compliance.

Plants

PCI's Plant Certification Program ensures that each plant has developed and documented an in-depth, in-house quality system based on time-tested, national industry standards. Each plant undergoes two thorough, unannounced audits each year. The audits are conducted by competent third-party engineers who audit the plant according to requirements specifically developed for the types of products being manufactured.

Personnel

The Plant Quality Personnel Certification Program, started in 1985, provides instruction and evaluation for three levels of trained, knowledgeable, and certified quality-control personnel. PCI also trains Certified Field Auditors (CFAs) and Certified Company Auditors (CCAs), who inspect and qualify, precast concrete erectors.

Slide 64:

The Post-Tensioning Institute (PTI) offers training and certification workshops for field personnel. Proper training and education of personnel involved in post-tensioning field operations—installers, inspectors, engineers, and others—are vital to ensuring the performance, serviceability, durability, and safety of post-tensioned concrete construction.

Level 1 & 2 Bonded PT Field Specialist training and certification is specifically aimed at field personnel involved in the installation, stressing, grouting, and inspection of bonded post-tensioning multi-strand and bar systems used in bridge and building construction.

Slide 65:

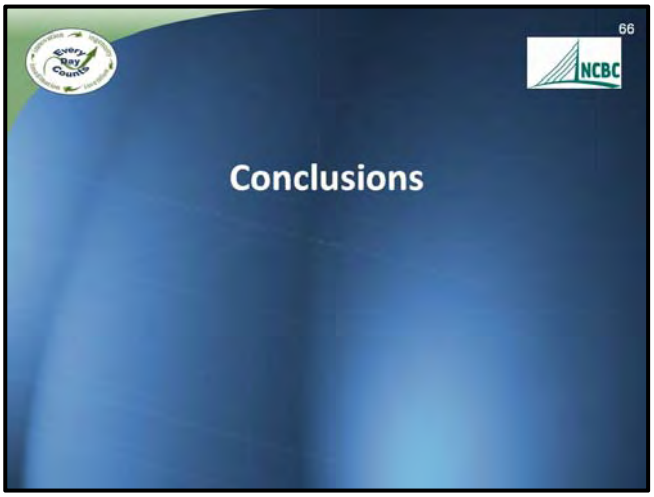
The purpose of the American Segmental Bridge Institute's (ASBI) Grouting Certification Training is to provide supervisors and inspectors of grouting operations with the training necessary to understand and successfully implement grouting specifications for post-tensioned structures. The Florida Department of Transportation has accredited the ASBI Grouting Certification Training Course; therefore, individuals who pass the final examination of the ASBI course satisfy one of the requirements for becoming a Qualified Grouting Technician with the Florida Department of Transportation.

ASBI Certified Grouting Technician

Individuals who successfully complete the ASBI Grouting Certification Training and provide verifiable documentation of three years of experience in construction of grouted post-tensioned structures, receive a certificate as an "ASBI Certified Grouting Technician." The certificate is valid for a period of five years, and is renewable at the end of that time through participation in an online recertification examination. To receive this certificate, submission of verifiable documentation of experience is required.

ASBI Grouting Training Certificate

Individuals who successfully complete the ASBI Grouting Certification Training and do not have three years of verifiable documented experience in construction of grouted post-tensioned structures, receive an "ASBI Grouting Training Certificate." In the five year period following completion of the training, individuals with this certificate may obtain an "ASBI Certified Grouting Technician Certificate" upon submission of verifiable documentation of three years' experience in construction of grouted post-tensioned structures.



Slide 66:

Now let's move to conclusions.

Slide 67:

Conclusions:

1. All Elements of a Typical Bridge Can Be Prefabricated.
2. Concrete Offers Myriad of Sections for Owners to Use
3. Numerous Connections Developed and Proven.
4. Multiple Resources Available to Assist Agencies/Consultants/Contractors with PBES Implementation.

Slide 68:

Thank you for participating today.

Module 9: Steel Industry Efforts & Capabilities to Support PBES Deployment

MODULE SLIDES & NOTES

Slide 1:

Slide 2:

Slide 3:

Using PBES can facilitate meeting several key needs:

Minimizes Traffic Impacts of Bridge Construction Projects
Using prefabricated bridge elements and systems means that time-consuming formwork, concrete curing, and other tasks associated with fabrication can be done offsite in a controlled environment without affecting traffic.

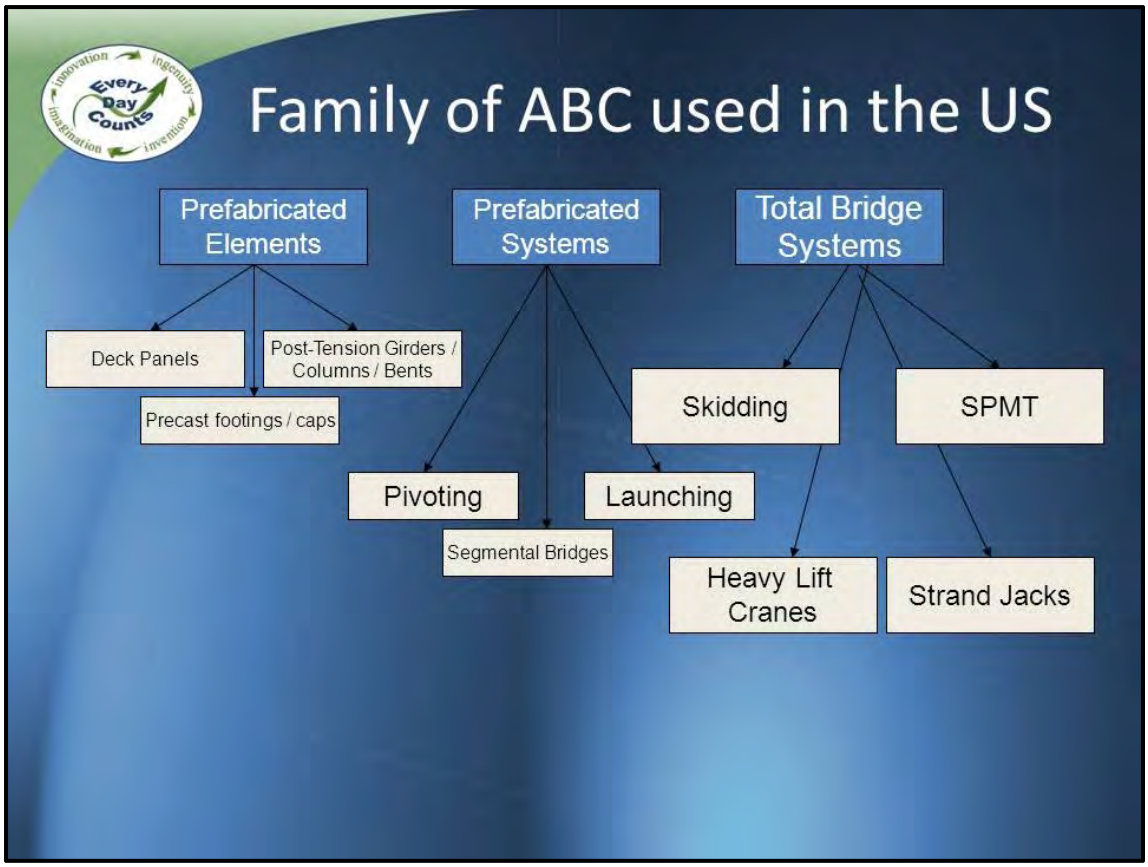
Improves Construction Zone Safety
Because prefabrication moves so much of the

preparation work for bridge construction offsite, the amount of time that workers are required to operate onsite, frequently in or near traffic or at high elevations or over water, is greatly diminished. Job site hazards and constraints such as nearby power lines are minimized when workers can complete most of their construction offsite.

Makes Construction Less Disruptive for the Environment
Bringing prefabricated superstructures and substructures to the site ready for installation reduces disturbance to the land surface at the site, and it reduces the amount of time required onsite for heavy equipment. Keeping equipment out of sensitive environments is less disruptive for those environments.

Improves Constructability
Many job sites impose difficult constraints on the constructability of bridge designs—heavy traffic on an Interstate highway that runs under the bridge being constructed, difficult elevations, long stretches over water, or restricted work areas due to adjacent properties, to name a few. Using prefabricated bridge elements and systems relieves such constructability pressures.

Increases Quality and Lower Life Cycle Costs
Prefabricating bridge elements and systems takes them out of the critical path of the project schedule: work can be done ahead of time, using as much time as necessary, in a controlled environment. This reduces dependence on weather and increases quality control of the resulting bridge elements and systems. All projects that use prefabricated bridge elements and systems increase the quality of their components; most also lower life cycle costs.



Slide 4: While there are many means that methods that contribute to ABC, we will mostly focus on Prefabricated elements such as deck panels and sub and superstructure assemblies. Look for the use of Self Propelled Modular Transporters in upcoming slides.

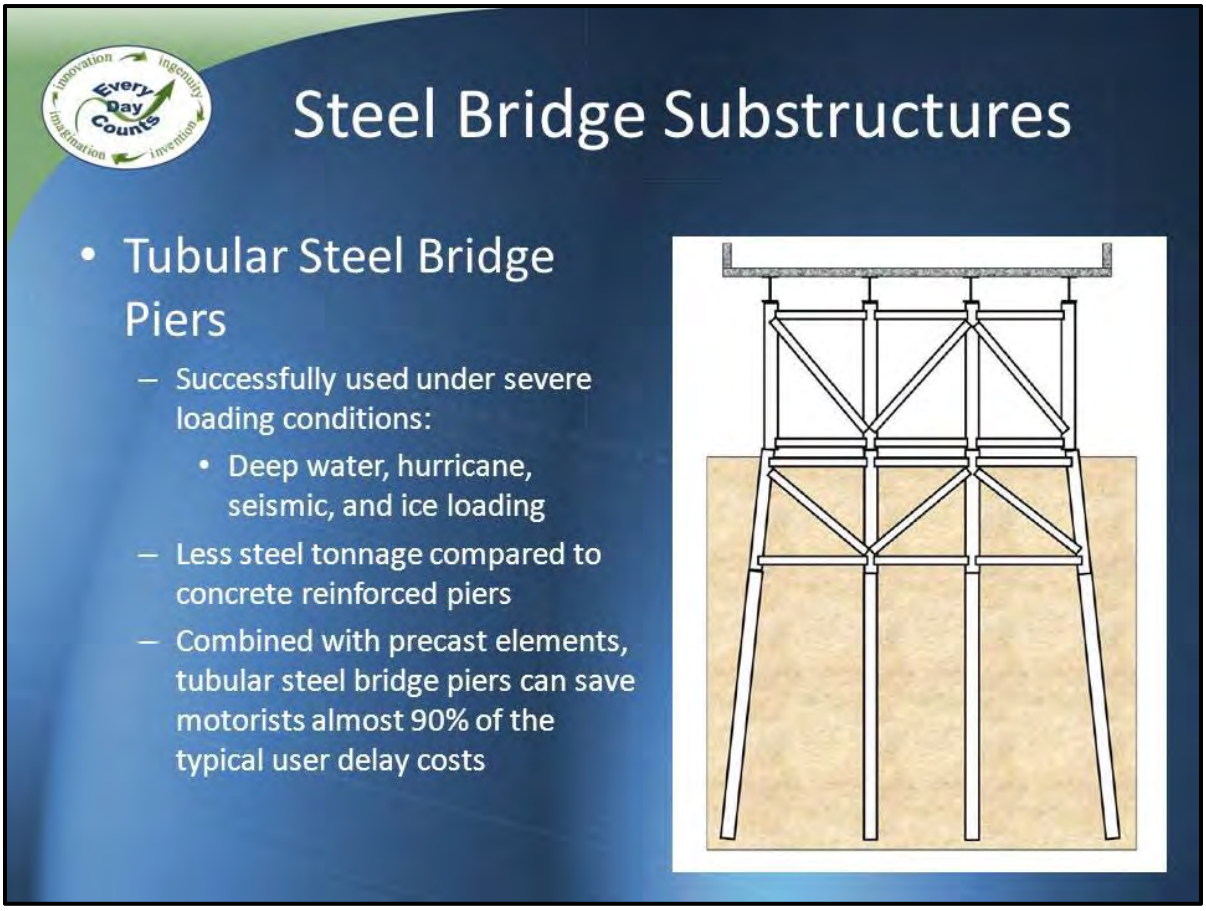
Slide 5:

Preformed steel piles can consist of H-sections, box sections, but also tubular sections, which usually are not filled with concrete after driving.

Driven steel piles have high load-carrying capacity for a given weight of pile, which can reduce driving costs.

Steel piles:

- Can have a high carrying capacity, when driven to a hard stratum
- Can withstand even hard driving without risk of damage
- Can readily be cut down and re shaped for further driving
- Cause relatively small soil displacement
- Can be readily extended/spliced without much delay by welding or splicing, thus long piles can be installed without the need of a very long leader
- Can be readily cut if not driven to full penetration, and the cut-off portions can be reused or have value as scrap material
- Can be roughly handled without risk of damage
- Can have good resistance to lateral forces and buckling
- Can be easily combined with water jetting and grouting



Slide 6:

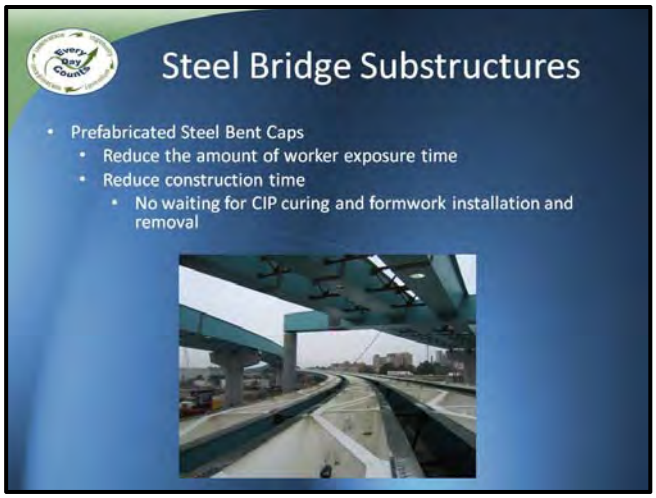
Proven Technology:

Developed for Offshore Structures Industry: To meet the construction demands for deep water fixed offshore platforms, modular tubular steel braced frames proved successful. The full depth space frames are fabricated on shore, transported to the offshore site, launched from the construction barge, positioned on the seafloor, and piles are driven to fix the structure to the seabed.
Modular Tubular Steel Technology has been applied worldwide over 70 years on more than 5,000 fixed offshore platforms.
It has been successfully used in the most severe conditions.

- Deep Water Platforms: North Sea
- Hurricane Loads: Gulf Coast
- Seismic Conditions: California Coast
- Ice Loads: Arctic Locations

Tubular Steel Bridge foundations significantly reduce the overall bridge construction schedule. Combined with precast elements, it can save motorists almost 90% of the typical user delay costs.
Source: Introduction to Tubular Steel Piers by Will Reeves

Slide 7:



Substructure: Bent Caps
Cast-in-place bent caps require sequential construction processes, including extensive formwork erection and removal, as well as concrete curing time. If they are fabricated offsite, these sequential processes are not a factor.
As a result, bridge owners and contractors are turning to prefabricated bent caps:

- For over-water bridges, they reduce the amount of time that workers need to operate over water.
- For bridges over existing roadways, they reduce the disruption to traffic on the lower roadway.
- For bridges with job-site constraints, such as power lines that affect work zone safety, they limit the amount of time that workers are at risk.

Slide 8:

Superstructure: Decks
Prefabrication offers exceptional advantages for deck construction, particularly for removing deck placement from the critical path of bridge construction schedules, for cost to place the deck, and for quality of the deck.

Slide 9:

Precast concrete panel system shown provides for the driving surface.

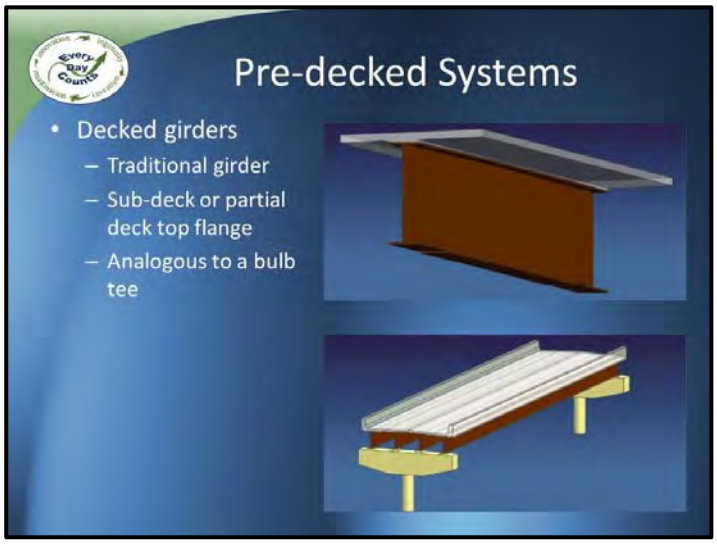
Longitudinal openings provide access for tensioning cables. As more and more panels are added, cables are tensioned to pull panels together. Once the tensioning strands reach the appropriate tensile stress, the openings are filled, engaging the shear studs, and locking the panels into place. Because the panels are pulled together, there is no need for grout within the transverse joints between panels.

For wider applications, a longitudinal closure pour is required.

Slide 10:

Deck options: Steel Grid Decks, FRP Decks, Partial Depth Deck Forms (which remain in place)

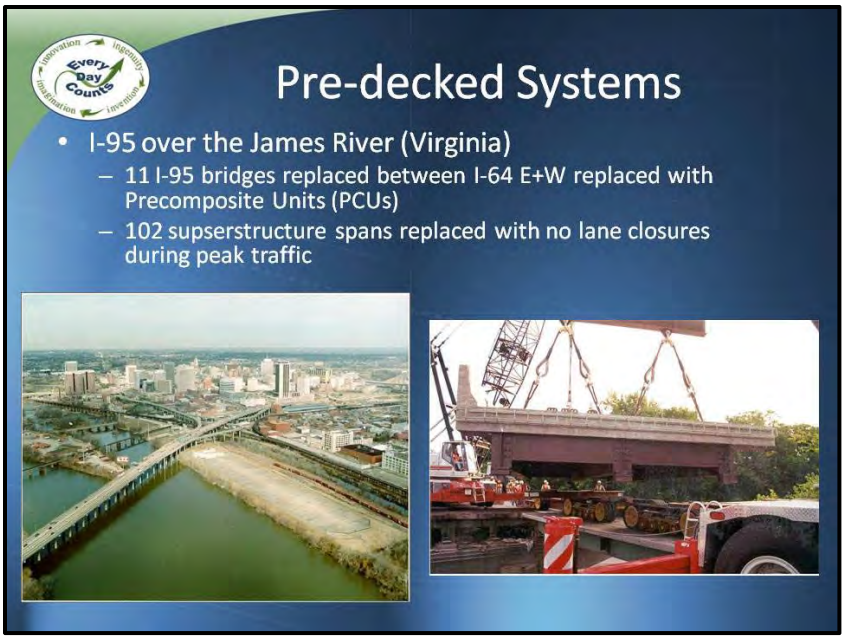
Full-depth prefabricated bridge decks (shown here) facilitate and speed construction, and bridge designers are finding innovative ways to connect full-depth panels to ensure durable connection details.



Slide 11:

Instead of just laying girders and then a cast in place deck…Lay modules down and connect in place for faster construction

Modules can even come with barriers already in place.



Slide 12:

Minimal impact on motorists was a project goal for replacement of the superstructure of the I-95/James River Bridge, which carries approximately 110,000 vehicles per day through the city of Richmond. After considering alternatives, the Virginia Department of Transportation opted for night-only construction, most of which occurred between 7 PM and 6 AM Sunday through Thursday nights. During nighttime construction, one lane of traffic was kept open in each direction. For most spans, bridge Preconstructed composite units (PCU's), which include an 8-¾-inch deck over steel plate girders, were precast at a nearby casting yard and then transported to the work site. Work crews cut out the old bridge span and removed it, prepared the gap for the new PCU, and set the new PCU in place.

Slide 13:

By building the bridges in sections, at locations away from the roadways, MassDOT is greatly reducing the duration of on-site construction. By erecting the bridges over weekends, MassDOT will not impact weekday rush-hour traffic. To lessen the impact on local communities, MassDOT is timing the work so that only one local street is impacted each weekend. MassDOT has also been working with emergency responders to ensure that emergency services operate without interruption throughout the project. The project team will also distribute the work schedule widely to advise visitors, residents and commuters on how to avoid delays and reach their destinations and businesses during construction.

Slide 14:

Inverset – system built upside down – only one company in the country can do it – grouted shear key – variable girder spacing
Great system for low volume roads

Simple precast deck on simple girders (unlike Inverset where slab is cast inverted) – details are essentially the same as traditional bridge construction.

Simple cast in place construction.

Emulating a traditional cast in place deck with precast – High early-strength concrete

Slide 15:

You'll notice that the section shown in this slide looks very similar to what is called the "Inverset" system which we'll look at on the next slide.

Threaded dowels are part of the Link-Slab technology concept in which structural beam spans are not continuous while the deck elements ARE continuous over the length of the bridge.

The key is that these elements are jointless.

MassDOT finished the last bridge this last weekend with a total of 10 55-hour closures (each bridge was completed in less than 48 hours!)

Learning/Cost curve that Jim McMinimee talks about:
1st weekend – 200 workers on site (tons of labor) because it was risky – they had not constructed a bridge in this manner before. Cost a lot of money.
By week 4 – number of workers onsite went down to 30 as they became comfortable with the technique
With lower labor costs and higher efficiencies, the marginal cost of each bridge installed went down dramatically – T his is a great, real, example on how ABC using PBES can be successful.

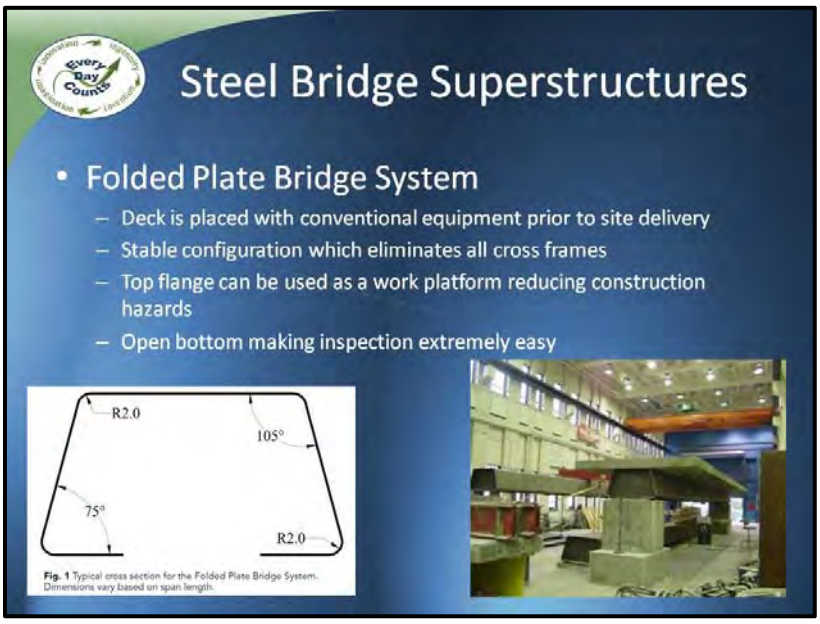
What's important to take away from this slide is that just doing one bridge using ABC will make a positive difference, but states will get the most bang for their buck if they can work a multitude of ABC bridges into their portfolio.

Slide 16:

The Inverset system is a precast, pre-compressed concrete/steel composite superstructure made up of steel beams and a concrete slab that acts as a composite unit to resist its own dead load. The deck is cast upside down in forms suspended from steel girders, allowing the combined weight of the forms and the concrete to produce a prestressing effect on the girders. Also, when the units are turned over the concrete deck is then pre-compressed. The resulting compression in the concrete deck offers enhanced resistance to cracking. The fabrication of the units in a controlled environment allows for replacement of bridge sections even in the coldest winter months with minimal lane closure time. The systems can be fabricated in any width with a span ranging from 20' to over 100'. When shipping on highways, the width of the units is generally limited to 8 feet. They can also be skewed or contain vertical curves as the site dictates.

It should be noted that this bridge type was first introduced and patented under the brand name "Inverset“ a play on Inverse – set (i.e. casting the deck upside down). Since then this patent has expired and the system is no longer proprietary.

Source: http://www.fhwa.dot.gov/bridge/prefab/psbsreport03.cfm
Image 1+2: Delta Engineers Prefabricated Bridges PDF

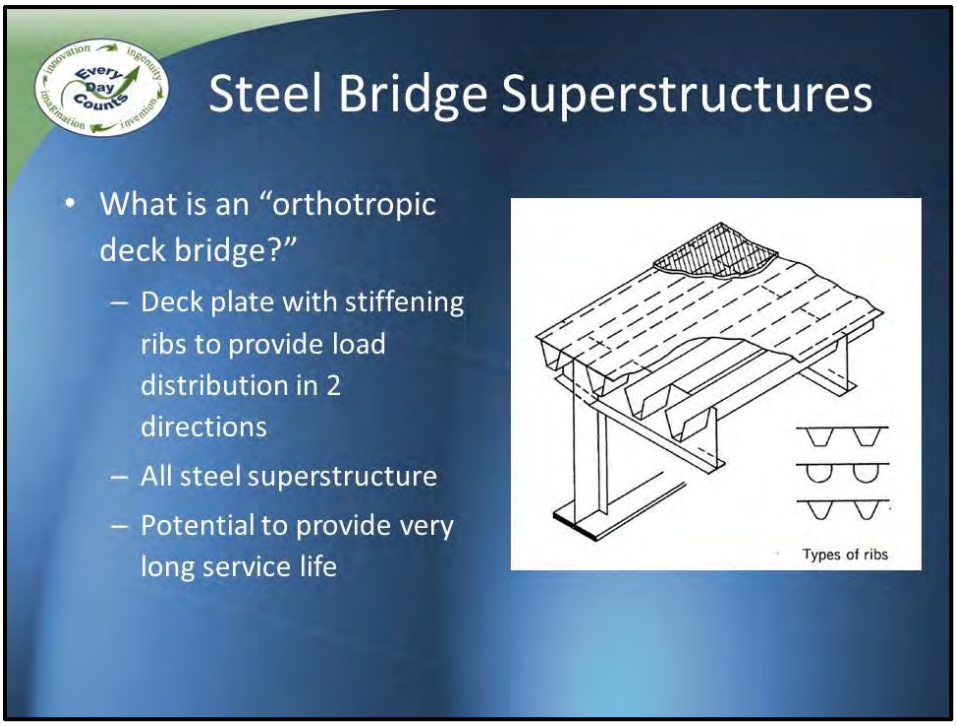


Slide 17:

Great solution for short span bridges.

Length is limited by plant equipment capabilities (i.e. press break) Mass Highway will be putting one into place this year.

Slide 18:



Slide 19:

In essence, the steel deck acts as the top flange for the steel girder supporting the section. Because concrete is cast on the deck, composite action is acquired through the finished assembly.

Orthotropic deck bridges make sense for large spans due to their light weight.

Slide 20:

Improve safety performance of structures and long –term safety improvement

- Light superstructure can be used to facilitate preassembly and rapid construction
- [KEY TAKEAWAY OF THIS SLIDE]Closed girder sections can provide superior service life with less surface area subjected to weather
- Boxed girders or decked I-girders eliminates torsional failure modes during erection
- Conventional cross frames eliminated minimizing elevated assembly work
- Erected girders provide a safe working platform, essentially eliminating one source of construction worker fatalities

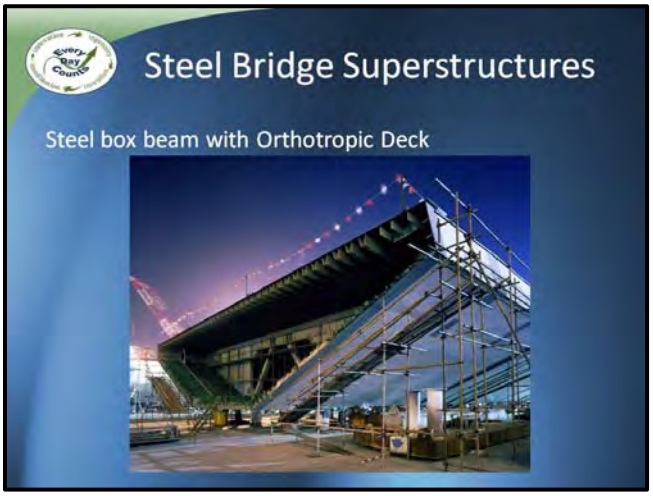
Slide 21:

The deck spans in two directions making it extremely stiff and able to carry the loads between girders.

Slide 22:

Slide 23:

This image shows one particular approach span to the self-anchored suspension unit of the Oakland Bay Bridge, the remainder of the bridge is concrete.



Slide 24:

Example of a steel box beam with an orthotropic deck

Slide 25:

This image is of the Carquinez Bridge between Crockett and Vallejo, CA.

In San Francisco, 24 bridge segments (like the one shown here) weighing over 800 tons are installed using a heavy lift ship and strand jacks.

Slide 26:

There are a lot of slides on orthotropic decks, but it should not be taken that they are the most important or best solution. Fabricators and researchers are working tirelessly to make orthotropic deck fabrication more cost effective, modular, and more efficient for smaller projects. Economies of scale could be achieved if the proper standards are developed.

Slide 27:

I-80 State Street to 1300 East – Bridge Farm (UDOT)

Superstructure: Total Superstructure Systems
Increasingly, innovative bridge designers and builders are finding ways to prefabricate entire superstructures. Pre-constructed composite units may include steel or concrete girders prefabricated with a composite deck, cast off the project site and then transported and lifted into place in one operation. Truss spans also can be prefabricated. Prefabrication this scale offers tremendous potential advantages in terms of improved constructability, reduced onsite construction time, and reduced time that equipment is on the construction site.

Slide 28:

An example to show size and context

Slide 29:

Example: Providence River Bridge Arch

The bridge was assembled on the ground where girders were at worker eye level which made it very efficient.
SPMTs move a fully pre-assembled network tied arch bridge onto (2) 300-foot barges.

Floated structure weighing 2500 tons 12 miles (3 hours) up Narragansett Bay
Barges used the tide to slowly lower the bridge onto its piers.
link to video:
http://www.youtube.com/watch?v=vROwFWDNe1c&feature=player_embedded

Slide 30:

Example: Arroyo Malo – 2006

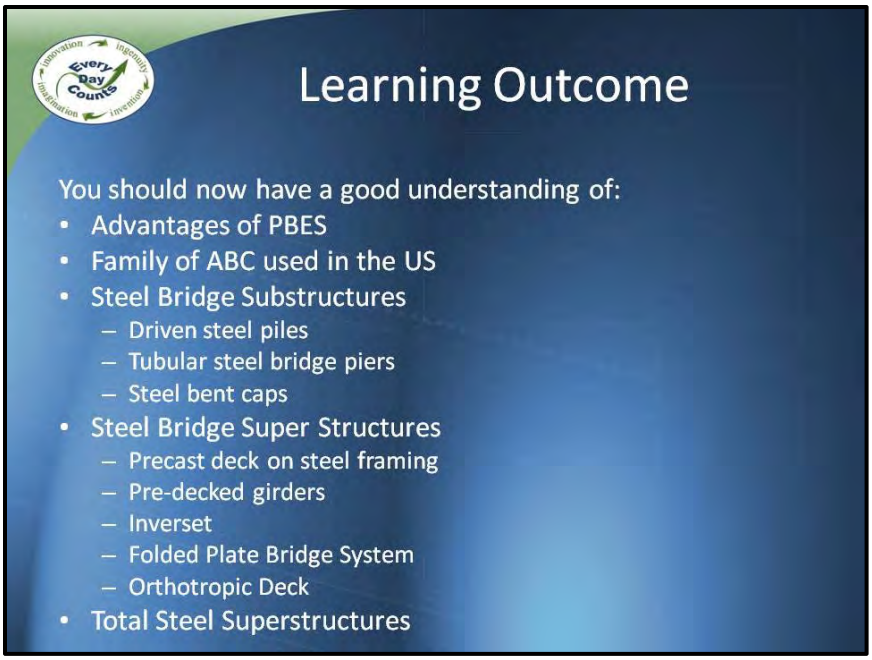
Large orthotropic deck units are designed to handle heavy wheel loads such as those created by the American loadings of HS20, HS25 or HL93. Wheel loads from the bridge design standards of other countries can be accommodated also.

The plate deck surface readily accepts surface overlays, such as asphalt or epoxy aggregates.

They are easily transported using standard trucks or standard dry ocean containers and they are quickly and easily erected.

Acrow Bridges can be rolled in full cantilever (launched) from one side of a river gorge or they can be lifted into place.

Slide 31:

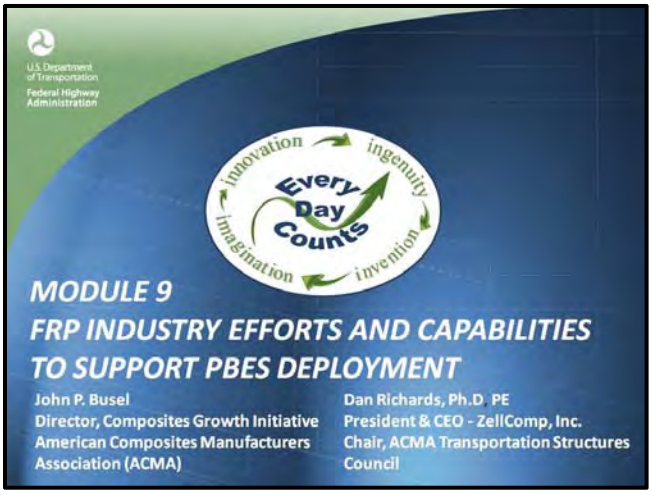


Slide 32:

Slide 33:

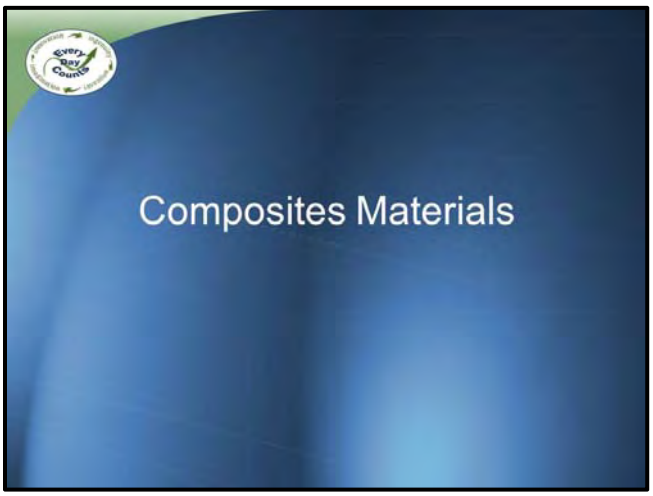
Module 10: FRP Industry Efforts & Capabilities to Support PBES Deployment

MODULE SLIDES & NOTES

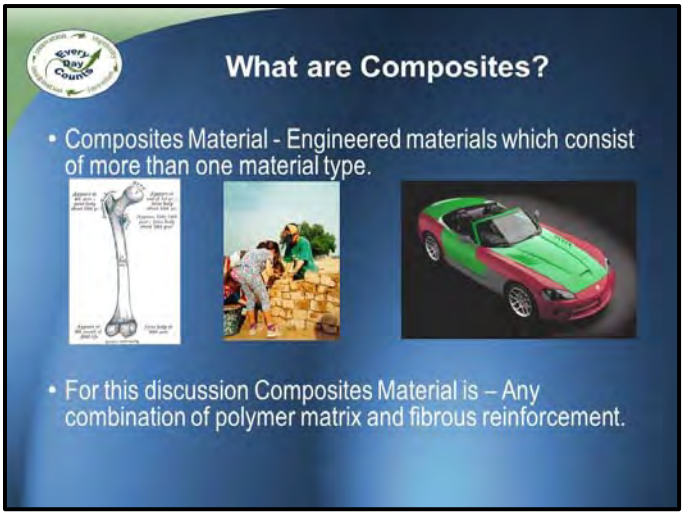


Slide 1:
Welcome. This is will cover the FRP Industry Efforts and capabilities to support PBES deployment.

Slide 2:
The outline for the presentation will cover a basic overview of composites materials. This will be followed by a review of current specifications and standards that engineers, designers and specifiers could use to specify various composites products. Next we will review various deck and girder and other infrastructure products that have been tested and deployed in the field by looking at several case histories. The presentation will be concluded with how composites supports FHWA's program of Every Day Counts.



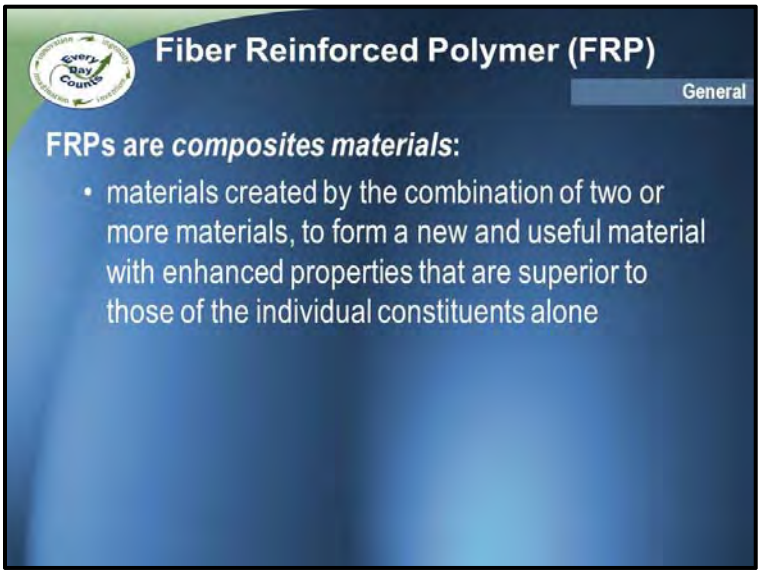
Slide 3:
Let's start with a review of the materials.



Slide 4:

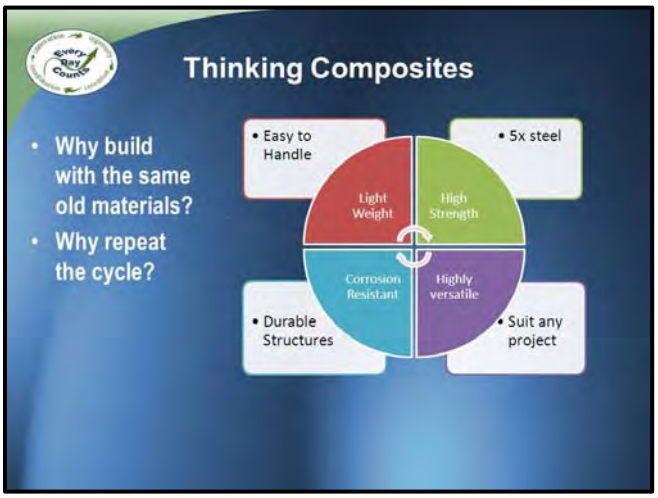
Composites are engineered materials. There are many forms of composites materials. Composites could be applied to the human bone structure. The first form of composites existed with the ancient Egyptians when they combined mud and straw to form bricks used in construction. Today's composites materials are found in many applications from automobiles, trucks, airplanes, recreational equipment, industrial equipment, and finally transportation infrastructure which is the focus of this presentation.

For this discussion, composites materials are simply the combination of a polymer resin matrix and a fibrous reinforcement.



Slide 5:

Composites are also referred to FRP, meaning Fiber Reinforced Polymers. Composites mean FRP and vice-versa. Basically, the definition of FRP or composites is the combination of two or more materials, that when combined, form a new materials with superior properties compared to the individual components.



Slide 6:

We need to ask ourselves - Why build with the same old materials? In this day and age of tight budgets and the increasing need to rehabilitate our infrastructure, can we afford to repeat the cycle when we need to install durable, longer lasting structures?
We need to think composites. The inherent properties of composites often translate to efficiently built structures. For example, composites are light weight and can be easily transported and installed because they are easier to handle.
Composites are high strength 5 times that of steels properties. Composites are highly versatile meaning that the designs and performance can be tailored to suit just about any project. Composites are naturally corrosion resistant in that they are non-metallic this results in more durable structures when exposed to harsh environments.

Slide 7:

But composites do not stop there. There are many more attributes whereby composites maintain greater value.

In addition to high strength, light weight, and corrosion resistance, composites can be engineered to:

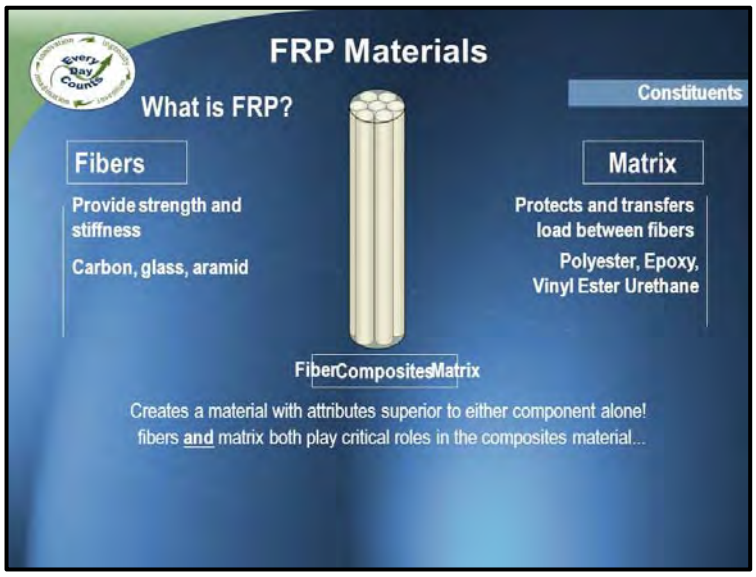
- have superior electrical properties, especially glass fiber where it functions as an insulator
- high thermal properties as composites do not transfer heat and cold and can perform in many environments
- non-magnetic – composites are non-metallic and therefore perform excellent in this environment
- composites are transparent to radar signals
- Ultimately, composites are durable materials that when designed and manufactured properly offer a long service life even exposed to the harshest environments.

Slide 8:

Composites are made with several components starting with man-made fibers such as glass, carbon or aramid. These fibers provide the strength and stiffness in a composite. The fibers are then combined with a polymer resin like polyester or epoxy. The resin protects the fibers from environmental attack and helps transfer the loads between the fibers.

The combination of the FIBER and the RESIN creates a material with attributes superior to either component alone and is critical in the performance of the composites material. Composites exhibit strength that is 5 TIMES stronger than steel at ¼ the weight, and offering corrosion resistance, and many other benefits.

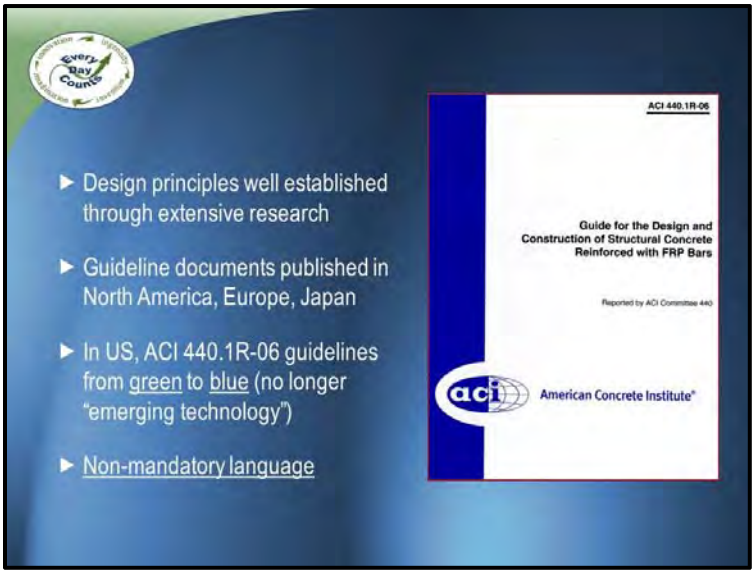
During this presentation, composites will be referred to as FRP – meaning fiber reinforced polymer, or “fiberglass” This is an industry term not only applied to the fiber component, but a description associated with a non-metallic material. You might be familiar with “fiberglass boats”.



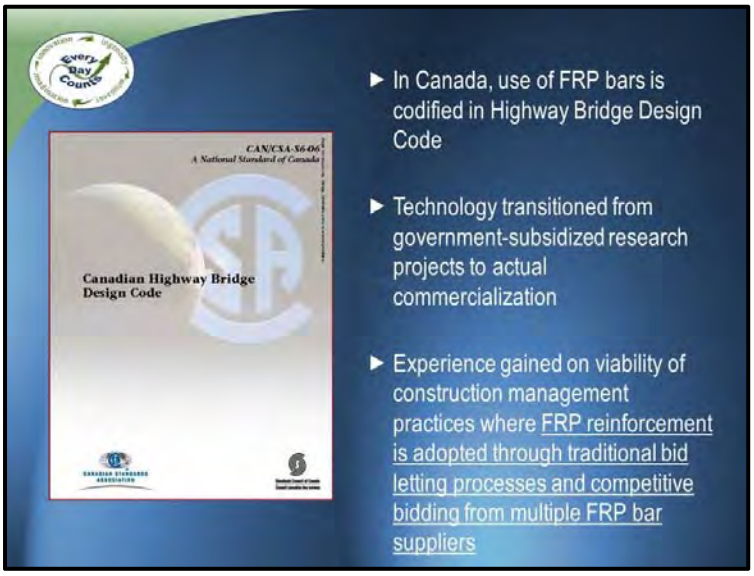
Slide 9:
We will now focus on currently available design standards and specifications for composites.

Slide 10:
One noteworthy design standard published by AASHTO in 2009 is the AASHTO LRFD Bridge Design Guide Specifications for GFRP Reinforced Concrete Bridge Decks and Traffic Railings. Using the ACI design guide as a foundation, this publication will assist bridge engineers in specifying

FRP rebar in concrete bridge decks. This was the second of two AASHTO publications to cover FRP.

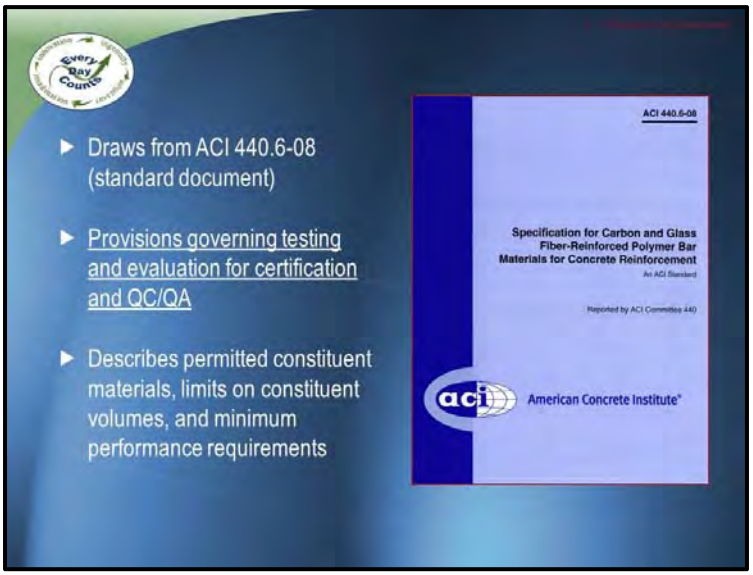


Slide 11:
First published in 1999, the ACI 440.1R-06 evolved from emerging technology to ACI standard publications on the use of FRP bars to reinforce concrete. This publication has gone through 3 iterations over the years to refine the design equations used in this document. This has become a well reference and used world-wide design document as the authority for internally reinforced concrete with FRP bars.



Slide 12:

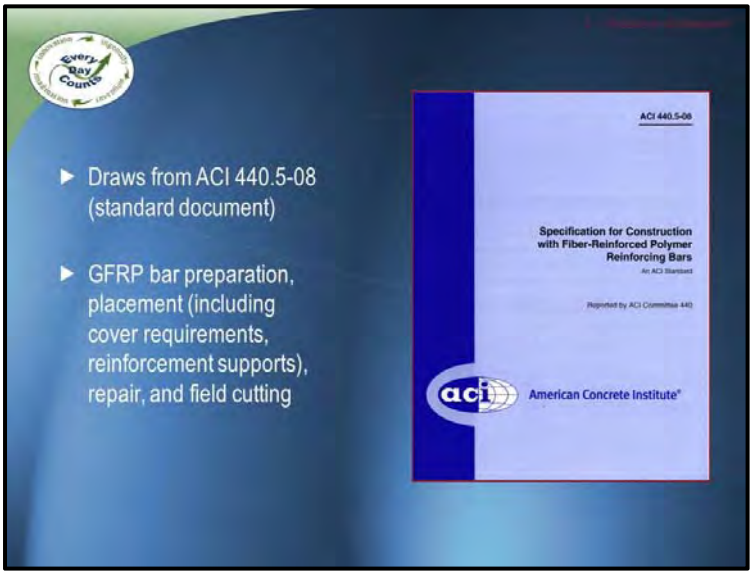
In Canada, FRP bars used in the design of concrete bridge decks have been codified in the Highway Bridge Design Code. The existence of this document has motivated all Canadian provinces to specify and install FRP rebar as a material of choice for concrete exposed to aggressive environments.



Slide 13:

As a compliment to the ACI 440.1R design specification, this ACI standard was developed for contractors and specifiers who use either glass or carbon FRP bars as a materials specification to be used in contract documents. It is written in mandatory language and contains provisions governing testing, evaluation, and certification of FRP bars used in reinforced concrete.

Attention was placed on minimum requirements the FRP bars must meet to ensure durable performance.



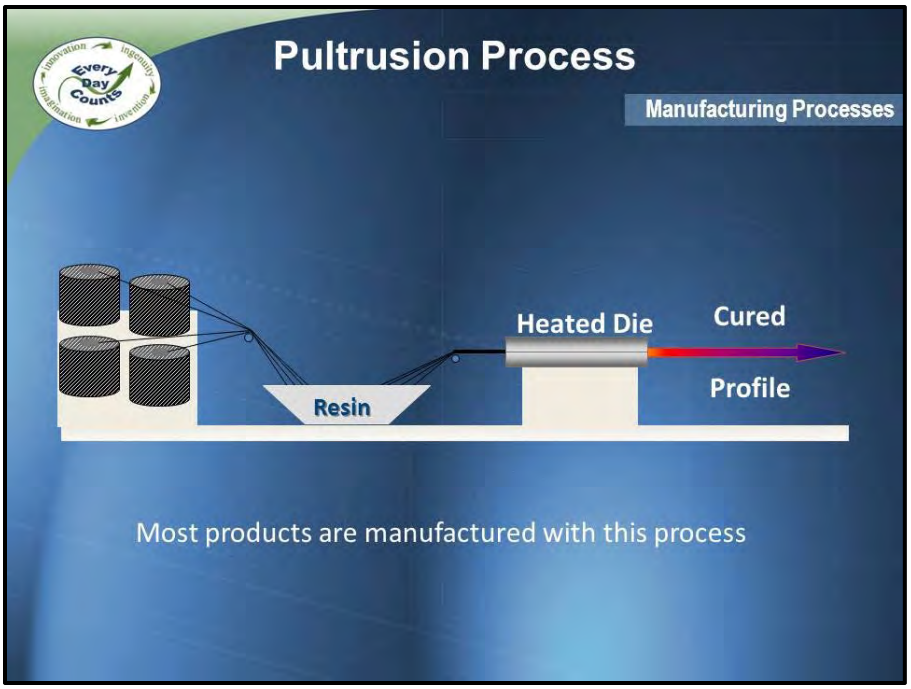
Slide 14:

This ACI standard also serves as a compliment to the ACI 440.1R design specification. This construction standard provides information for contract documents that guide contractors and engineers on the proper use and installation of FRP bars for reinforced concrete.

Slide 15:
ASCE, under contract with the American Composites Manufacturers Association completed a 3-year project to develop a new design pre-standard titled LRFD of Pultruded Fiber Reinforced Polymer (FRP) Structures. This pre-standard was published in late 2010 and is currently going through the ASCE standards process to promulgate this document as a standard.

The publication covers a number of areas of pultruded composites including tension members, compression members, flexural and shears members, combined forces and torsion, plates and built up members, and bolted connections. Each of the chapters follows the LRFD design provisions laid out in chapters 1 and 2. The LRFD document can be applied to all pultruded structural elements.

Slide 16:
Now, let's focus on the products and field installations.



Slide 17:

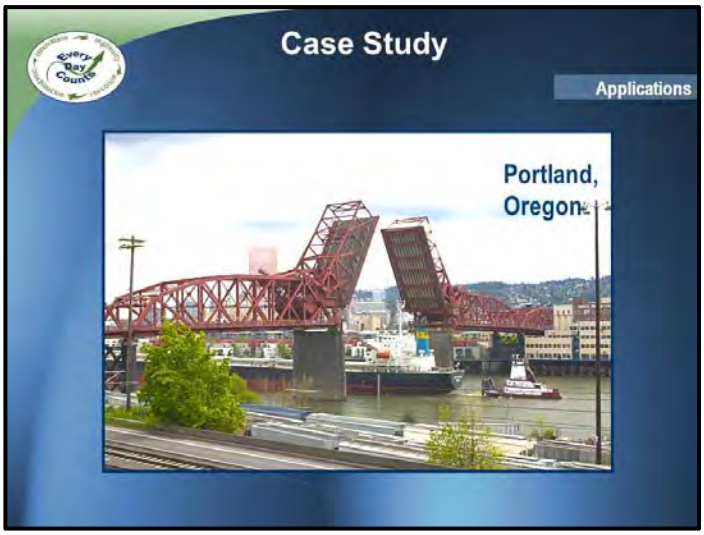
First, we need to understand a composites manufacturing process called pultrusion. Most products used for transportation infrastructure applications including rebar, structural profiles, girders, decks, and strengthening materials use pultrusion to manufacture the product.

The process starts as long continuous fibers called rovings (either glass or carbon fiber) are pulled through a resin bath to saturate the fibers, then the wet fibers are aligned and pulled through a shaped mold die which is heated. While the composites are in the die, the shape is formed and fully cured. The completed profile exits the die and is cut to length based on the requirements for the order.

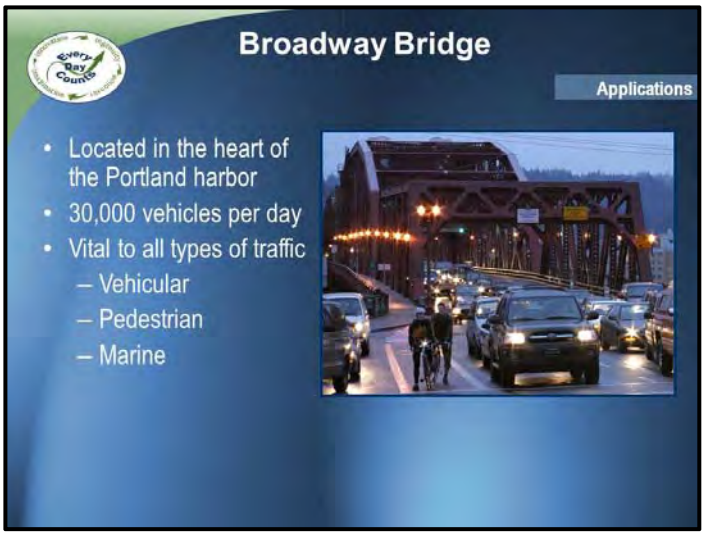
Slide 18:

This is a picture of a pultruded part exiting the heated die. This part is used as the lower part of a bridge deck. Depending on the width of the bridge, the part is cut to final shape. The part is fully cured and retains its shape.

Slide 19:
Pultruded FRP decks are not new. First developed in the mid 1990's, pultruded FRP decks have been extensively tested in the laboratory and the field. Primarily deployed to rehabilitate existing bridges, FRP decks can transform a deteriorated structure into a beautiful and durable structure. There are various pultruded bridge deck configurations that range from a 1-piece full section depth to multi-piece configurations. FRP decks are factory built and assembled, transported to the field either as the entire bridge or in a few components to minimize field joints and speed the installation time.



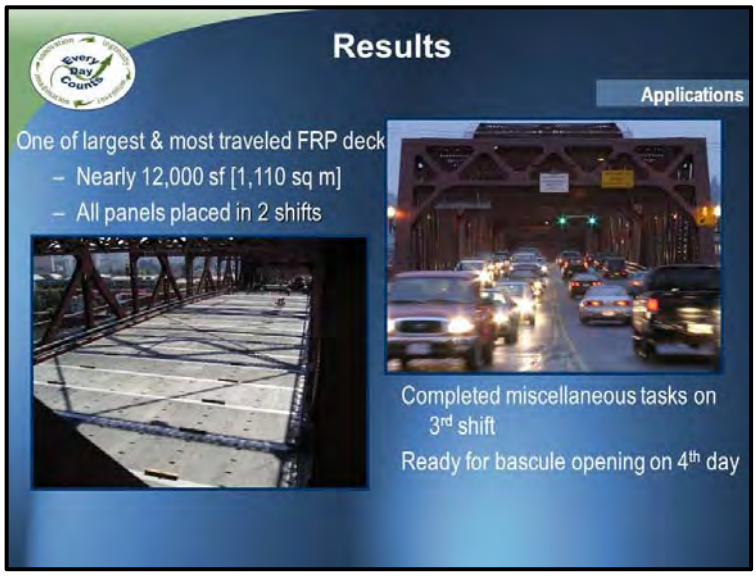
Slide 20:
Let's take a look at a case study in Portland Oregon.



Slide 21:
The Broadway Bridge is an aging historic bascule bridge that is located in the center of Portland. It is a well traveled bridge with 30,000 ADT and services vehicular and pedestrian traffic, and is also a major component for marine traffic with ships and barges. This significant structure, if out of service for an extended period of time will have a huge impact to all forms of traffic in Portland.
The problem with this bridge was that the open steel grating for the road bed was severely deteriorated and needed to be replaced. There was a desire by the DOT to improve the skid resistance on the deck. In addition, it was desired to lighten the deck to minimize rework on the motors to control the bascule portion of the bridge.

Slide 22:

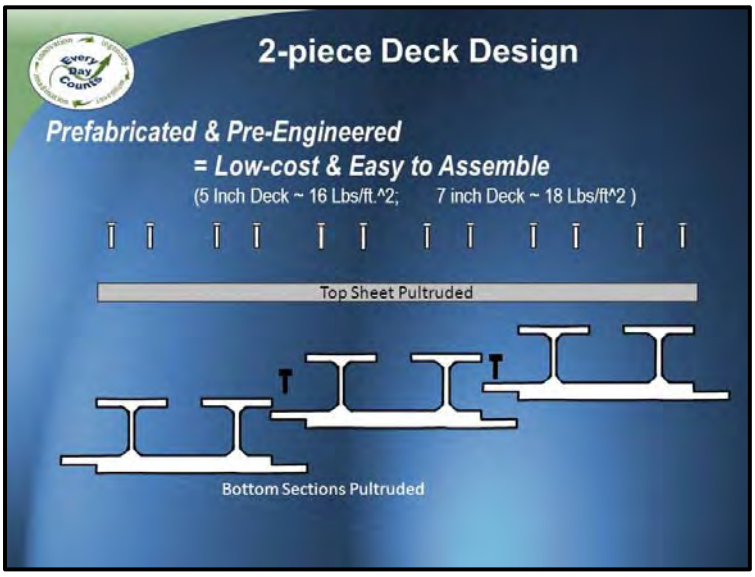
The solution was to install a light weight FRP deck which provided a solid surface to provide better skid resistance. The FRP deck was assembled into panels at the factory and delivered to the site. Light duty crane trucks were used to place the panels into place on the bridge. Each panel was sized to go the full width of the bridge to minimize any seams and joints.



Slide 23:

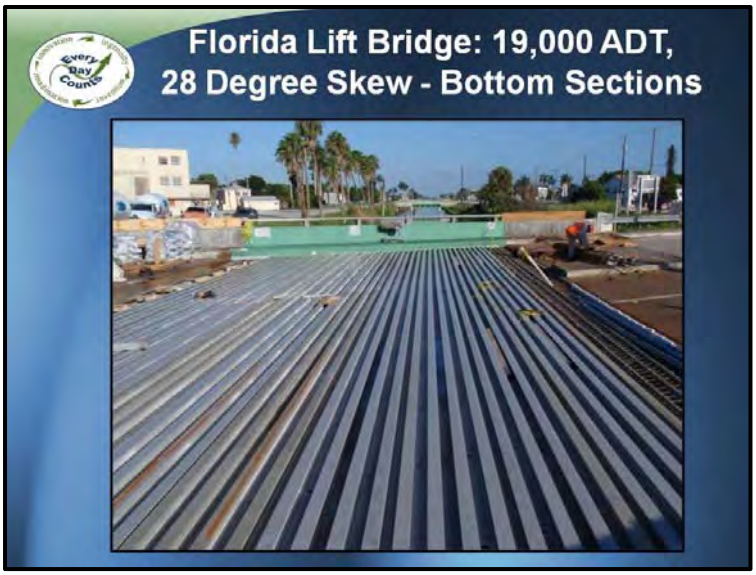
The construction was carefully planned not to disrupt the marine traffic. Over 12,000 sq ft of FRP bridge deck was installed on this bridge in 2 shifts. By the 3rd shift, all miscellaneous tasks were completed making the bridge ready by the 4th day to allow marine traffic to move down the river.

The pre-engineered, pre-fabricated bridge decks allowed for minimal disruption of traffic. In this case, Every Day did Count.



Slide 24:

The next case study deals with the replacement of an old corroded open steel deck in Florida. For this project a two part FRP deck system was selected. This system utilizes mechanical fasteners, which are locked with epoxy to prevent any backing out. This deck is an “open” design, which offers flexibility on site and the ability to repair and reassemble if ever needed. The pultruded bottom section (the base plate with T sections) provides the majority of the structural capacity. The bottom section can be manufactured in different depths, depending on the spacing of the stringers for the particular project. This open deck system allows for easy connections to the superstructure and can be used with both shear studs and grout or with bolts.



Slide 25:
FRP decks are an excellent choice for moveable bridges due to their light weight and corrosion resistance characteristics. This particular deck design was tested by the Florida Department of Transportation and the University of Central Florida in advance of this installation. This bridge in Florida was a 6-lane lift bridge over a canal. This slide shows the bottom sections that were installed. There was a skew of 28 degrees that would normally require extra reinforcement, but this design was cut to the skew and eliminated the need for additional and costly structural steel reinforcement.

Slide 26:
Connections are easy and fast with this two-part deck. This slide shows the shear studs with foam dams that create a grout pocket around the shear stud.

Slide 27:
The top sheet is attached with mechanical fasteners. The fastener heads can be set at different depths depending on the wear surface material to be used. Customers typically select a polymer concrete wear surface with an FRP deck, but asphalt can also be used if preferred by the customer.

Slide 28:
The next case study covers the installation of an FRP bridge superstructure (deck and beams) in Ohio. This deck is manufactured via the resin infusion process.

Slide 29:
This design can be used in a variety of bridge types.

Slide 30:
This picture of the original bridge site shows the harsh environment that the materials are subjected to. Fast and easy installation was important to the customer.

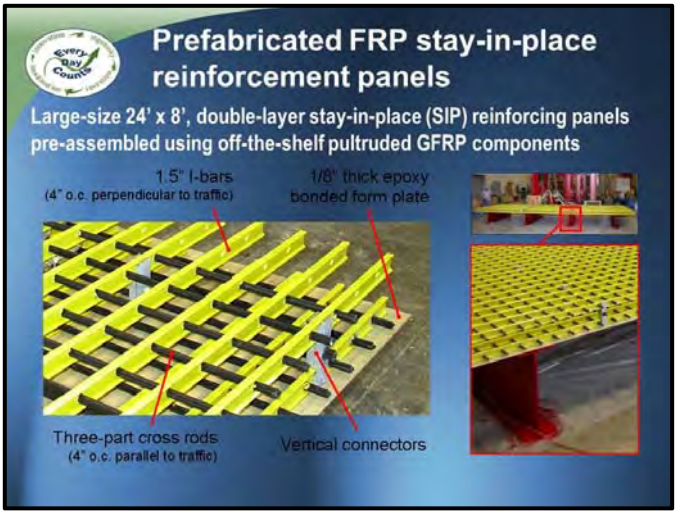
Slide 31:
The deck/beam modules were easy to drop into place with a crane. Prefabricated composite bridge components clearly eliminate days from a construction schedule.

Slide 32:
This close-up of the sections being dropped in shows that the design eliminates joints. The abutments were constructed to allow for easy connection.

Slide 33:
The main structure was completed in one day—certainly meeting the goal of Every Day Counts.

Slide 34:

This is the final installation. Now a very clean looking bridge. In addition to working with accelerated construction, composite materials offer a very long life cycle compared to traditional construction materials.



Slide 35:

A technology developed over 8 years ago introduced another approach to reinforced concrete decks that incorporate a structural stay-in-place formwork coupled with a 3 dimensional grid reinforcement. The reinforcement is made from existing pultruded grating bars that are joined together to form a grid. These grids can be formed into panels, much like prefabricated FRP decks, and installed on a bridge.
Prefabricated stay-in-place FRP reinforcing panels take advantage of advanced composites' versatility, light weight, and corrosion resistance, to make the construction of durable bridge decks faster, safer, and competitive.

Slide 36:

The grid panels can be stacked and shipped on trailers very efficiently.

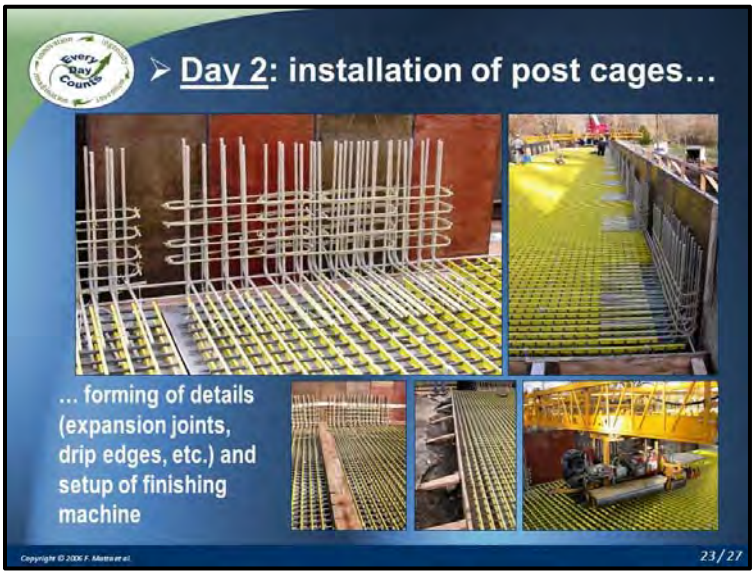
I-bars (38 mm) running continuously in the direction perpendicular to traffic;

Three-part cross rods running through pre-drilled holes spaced at 100 mm on-center in the I-bars web in the direction parallel to traffic; and

Two-part vertical connectors that space the grating layers 100 mm apart.

Slide 37:
Let's take a look at a case history. This bridge in Greene County, MO was long overdue to be refurbished. The bridge was posted and was in various state of disrepair.

Slide 38:
The construction process was performed in a simple 5-day sequence of events. Day 1 was assigned to setting the panels in place. Note that a light duty truck crane was used to place the panels.



Slide 39:
During Day 2, the traffic railings were built up with standard FRP rebar and tied to the prefabricated stay-in-place grid forms. Details such as drains, drip edges and expansion joints were built in.

Slide 40:
By Day 3, the bridge deck was ready for casting of the concrete. The surface was safe for workers to walk on and perform the casting process.

Slide 41:
Days 4/5 were assigned to finish the railings and other details on the bridge.

Slide 42:
This composite picture shows various views of the completed structure.

Easier and faster construction – the elimination of labor-intensive and time-consuming field operations (formwork setting between the girders, and tying of rebars) by means of large-size prefabricated FRP panels lifted with a single pick of a crane, translates into over 70 percent reduction in construction time from reinforcement installation to deck casting and finishing, as well as into significantly improved working conditions.

Higher Productivity – the rate of concrete placement is increased by 50 percent compared to traditional steel reinforced decks with similar dimensions.

Reduced Labor Cost – the reduced need of manpower, faster and easier field operations, and higher productivity translate into over 75 percent reduction in deck construction labor cost.

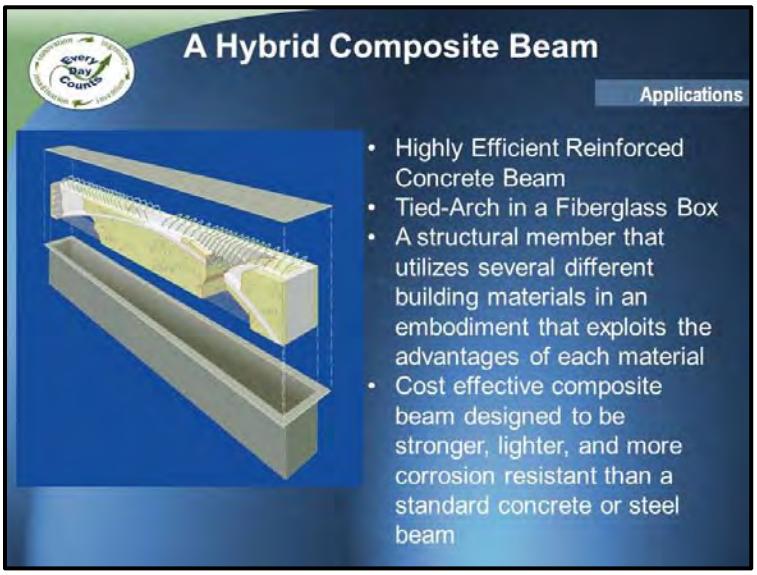
Improved Safety – the use of very lightweight FRP panels, easy to handle and placed with no need of formwork (as opposed to heavy partial-depth precast prestressed panels commonly used), and the design of the reinforcing profiles to facilitate walking over the top mat, result in improved safety in the work area.

Enhanced Durability – to date, the results of extensive research have demonstrated the superior durability of internal FRP reinforcement for concrete when compared to steel rebars. The corrosion resistance of FRP composites represents a critical advantage for bridge decks, which are highly susceptible to deterioration due to chloride (deicing salts) penetration. This translates into a reduction in bridge maintenance operations, thereby supporting a more efficient bridge management, and prioritization of limited funds.

Slide 43:
In the early 1990's, researchers in Canada first applied CFRP tendons for prestressed concrete beams. This multi-span bridge in Manitoba Canada performs beautifully today. The girders have internal sensors that are used to monitor the service of the girder and bridge system.

Slide 44:
Rehabilitation is another tool for engineers to get structures in service and extend the service life of installations. The use of FRP composites for external strengthening of concrete structures is well documented and used in thousands of installations. The upgrades can be tailored to enhance shear, flexure, of girders or decks.

Slide 45:
Enhancing the durability of bridge columns has been widely used with both glass and carbon fiber FRP systems. This is a picture of a technician applying CFRP to a column.

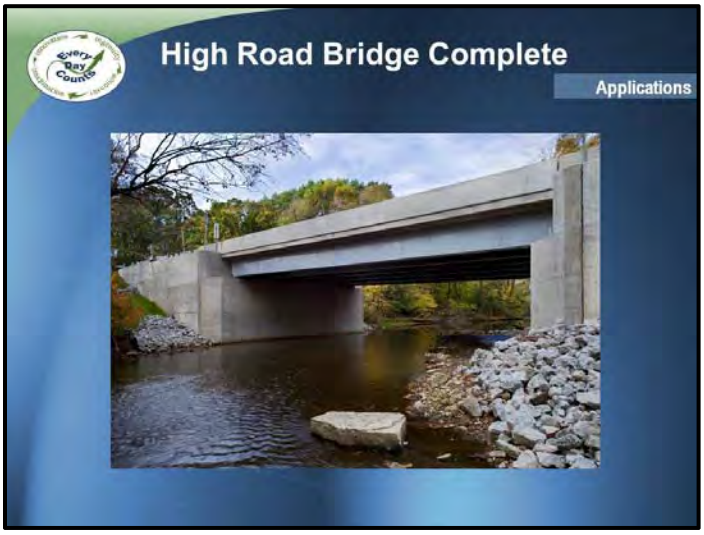


Slide 46:
In development for over 10 years is this Hybrid Composite Beam. It is a highly efficient concrete beam that includes a tied-arch in a fiberglass box. This design provides a cost effective solution that uses the best of FRP composites, steel, and concrete which provides for a stronger, lighter and more corrosion resistant alternative to current precast girders. This girder has been extensively tested and approved to be used for railroad bridges.

Slide 47:
The HCB girder has been installed on a number of bridges in Illinois, New Jersey, and Maine. The girders light weight allows many girders to be transported in a single shipment. This reduces the number of trucks needed to transport the girders, reduces the energy needed to drive the trucks, and reduces the number of trucks on site in a staging area. The reduction of the staging area reduces congestion and increases safety.

Slide 48:

While on site, typical construction equipment can be used to lift and place the girders on the site reducing a contractors cost of renting special lift cranes and other equipment. Again, the light weight beam allows for quick installation, often completing the placement in a matter of hours. The quick installation translates to less traffic congestion while increasing safety on site.



Slide 49:

When completed, the HCB girder looks like any other bridge girder that provides pleasing aesthetics to the overall structure. Currently, a large multi-span bridge is being constructed in Maine using this girder system.

Slide 50:

The Bridge in a Backpack system was developed at the University of Maine's AEWC Advanced Structures & Composites Center over an 8 year period. Through a combination of research funding from the Maine DOT, the US Army, and several other sources total research funding to date is approximately $4 million. The system is currently being commercialized by Orono, ME Advanced Infrastructure Technologies, a five person team of engineers and investors.

The system is comprised of an external shell made from CRFP fabric assembled into a sock in which concrete is pumped into the arch girder. The process is done on site. The complete arch is then lifted into place using light duty crane equipment. A corrugated decking is then placed on top of the girders and backfill soil placed to complete the structure.

Slide 51:

The entire process can be done within a week for most structures. The FRP materials used provide a structure with a service life of 100+ years. Currently, 7 installations are planned for the State of Maine, along with many more in other locations around the world. The use of composites naturally preserves the environment around these short span bridges.

Slide 52:

In summary FRP composites are:

- Engineered systems
- Prefabricated components, factory built, quality controlled
- Reduces the need for large, heavy, expensive equipment during installation
- Increases safety on site
- Lighter Weight for Reduced Shipping, Handling and Erection Time and Costs (Accelerated Bridge Construction)
- Reduced Carbon Footprint
- Greater Corrosion Resistance than Conventional Materials Providing Service Lives Beyond 100 Years
- LOWER OVERALL BRIDGE COST!!

Slide 53:

Slide 54:

So what do you call a material that is lightweight, can be made into prefabricated structures and translate to quick installations that will last longer than a life time – we call them FRP composites.

Slide 55:

Module 11: Lightweight Concrete Benefits for PBES Deployment

MODULE SLIDES & NOTES

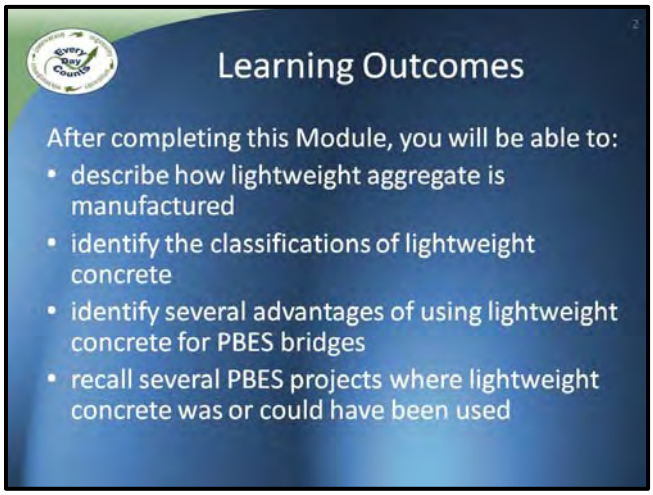
Slide 1:
My name is Reid Castrodale.

I am the Director of Engineering for Carolina Stalite, one of the companies that manufacture lightweight aggregate in the US. I am representing the lightweight concrete industry today, as we discuss the use of lightweight concrete in the deployment of PBES.

But before we get into the details of how lightweight concrete can be a benefit for accelerated bridge construction using PBES, I'd like to give you some information on lightweight aggregate and lightweight concrete.

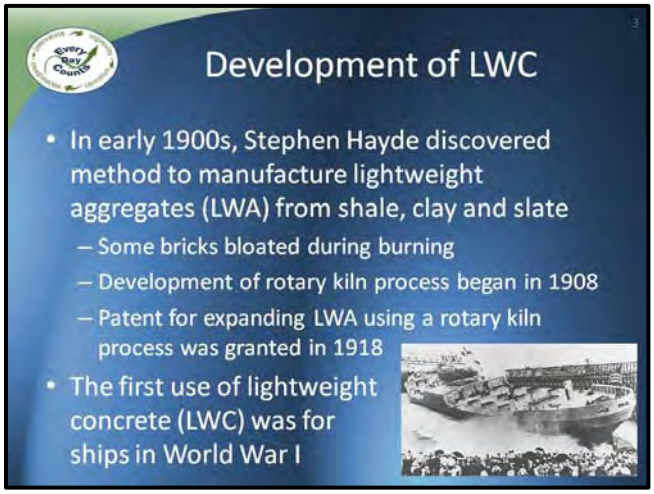
Slide 2:
After completing this Module, you will be able to:

- identify roadblocks to accelerated bridge construction
- identify the resources contained in Connection Details for PBES
- describe features of PBES that improve the quality of the finished product
- recognize a typical construction schedule for a bridge built with PBES
- recall ways to save money by using PBES
-

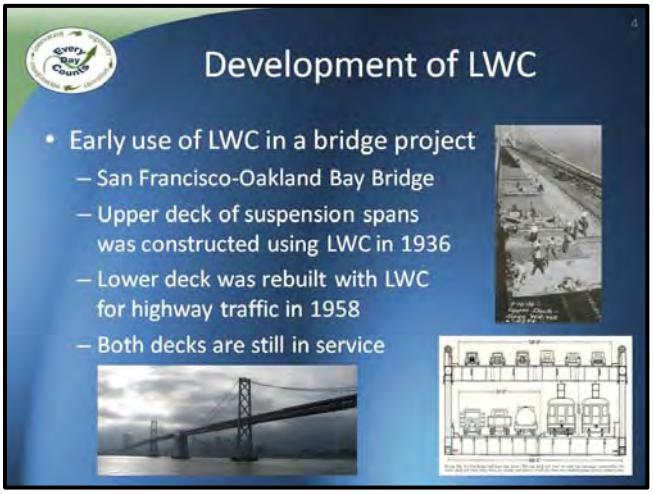


Slide 3: In the early 1900s, Stephen Hayde, a brick maker in Kansas City, noticed that some of his bricks bloated during firing. He realized that the expanded material could be used as a lighter aggregate for concrete and other uses, so he set out to develop a way to manufacture expanded aggregate.

When he was granted a patent in 1918, WWI was still underway and had created a shortage of plate steel for shipbuilding. He provided the use of the patent to the government so they could use lightweight concrete to build ships. The photo shows the launching of one of the first lightweight concrete ships, the USS Selma, in 1919. The ship is still visible in Galveston Bay



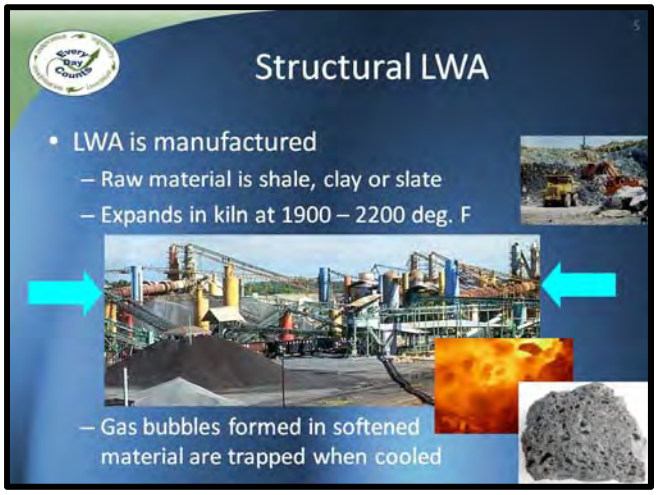
off the east side of Pelican Island where it has been beached since it was taken out of service in the 1920s after providing satisfactory service. In areas of the ship where the concrete is undamaged, the 0.5" to 1.2" cover has done a surprisingly good job of protecting the reinforcing steel from corrosion.



Slide 4:

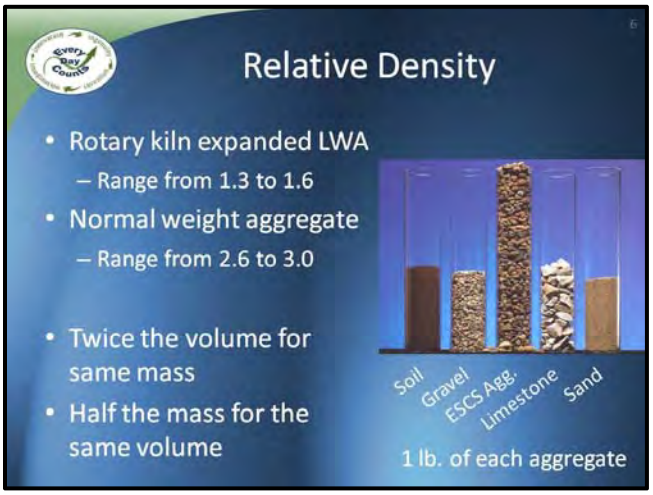
An early use of lightweight concrete for bridges is the upper deck of the suspension spans of the San Francisco-Oakland Bay Bridge. The deck was completed in 1936 using "all lightweight concrete" with a dry density of about 95 lbs/cf. Lightweight concrete was used again in 1958 when the lower deck was reconfigured for highway traffic. Both decks are still in service today.

An even earlier example of lightweight concrete for bridge decks is the original deck on the Lewis and Clark Bridge over the Columbia River between OR and WA. That bridge was completed in 1930 with a lightweight concrete deck, which served until it was replaced using SPMT technology with large precast deck panels in 2003, as mentioned in some of the other presentations on PBES. I'll talk about this bridge again later in this presentation.



Slide 5:

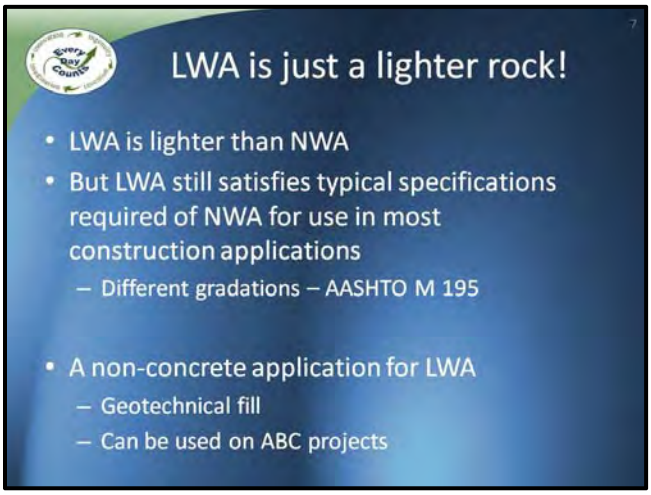
Almost all of the structural lightweight aggregate used in the US is manufactured by expanding raw materials in a rotary kiln, using the same process that was developed by Stephen Hayde nearly a century ago. The raw materials used in the US are shale, clay and slate which are extracted from the ground using standard excavation or mining techniques. The raw material is then fed into a rotary kiln, very similar to those used to manufacture cement. As the material moves through the kiln, it is heated until it reaches 1900 to 2200 deg. F at the lower end of the kiln. At these temperatures, the material softens and gas bubbles form within it. The soft material is thick enough that the gas bubbles do not escape. When the heated material exits the kiln and is cooled, the bubbles remain as the material hardens, producing a porous lightweight ceramic aggregate.



Slide 6:

The expanded material has a relative density, or specific gravity, in the range shown, which is about half the relative density of normal weight aggregate. This is illustrated by the photo which shows the volume occupied by a pound of different materials. It is clear that the expanded aggregate has twice the volume as the same mass of normal weight materials.
Another way of looking at this is that the same volume of lightweight aggregate will weigh about

half as much as normal weight aggregate. This is what happens with lightweight concrete, where normal weight aggregate is replaced with an approximately equal volume of lightweight aggregate that weighs about half as much.
It should be noted that the relative density and other properties of the expanded aggregate vary somewhat between sources of aggregate and types of raw material.



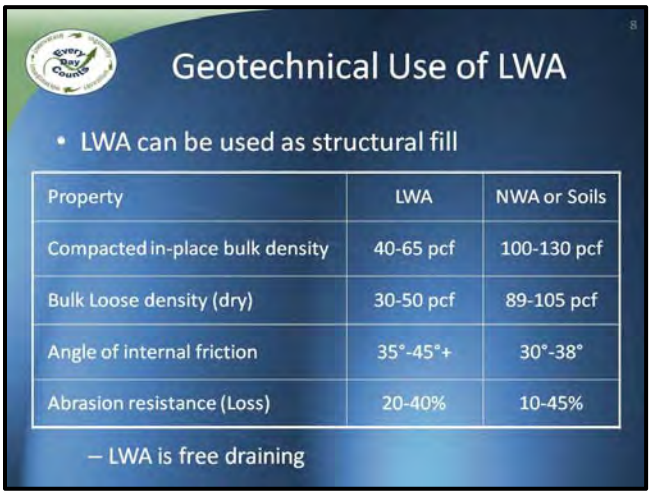
Slide 7:
It is important to realize that after expansion, structural lightweight aggregate is just a lighter rock! The high temperature firing of the raw materials converts them into a vitrified ceramic material that has a hardness equivalent to quartz.

Lightweight aggregate should satisfy the requirements for normal weight aggregates. The only exception is that the gradations are defined differently. The AASHTO materials specification for structural lightweight aggregate is M 195, which covers both coarse and fine gradations.

Lightweight aggregate has a higher absorption than normal weight concrete. Because of this, prewetting of the aggregate is important, especially when lightweight concrete will be pumped.

When lightweight aggregate is used in concrete, lightweight concrete results. The same batch plants and mixing procedures are used for lightweight concrete. The same admixtures can also be used for lightweight concrete. Mix design procedures can also be the same as for normal weight concrete. The absorbed moisture does not participate as mix water since it will not be released into the concrete until after hydration is underway.

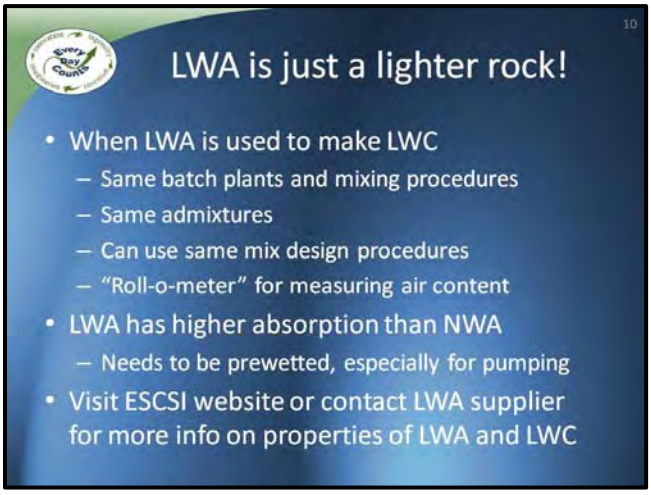
A final notable difference between lightweight and normal weight concrete is that the air content of lightweight concrete is tested using the “roll-o-meter”, or the volumetric method.



Property	LWA	NWA or Soils
Compacted in-place bulk density	40-65 pcf	100-130 pcf
Bulk Loose density (dry)	30-50 pcf	89-105 pcf
Angle of internal friction	35°-45°+	30°-38°
Abrasion resistance (Loss)	20-40%	10-45%

Slide 8:

Slide 9:



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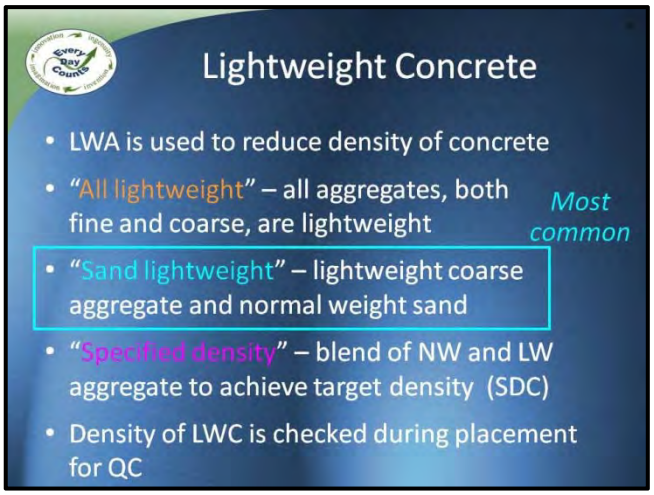

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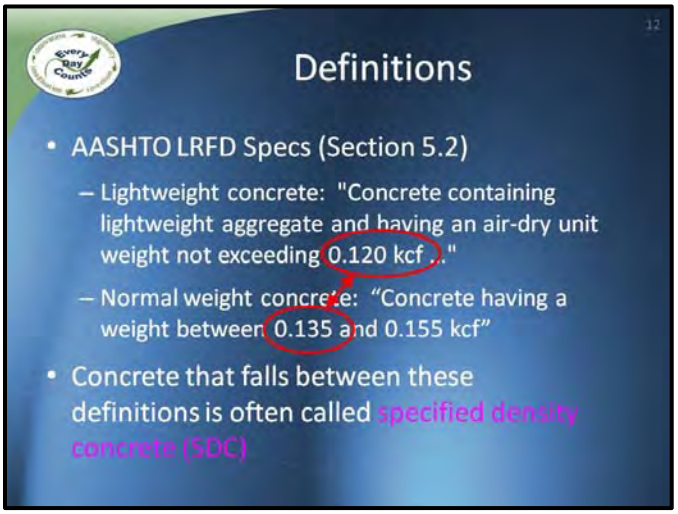
Slide 11:
Now we'll turn from looking at lightweight aggregate to lightweight concrete, which, as I just mentioned, is made by using lightweight aggregate in concrete. While we have talked about the "unit weight" of concrete in the past, I'll be using the term "density" for this presentation.

Two types of lightweight concrete are recognized in the design specifications:

The first type is “all lightweight concrete” in which all of the aggregate in the mixture, both coarse and fine gradations, are lightweight.
The second type, which is most common, is “sand lightweight concrete” in which the coarse aggregate is lightweight but the fine aggregate is normal weight sand. In almost all cases today, when someone mentions “lightweight concrete” or “structural lightweight concrete”, they mean sand lightweight concrete.

A third type of concrete containing lightweight aggregate is usually called “specified density concrete”. It uses a blend of lightweight and normal weight aggregates to achieve the desired density, which is usually in the range between “sand lightweight concrete” and normal weight concrete, i.e., from about 125 to 145 pcf. This type of concrete is most often used by the precast/prestressed concrete industry to address handling and shipping issues.

An important issue related to the use of lightweight concrete is that its density is specified. This is important because the structure has usually been designed using a reduced density. Therefore, the density of the fresh lightweight concrete is checked for acceptance as an important aspect of quality control during construction. This means that lightweight concrete gets more attention during batching and placement than most normal weight concrete mixtures, because the density of normal weight concrete is not specified and is therefore not an issue for acceptance.



Slide 12:

Two definitions for concrete are repeated here from the AASHTO LRFD Bridge Design Specifications: lightweight concrete and normal weight concrete.

An upper limit is given for the density of lightweight concrete, although for higher strengths, such as for prestressed concrete girders, sand lightweight concrete mixtures may exceed this limit by a small amount.

For normal weight concrete, the definition includes a range of densities. Since the density of normal weight concrete is most often between 140 and 150 pcf, a density of 135 may be achieved using specified density concrete with a blend of lightweight and normal weight aggregates.

The fact that the LRFD Specifications have a definition for lightweight concrete reveals that design using lightweight concrete is addressed in the specifications.

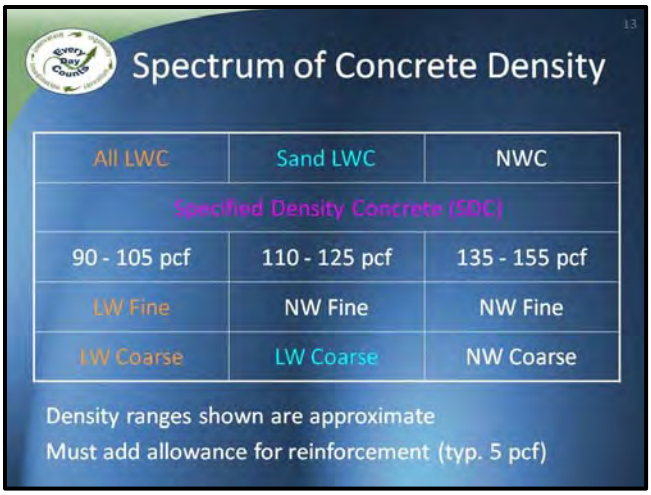
While not defined in the specifications, specified density concrete with densities between lightweight and normal weight concrete, can be used where a partial reduction in density is needed to achieve certain construction or design objectives.

Slide 13:

This slide illustrates the concept that there is a range of concrete densities that can be achieved using lightweight aggregate.

The lightest concrete is “all lightweight concrete” which can have densities as low as 90 pcf for structural concrete mixtures.

The intermediate density concrete is “sand lightweight concrete” which typically has densities in the range of 110 to 125 pcf.

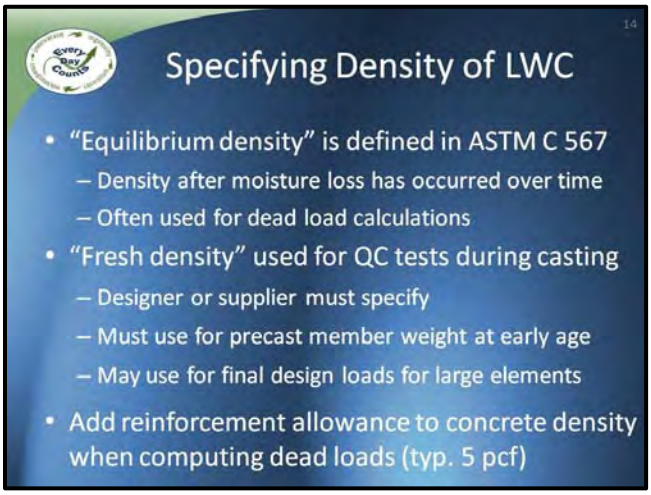


Strictly speaking, "specified density concrete" is any type of concrete which contains lightweight aggregate and is not "all lightweight" or "sand lightweight" concrete. But the term is most often used to achieve densities between sand lightweight and normal weight concrete.

The types of aggregate used to make the different types of concrete are also shown in this table.

The density ranges are approximate and depend on aggregate type, specified compressive strength and other mix parameters. Consult lightweight aggregate suppliers for densities that can be achieved for a specific project.

Please note carefully that the densities shown here are for plain concrete. The designer must add an allowance for reinforcement when determining the density to be used for reinforced concrete in dead load computations. This allowance is often taken as 5 pcf, but this may not be enough for heavily reinforced elements.



Slide 14:

When specifying the density of lightweight concrete mixtures, two conditions should be considered.

The first is the "equilibrium density", which is the density that results after the concrete has been allowed to dry. The reason this is considered for lightweight concrete is that it contains more moisture because of the water absorbed when the lightweight aggregate is prewetted. In many cases, this density is used for dead load computations for service load conditions.

The second density is the "fresh density" or plastic density. This density is used for QC testing during construction. It must also be used for handling loads for PBES structures where precast elements are used, since it is greater than the equilibrium density. Shortly after casting, when precast elements are removed from the forms, very little drying has occurred, so the weight of the element is defined by the fresh density. Some also suggest that the fresh density be used for dead load computations at service load conditions, especially where element dimensions are relatively large and supplementary cementitious materials are used. Both of these factors result in a decreased potential for the migration of moisture out of the element, making the fresh density the reasonable, and conservative, choice for defining density of lightweight concrete.

The contract documents must clearly state the type of density that is intended for acceptance.

Furthermore, the contract documents should state the density used for dead load computations, which includes the reinforcement allowance.

Slide 15:

Since lightweight concrete has been available to DOTs for use for about 80 years, some states have addressed the requirements for lightweight aggregate and lightweight concrete in their standard specifications or by special provisions. Some examples are listed here.

Sand lightweight concrete for bridge decks:

- The Tennessee DOT includes sand lightweight concrete for bridge decks in their Standard Specifications.
- Several states, including NCDOT and UDOT, have developed standard special provisions for sand lightweight concrete for bridge decks.
- Other states have used project specific special provisions when lightweight concrete has been specified in a project.

All lightweight concrete:

- This type of concrete has not been specified for quite a few years. However, its value is again being recognized, especially for situations such as truss rehabilitations where the reduction in dead load of a bridge deck can result in significant savings if modifications to a truss can be minimized or avoided.

NCDOT has a demonstration project with an all lightweight concrete deck for which a project specific special provision is being developed.

Slide 16:

Semi-lightweight concrete for girders:

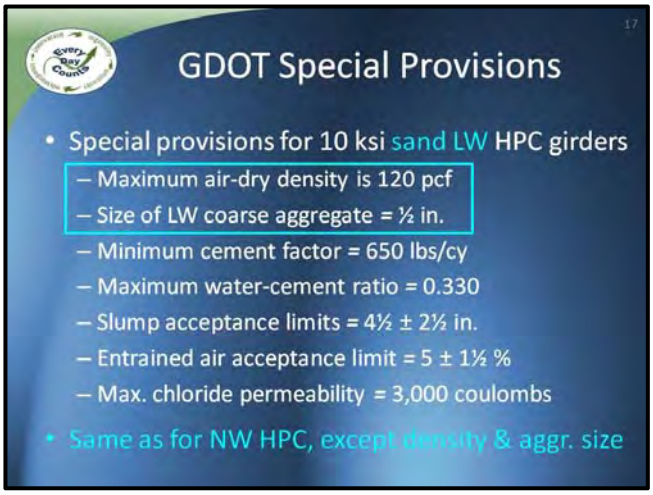
- This is a term used by the IN DOT for specified density concrete. It has been widely used in the state for large pretensioned bridge girders. A standard special provision, also known as a recurring special provision in IN, is being developed.

Sand lightweight concrete for girders:

- GDOT has built a demonstration project with 10 ksi sand lightweight concrete girders with a density of 120 pcf. Project specific special provisions were developed for the project.
- VDOT has built 3 bridges for which sand lightweight concrete was used in the girders. Project specific special provisions were developed.

A key issue for most states is that an aggregate must be approved before it can be used in the state. Therefore, it is important for aggregates to appear on the approved aggregate list in a state. In a number of states, lightweight aggregate sources have been approved and appear on the approved aggregate list.

Slide 17:

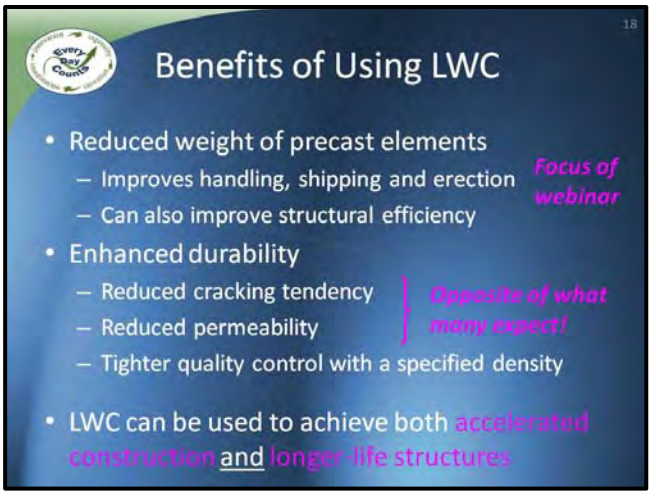


As an example for special provisions for lightweight concrete, the GDOT special provision requirements for lightweight concrete girders are shown. The requirements are the same as for normal weight high performance concrete, except the maximum density is specified (120 pcf) and the maximum aggregate size is ½" rather than the 67 stone used for normal weight HPC.

Slide 18:

Now that you have been introduced to lightweight aggregate and lightweight concrete, the question must be asked, why should lightweight concrete be used for bridge structures?

The main reason is obvious: the weight of the structure will be reduced, and in bridges, the dead load of the structure is often a significant portion of the design loads. However, precast concrete elements for bridges are often very large. As a result, a reduction in weight affects the shipping, handling and erection of these elements. The structural efficiency of the bridge is usually improved by reducing the weight of the structure.



Another benefit of lightweight concrete for bridges is that lightweight concrete provides enhanced durability compared to normal weight concrete. This is because lightweight concrete has been shown to have a reduced cracking tendency and reduced permeability. These features are not expected by some engineers, since they think that a “porous” aggregate could not provide equal durability to normal weight concrete. However, research and field performance of structures, such as the upper deck of the San Francisco-Oakland Bay Bridge, demonstrate the improved performance.

Slide 19:

Slide 20:

But before moving on to look at potential benefits for PBES projects, we must first address the cost associated with the reduction in density of concrete.

For lightweight concrete, the cost is greater than normal weight concrete because of the increased cost of the lightweight aggregate.

The cost of lightweight aggregate is greater than normal weight aggregate because:

- The cost of production of lightweight aggregate is significant, because of the high temperature processing of the raw materials.
- The cost of shipping of the finished

aggregate may be significant. However, it should be noted that lightweight aggregate can be shipped long distances relatively economically. In some cases, lightweight aggregate has been shipped across the country or even overseas to projects where it becomes an important part of an economical structural solution.

Slide 21:

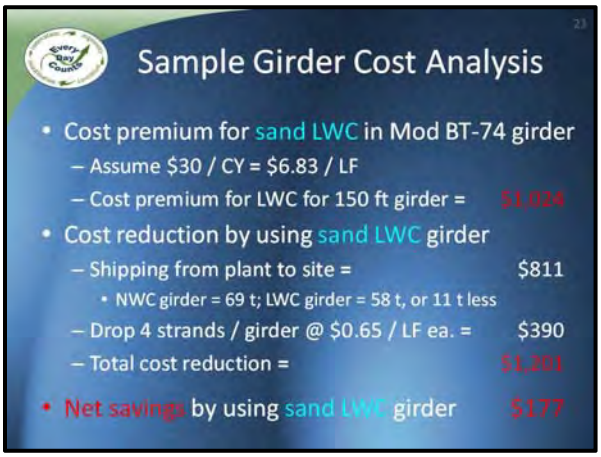
This slide shows a range of cost premiums for lightweight concrete for a bridge deck concrete.

The cost premium for lightweight concrete depends on the cost of the lightweight aggregate, including the shipping cost, and the cost of the normal weight aggregate that is being replaced.

Here it is shown that even though the cost premium for lightweight concrete may appear significant, when this cost is spread out to an equivalent cost per square ft of deck area, the cost is relatively minor. Using data reported on the FHWA's NBI website, the average of the unit cost for bridges on the Federal Aid system for each state was $162/sf in 2009. For the same year, the average unit cost for bridges not on the Federal Aid system was $153/sf. This means that the additional cost for lightweight concrete for a bridge deck is less than 1% of the cost of a typical bridge. This cost does not consider any savings that may result from the use of lightweight concrete.

Slide 22:

Areas: PCBT-29: 643.7; PCBT-61: 858.7; PCBT-93: 1082.7 in2
Ratio for example is based on 125/150 reduction from 899 plf.



Slide 23:

This slide shows a cost analysis for using lightweight concrete for a bridge girder that was proposed for an actual project.

The girder was a 74" deep modified bulb-tee girder that was 150 ft long. Assuming a reasonable cost premium of $30/CY for sand lightweight concrete, the additional cost of the lightweight concrete for this girder would be $1,024 per girder.

The prestressed girder manufacturer asked his shipper to provide an estimate for shipping the 150 ft girder from his plant to the project location about 300 miles away. The cost to ship a sand lightweight concrete girder (125 pcf) that weighed 115.3 kips was $811 less than the cost to ship a normal weight

concrete girder (150 pcf) that weighed 138.3 kips. Not only did the lightweight concrete girder cost less to ship, but it also weighed 23 kips less, which could be a significant benefit for the fabricator for handling, or the contractor for erection.

A further cost reduction was realized because the sand lightweight concrete girder design required 4 fewer strands. For the proposed design, an all lightweight concrete deck was used on the sand lightweight concrete girder, while a normal weight concrete deck was used on the normal weight concrete girder. The cost of an installed prestressing strand was taken to be $0.65 / ft. Therefore, the elimination of 4 strands resulted in an additional cost reduction of $390 for the sand lightweight concrete girder.

The total savings for the lightweight concrete design compared to the normal weight concrete design was $1,201, or a net savings of $177 per girder. Therefore, the cost of the lightweight concrete has been paid for by savings without considering any other potential cost savings in the bearings, substructure or foundations, or for the contractor in erection.

Slide 24:

So what types of lightweight concrete should be considered for PBES applications?

And what concrete densities should be used for preliminary evaluation of the benefits?

Sand lightweight concrete can be used for any type of precast concrete element, including prestressed concrete girders. A typical fresh density for sand lightweight concrete with design compressive strengths up to about 6 ksi is shown in the table. A density of 125 pcf could be used for up to 10 ksi compressive strengths, which is the maximum reasonable design compressive strength for sand lightweight concrete.

All lightweight concrete can also be used for any precast concrete element. While use of all lightweight concrete is probably feasible for prestressed concrete elements, data supporting this use is not yet available. A typical fresh density for design compressive strengths up to 6 ksi is shown in the table.

Again, an allowance for the increased density due to reinforcement must be added to these densities for the computation of element weights and dead loads.

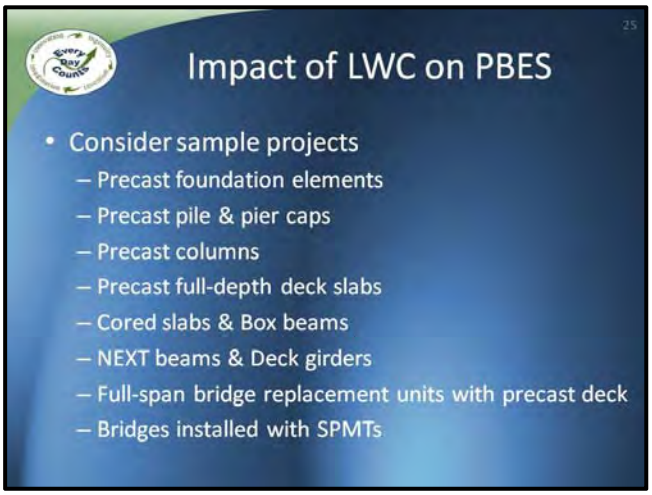
Slide 25:

With this information in hand, we will look at a number of actual PBES projects where lightweight concrete was or could have been used. The difference in element weights for lightweight concrete and normal weight concrete will be computed.

The full range of possible precast concrete elements will be considered as shown:

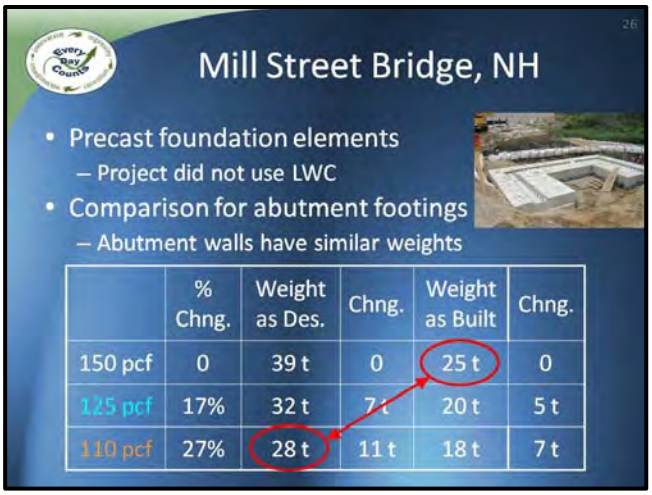
- foundation and substructure elements;
- deck and girder elements; and
- full span elements with precast decks.

The discussion is organized by element type.



Slide 26:

The replacement of the Mill Street Bridge in Epping, NH, has been frequently used as an example of a prefabricated bridge that was put in place very quickly and successfully. The project did not use lightweight concrete.



Using the plans and shop drawings, the weight of the largest abutment footing piece was computed. The contractor proposed using more pieces to reduce the weight of the largest piece, so both the "as designed" and "as built" weights are shown, based on a concrete density, with reinforcement, of 150 pcf.
For foundation elements, both sand lightweight and all lightweight concrete could be an option.

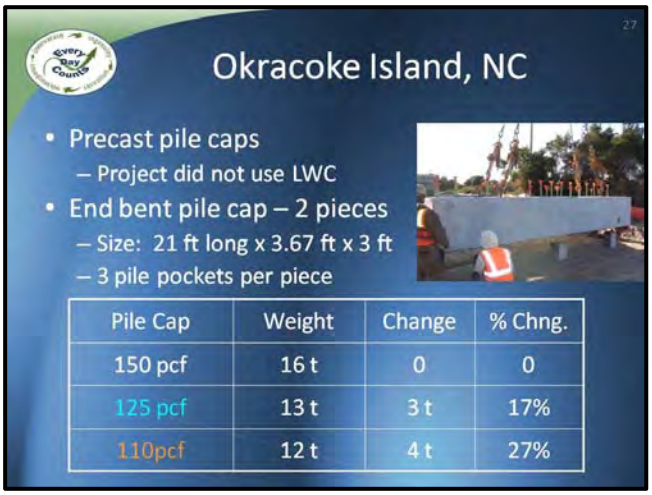
Using sand lightweight concrete would have reduced the weight of the piece by 5 tons, or 17%, for the "as built" footing. Using all lightweight concrete would have reduced the weight of the piece by 7 tons, or 27% for the "as built" footing.

While the reductions may not appear large, it should be noted that the contractor redesigned the footing segments to reduce the weight of the largest piece by 14 tons. After this redesign, the footing segments weighed about as much as all of the other pieces.
The reduction in piece weights that is achieved using lightweight concrete could possibly

- reduce shipping costs,
- allow for a smaller crane, or
- allow a greater radius for the crane, which can be very important where crane placements may be restricted.

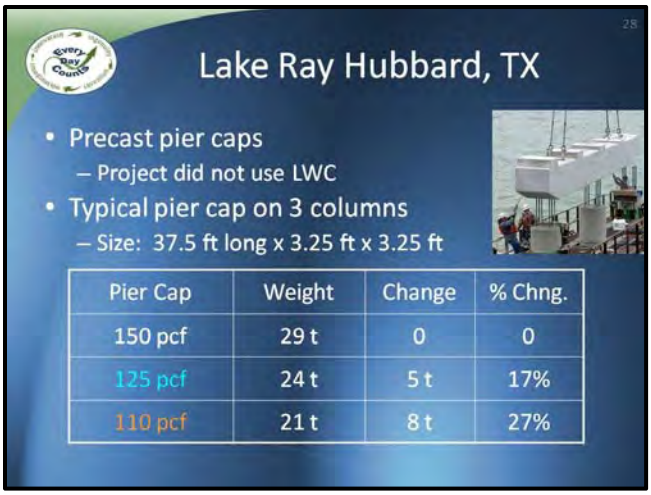
Slide 27:

The replacement of seven bridges on a remote island of the Outer Banks of North Carolina utilized precast elements to accelerate construction. All materials and equipment for the project had to be delivered to the island by barge. The project was not designed to use LWC.



The weight of a typical precast pile cap for an end bent was computed using the project plans assuming a concrete density, with reinforcement, of 150 pcf. Each end bent was cast in two pieces that were 21 ft long and 3 ft deep.

For substructure elements, both sand lightweight and all lightweight concrete could be an option.
Using sand lightweight concrete would have reduced the weight of the piece by 3 tons or 17%.
Using all lightweight concrete would have reduced the weight of the piece by 4 tons or 27%.

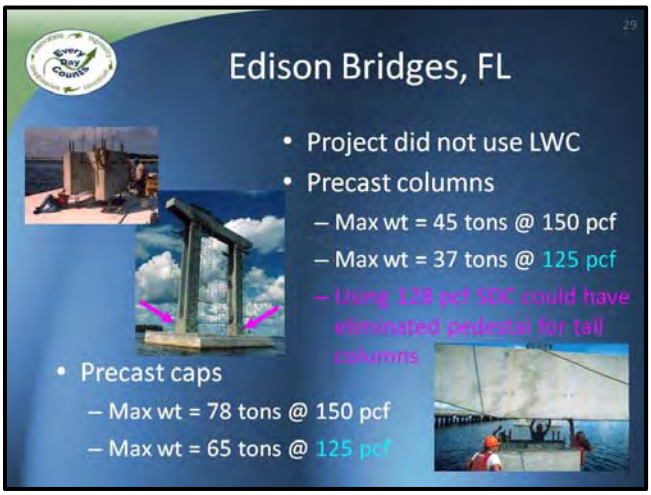


Slide 28:

The construction of the bridge over Lake Ray Hubbard in TX is another project that is frequently used as an example of a project that successfully employed prefabricated bridge elements. The project did not use lightweight concrete.

The weight of one of the 43 identical precast pier caps was computed using the project plans assuming a concrete density, with reinforcement, of 150 pcf. Each pier cap was constructed as a single piece that was 37.5 ft long with a 3.25 ft square cross section.

For substructure elements, both sand lightweight and all lightweight concrete could be an option. Using sand lightweight concrete would have reduced the weight of the piece by 5 tons or 17%. Using all lightweight concrete would have reduced the weight of the piece by 8 tons or 27%.



Slide 29:

The Edison Bridge in Fort Meyers, FL, was constructed a number of years ago using precast columns and pier caps. The project did not use lightweight concrete.

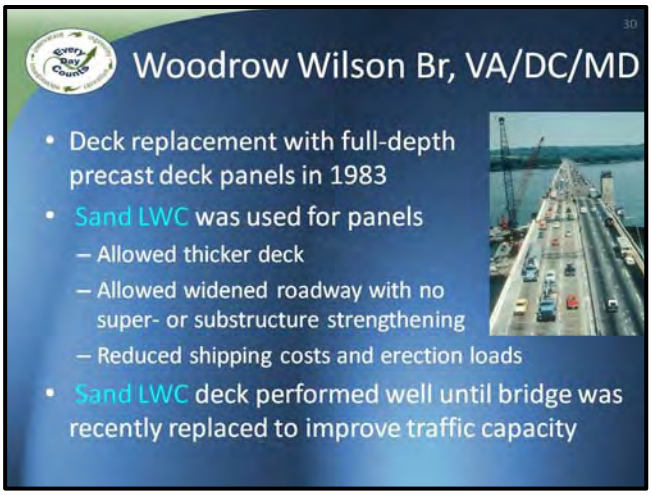
The maximum precast column weight was 45 tons. Each H-shaped column was cast as a single piece. Using the ratio of concrete densities, the weight of a sand lightweight concrete column would have been 37 tons, for a reduction of 8 tons or 17%.

I used the photo of the completed pier in a presentation several years ago. After the presentation, an engineer came up and asked if I knew why the tall column had been placed on a pedestal. He had been involved in the project and told me that the contractor's crane could not lift the full-length column, so their standard methods of pier construction had to be changed and a pedestal had to be used. Scaling lengths off of the photo, I estimate that concrete with a density of 128 pcf could have eliminated the need for the pedestal.

The maximum precast pier cap weight was 78 tons. Each pier cap was cast as a single piece, using an inverted U-shape to reduce the weight. Using the ratio of concrete densities, the weight of a sand lightweight concrete cap would have been 65 tons, for a reduction of 13 tons or 17%.

Shipping a pier cap of this size on highways is often difficult because of the large weight and relatively short length. This combination can make it difficult to have enough room to place the required number of axles under the load to satisfy permitting requirements. With a short, heavy load, it may also be difficult to find a route for which bridges will not be overloaded since the short load length will place most of the load on a medium span bridge. Therefore, sand lightweight, or even all lightweight concrete, is a good solution for such large precast elements.

Slide 30:



An early example of using precast concrete for accelerating bridge construction was the redecking of the Woodrow Wilson Bridge just south of Washington, DC, that was completed in 1983.

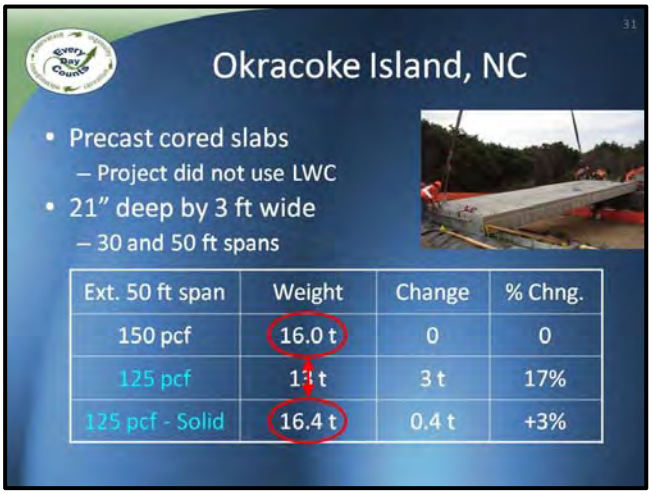
For this bridge, precast deck panels were designed using sand lightweight concrete for the following reasons:

- Since the concrete deck panels were lighter, the existing structure could support a thicker deck. The original normal weight concrete deck had been too thin, which had led to its early deterioration.
- The reduced deck weight also allowed the roadway width to be increased several feet without requiring any modifications to strengthen the existing superstructure or substructure elements.
- Finally, since the precast concrete panels weighed less, the cost for shipping the panels from the precast plant to the site, which was about 75 miles away, was reduced. The erection loads were also reduced.

The specified "air-dry" density of the sand lightweight concrete was 115 pcf without reinforcement. The use of lightweight concrete reduced the weight of the panels by about 20%. The "air-dry" density is roughly equivalent to the equilibrium density discussed earlier.

The new lightweight concrete deck, which was post-tensioned in both the longitudinal and transverse directions, performed well until it was replaced by a new structure to improve the traffic flow on this very busy interstate.

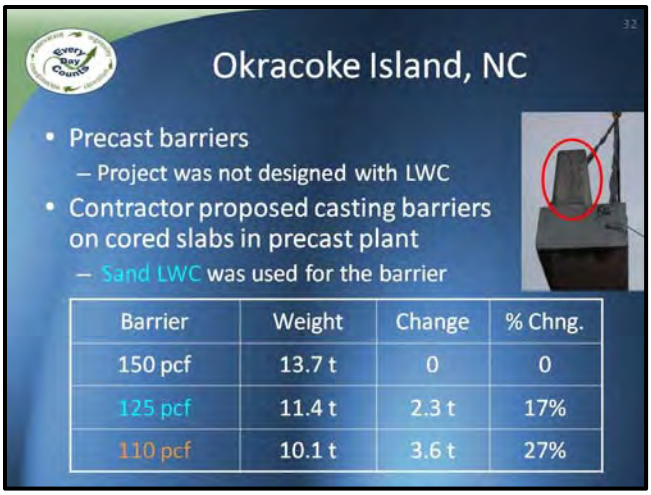
Slide 31:



We will now look at the main bridge elements for this project on the Outer Banks of North Carolina – the precast prestressed concrete cored slabs. These slabs were not designed to use lightweight concrete.

The weight of a typical exterior cored slab unit for a 50 ft span was computed using the project plans assuming a concrete density, with reinforcement, of 150 pcf. The cored slabs were 21" deep and 3 ft wide. The exterior units were the heaviest because they use smaller voids to accommodate the reinforcement for the barrier.

Since these elements were pretensioned, only sand lightweight concrete was considered as an option.
The use of sand lightweight concrete would have reduced the weight of the slab by 3 tons or 17%.
The option of using sand lightweight concrete and eliminating the voids, i.e., using a solid slab, was also evaluated in this comparison. For this case, the solid lightweight concrete slab weighed only slightly more than the normal weight cored slab. A solid slab would be more economical to fabricate, so the cost of the lightweight concrete may be offset by the savings in cored slab production costs.

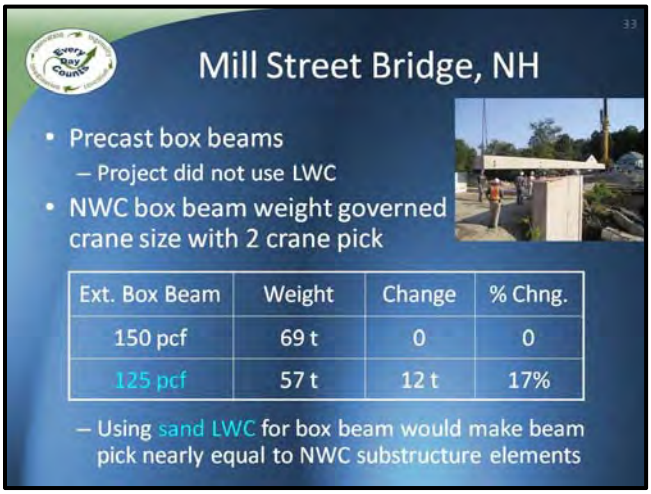


Slide 32:

Now we will now look at one more element of the Okracoke Island project – the barriers. The original plans called for precast barriers to be used, made with normal weight concrete. However, the contractor decided that it would be better to have the barriers cast on the cored slabs in the precast plant, eliminating the operations of installing the barriers after the cored slabs were set. Sand lightweight concrete was used for the barriers to reduce the weight of the exterior slabs, which were now becoming even heavier with the addition of the barrier.

The sand lightweight concrete barrier saved 2.3 tons per slab compared to the weight of a barrier made with normal weight concrete.

If all lightweight concrete had been used for the barrier, it would have saved an additional 1.3 tons, or a total of 3.6 tons from the normal weight concrete barrier.



Slide 33:

We will now take a look at the box beams used to replace the Mill Street Bridge in Epping, NH. The project did not use lightweight concrete.

Using the plans, the weight of a the 36” deep box beam was computed, based on a concrete density, with reinforcement, of 150 pcf. From photos, it was clear that the contractor was using 2 cranes to erect each box. Therefore, each crane was required to lift about 35 tons, which exceeded the weights of other single elements on the project.

Since these elements were pretensioned, only sand lightweight concrete was considered as an option.

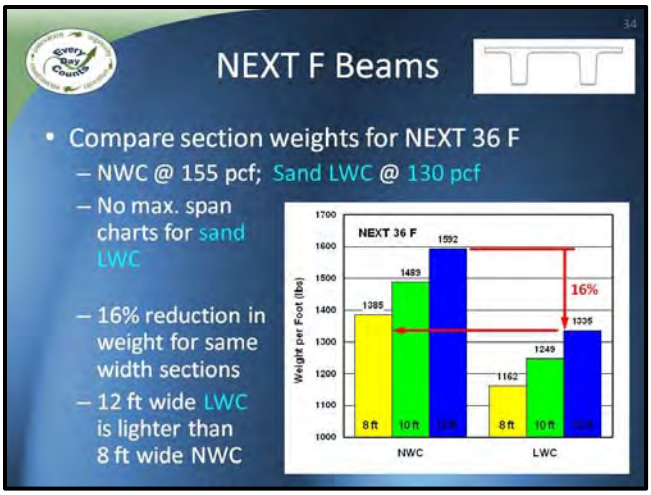
Using sand lightweight concrete would have reduced the weight of a box beam by 12 tons, or 17%. This would reduce the crane pick to about 29 tons, which is in the range of the maximum pick for the other normal weight concrete elements. The reduction in weight could also allow the cranes to boom out further in handling and placing the box beams.

Slide 34:

After considering cored slabs and box beams, we will now consider the new decked beam sections that have been developed by the PCI Northeast (PCINE) Technical Committee: the NEXT Beam series. These were mentioned very briefly in an earlier module.

These beams have 8 to 12 ft wide top flanges, and will greatly assist in making possible the rapid construction of short and moderate span bridges.

There are two families of the NEXT beams. The first, the NEXT F or Flanged section, is considered on this slide. It has a 4” thick top flange which is designed as a form for an 8” thick cast-in-place structural slab. The beams have been detailed with 4 different depths: 24”, 28”, 32”, and 36”. This slide considers only the deepest section (36”).

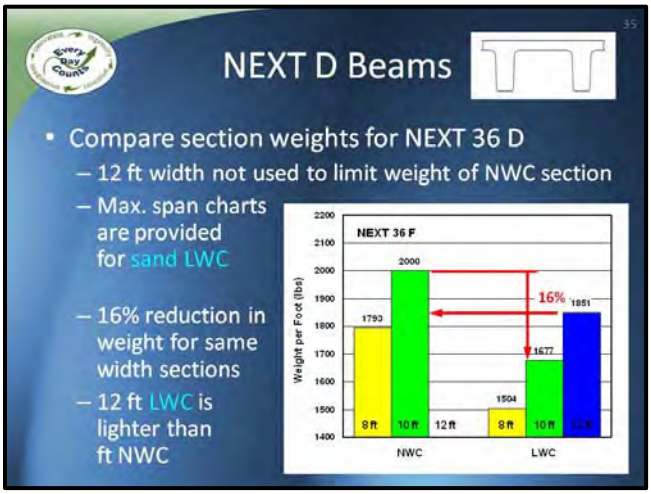


Considering densities of normal weight concrete and sand lightweight concrete that are shown (note: the design concrete compressive strength is 10 ksi, which increases the density), the weight per foot of the 36" deep sections are compared for 8, 10 and 12 ft flange widths.

For all three widths, the use of sand lightweight concrete reduces the weight of the beam by 16%. The PCINE design aids only provide maximum span charts for normal weight concrete beams, so the maximum spans for sand lightweight concrete beams are not known. However, they are expected to be slightly longer than those for normal weight concrete.

It is also noted that the widest (12 ft wide) sand lightweight concrete beam section weighs less than the narrowest (8 ft wide) normal weight beam section. This means that the use of lightweight concrete could allow the use of wider beams, which may reduce the number of beams that must be transported to the job site.

Specified density concrete could also be a good solution for beams such as these, if specific limitations on shipping or lifting need to be overcome for a given project.



Slide 35:

The second type of NEXT beam is the NEXT D or Deck section, which has an 8" thick top flange that is designed to be the structural deck in the completed structure. For these girders, connections between flange tips must be made. A waterproofing membrane and asphalt wearing surface would typically be applied to the bridge. The beams have been detailed with 4 different depths, each of which is 4" deeper than the NEXT F sections: 28", 32", 36", and 40". As for the NEXT F beam, this slide considers only the deepest section (40").

Because this beam is significantly heavier than the NEXT F section, a 12 ft width was not considered in the beam standards. Therefore, only 8 and 10 ft widths appear in the PCINE design standards.

Considering densities of normal weight concrete and sand lightweight concrete that are shown on the previous slide, the weight per foot of the 40" deep sections are compared for 8 and 10 ft flange widths. The weight of a sand lightweight concrete section with a 12 ft flange is shown for comparison purposes.

For sections with the same width, the use of sand lightweight concrete reduces the weight of the beam by 16%. For the NEXT D beams, maximum span charts are given for both normal weight and sand lightweight concrete, but only for the 8 and 10 ft widths. In all cases, maximum spans for the sand lightweight girders is slightly longer than the spans for the normal weight girders.

Again, it is noted that the widest sand lightweight concrete beam (12 ft wide) weighs less than the 10 ft wide normal weight beam and just a small amount more than the 8 ft wide section. This means that the use of lightweight concrete could again allow the use of wider beams, which may reduce the number of beams that must be transported to the job site.

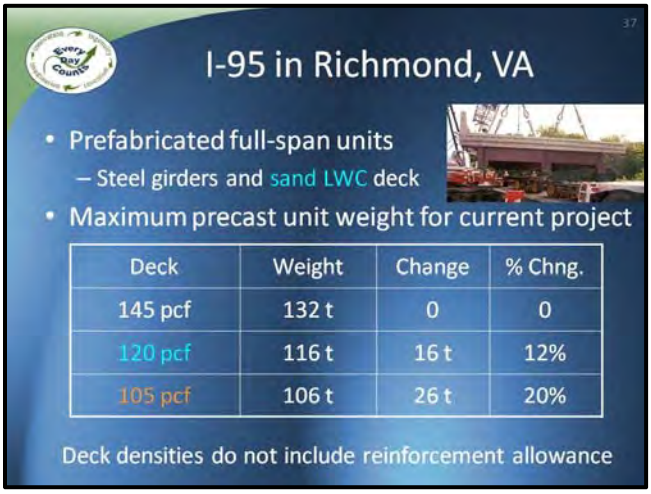
Slide 36:

We will now take a look at the deck girders that were recently used for a bridge in NY State. The project did not use lightweight concrete.

These deck girders were 41" deep and had a 5 ft wide top flange, which provided the deck for the structure when the girders were placed side-by-side. This type of structure is very efficient, allowing unusually shallow structure depths. However, having the deck on the girder when it is fabricated, shipped and erected, means that the girders are very heavy.

Using normal weight concrete with a density of 158 pcf, including reinforcement, the weight of the 87.4 ft long girders is computed to be 45 tons. The normal weight concrete density and reinforcement allowance used here were provided by the girder manufacturer. The higher density reflects the NYS DOT requirement for pretensioned girders to use 10 ksi concrete.

Since deck girders are pretensioned, only sand lightweight concrete was considered as an option. Using sand lightweight concrete would have reduced the weight of a deck girder by 8 tons, or 18%.



Slide 37:

The heavily traveled bridges carrying I-95 over the James River through Richmond, VA, were replaced a number of years ago using prefabricated full span units. This bridge has also been mentioned several times already in this webinar.

The deck was precast on the steel girders off-site, then the units were transported to the bridge and placed. The bridge was designed with a sand lightweight concrete deck to reduce the weight of the precast deck units. The lightweight concrete decks are exposed to traffic, i.e. there is no wearing surface, and have performed very well.

A second contract to replace nine smaller overpass structures just north of the James River Bridge has just been awarded. The bridges have again been designed using full-span units with a sand lightweight concrete deck on steel girders. Using the plans for one of the new bridges, the weight of a precast unit has been computed using the different concrete densities. Since the plans gave quantities for reinforcement, it was accounted for separately in computing the unit weight rather than including it in the density of the reinforced concrete. While the design uses sand lightweight concrete, comparisons are shown with respect to normal weight concrete to show the weight savings achieved.

Although the precast decks are designed to be post-tensioned, all lightweight concrete is also shown as an option here.

The use of sand lightweight concrete reduced the weight of the precast slab unit by 16 tons or 12%. The percent reduction is less than for other situations because the weight of the unit also includes structural steel.

If all lightweight concrete had been used, the weight of the precast slab unit would have been reduced by 26 tons or 20%.

The plans specify normal weight concrete for the barriers, so the precast unit weights shown were computed using normal weight barriers for all concrete types. However, if sand lightweight concrete or all lightweight concrete were used for the barriers, the precast unit weights would be reduced another 2 and 3 tons, respectively.

Slide 38:

The Lewis and Clark Bridge is another commonly used example of how to replace a bridge deck using prefabricated elements. It is similar to the I-95 bridges in VA since it uses full span units comprised of steel beams and a precast concrete deck. The difference here is that the deck is supported by a truss. A system of SPMTs was used to remove the existing deck and replace it with the new panels.

For this bridge, the deck was designed to use sand lightweight concrete. Using lightweight concrete reduced the weight of the largest precast unit from about 92 tons to 78 tons, for a weight savings of about 14 tons.

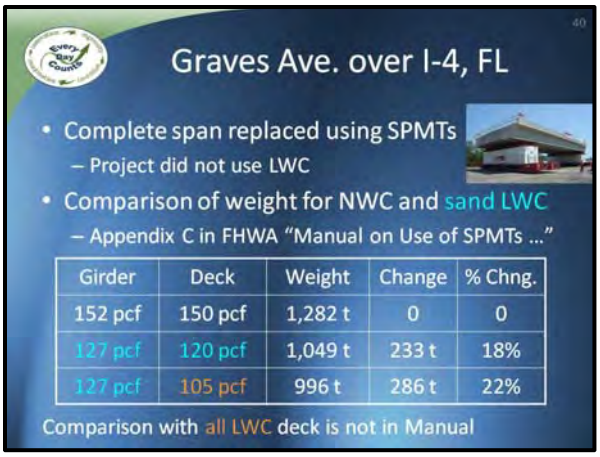
It is also interesting to note that the original deck on the truss bridge, which was opened to traffic in 1930, was lightweight concrete. It provided service for over 70 years, a pretty remarkable record considering the northern location.

Slide 39:

You have already heard about the experience of Utah in placing bridges using SPMTs. The initial bridges placed by SPMTs had normal weight concrete decks. However, the 3300 South bridge over I-215, constructed in 2008, was the first bridge installed using SPMTs that was designed with a sand lightweight concrete deck. Inspections of the deck after a few years in service revealed that this bridge deck had less cracking than the normal weight concrete decks constructed and moved in the same or earlier years.

Three bridge moves in Utah have been announced for 2011. Two of them are going to be moved as 2 span structures. All three of the bridges have been designed with sand lightweight concrete decks.

The use of lightweight concrete decks for these structures reduces the weight of the structure to be moved, but also reduces the weight of the portion of the bridge overhanging the SPMTs. This is expected to reduce the cracking in the decks during movement of the bridges.



Girder	Deck	Weight	Change	% Chng.
152 pcf	150 pcf	1,282 t	0	0
127 pcf	120 pcf	1,049 t	233 t	18%
127 pcf	105 pcf	996 t	286 t	22%

Slide 40:

The Graves Ave. Bridge over I-4 in FL is the final example we will consider. The bridge is 143 ft long and 59 ft wide and was one of the first spans installed in the US using SPMTs. The project did not use lightweight concrete.

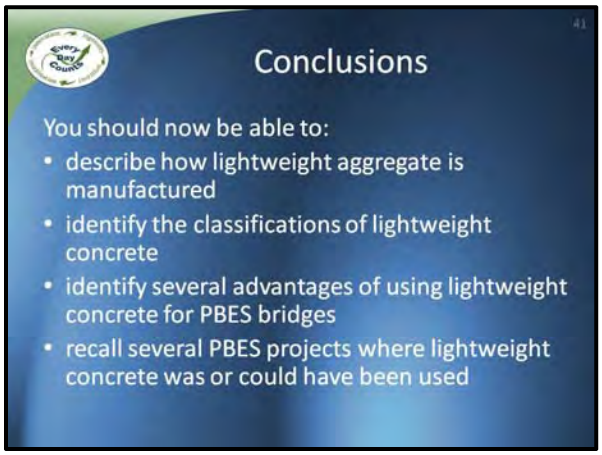
A comparison of using normal weight concrete and sand lightweight concrete for the prestressed concrete girders and deck on this bridge can be found in Appendix C of the FHWA's "Manual on Use of Self-Propelled Modular Transporters to Remove and Replace Bridges," which is listed as a reference for this webinar. The results of the comparison are repeated in the first two lines of this table. It can be seen that the weight of the structure to be moved would have been reduced by 233 tons, or 18%, if sand lightweight concrete had been used for both the girders and deck. This reduced weight could affect the number of axle lines that would be required to move the structure.

This slide also shows a third comparison which does not appear in the Manual. If all lightweight concrete had been used for the deck and sand lightweight concrete had been used for the girders, the weight of the structure would have been reduced another 53 tons, for a total reduction from the normal weight concrete design of 22%.

Slide 41:

You should now be able to:

- identify roadblocks to accelerated bridge construction
- identify the resources contained in *Connection Details for PBES*
- describe features of PBES that improve the quality of the finished product
- recognize a typical construction schedule for a bridge built with PBES
- recall ways to save money by using PBES



Slide 42:

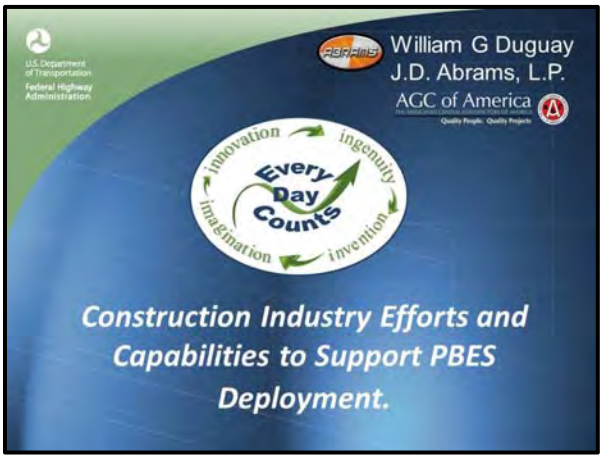
In conclusion, I hope that the information I have presented has demonstrated the potential for using lightweight concrete to reduce the weight of precast elements used to accelerate bridge construction.

It appears that the advantages of lightweight concrete may be easiest to consider in design / build projects where the contractor, designers and precast fabricators can work together to optimize the design by considering handling, shipping and erection requirements.

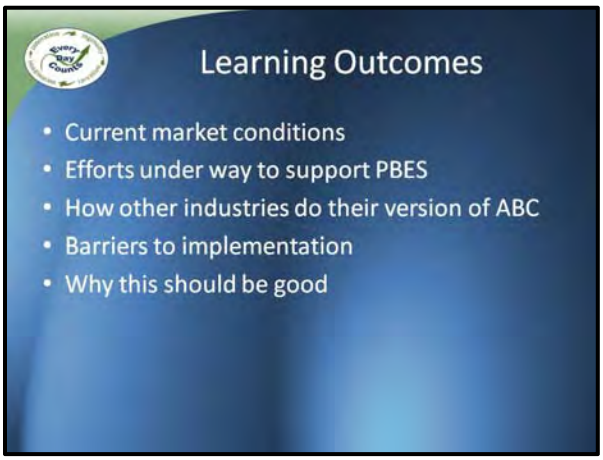
The lightweight aggregate industry would be glad to assist you as you make plans to implement PBES in your structures. Please use the information on the slide if you would like to contact us to obtain more information on lightweight aggregate or lightweight concrete

Module 12: Construction Industry Efforts and Capabilities to Support PBES Deployment *(Presenter, Bill Duguay)*

MODULE SLIDES & NOTES



Slide 1:



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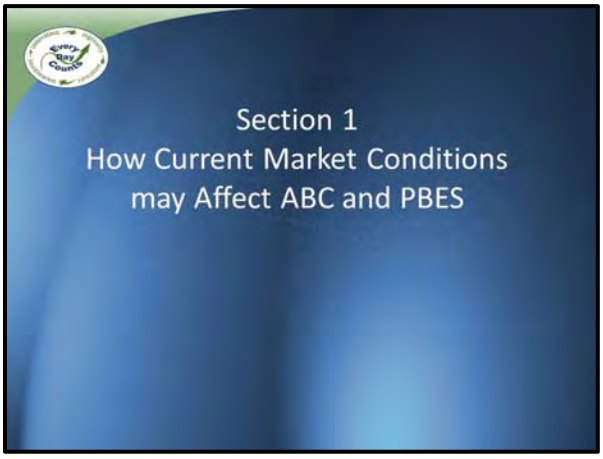
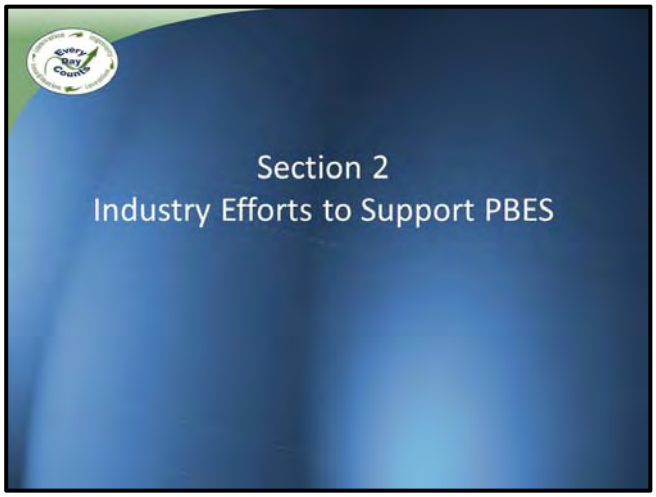


Slide 3:

Slide 4:
Current market conditions make transportation investment ideal, and how will ABC and PBES fit into this?

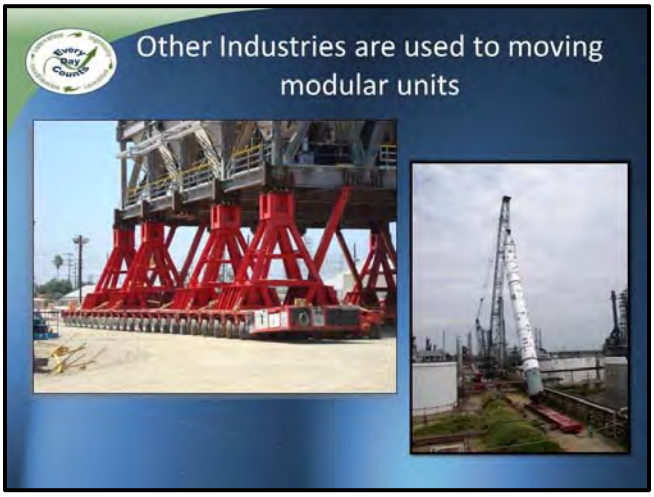
Slide 5:
146K number per TRIP; The NHS says the majority are less than 90 feet.



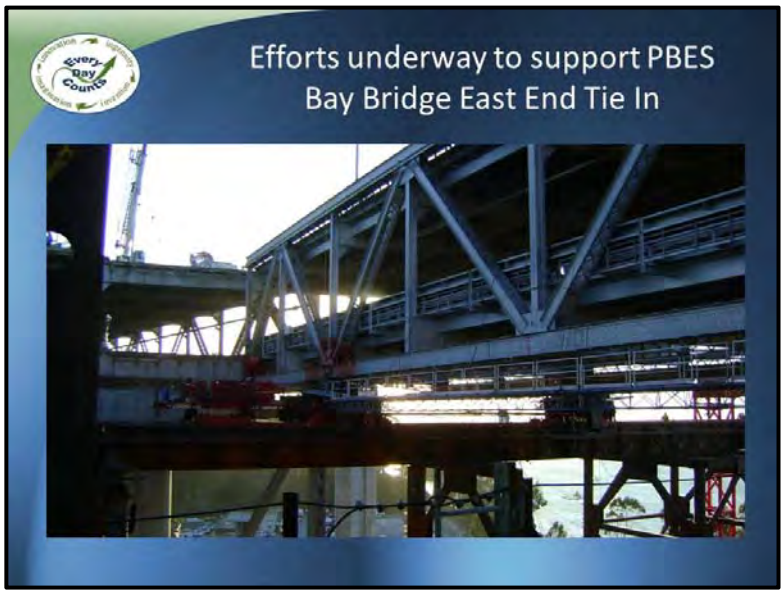
Slide 6:
PBES can be a sole solution based on site constraints of some sort, access constraints or mobility concerns, and these may be more of a requirement than a desire.

Slide 7:

Slide 8:
Photo courtesy of Barnhart Crane/Hake Rigging

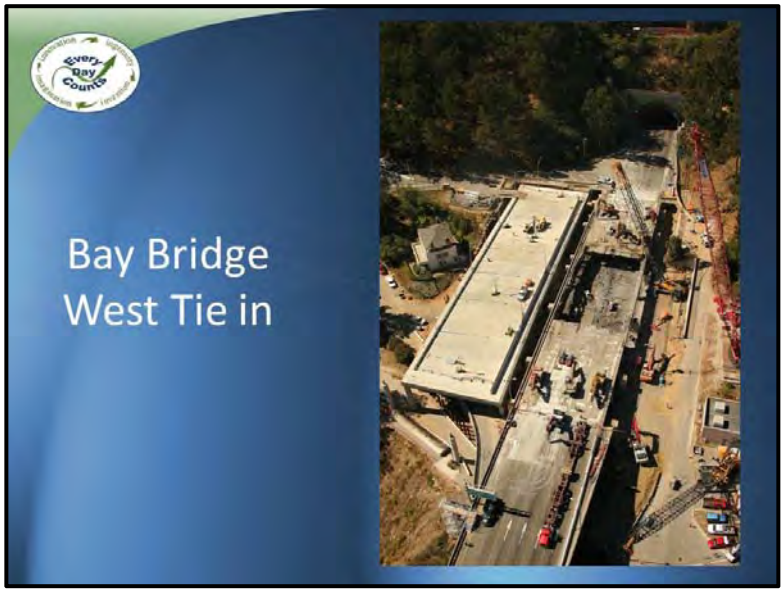


Slide 9:
Photo's courtesy of Barnhart Crane



Slide 10:
The Bay Bridge in San Francisco East Tie-in, segment skidded over on Labor Day 2009. Weight is 3,300 tons ea. Old piece out, new piece in. Old piece lowered 150 ft to the ground for demo. Photo Courtesy Mammoet

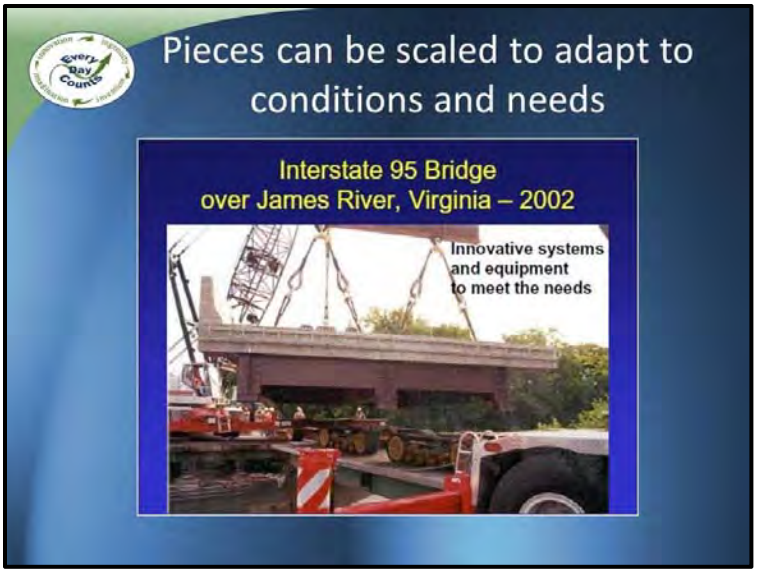
Slide 11:
Old bridge demolished and new one skidded in. Road closure was 1 weekend. There is a nice video of this one on the Oregon DOT website under the Redland Rd Crossing Project. Photo Courtesy Mammoet



Slide 12:
Done over Labor Day Weekend; weight 6,500 tons. Old one demolished conventional way, new one skidded in. Photo Courtesy Mammoet

Slide 13:
Bridge weight around 2,100 tons. Installed with SPMTs. Road closure from 10.00 PM until 06.00 AM Saturday. Photo Courtesy Mammoet

Slide 14:
Transport of typical mid-sized elements using conventional equipment

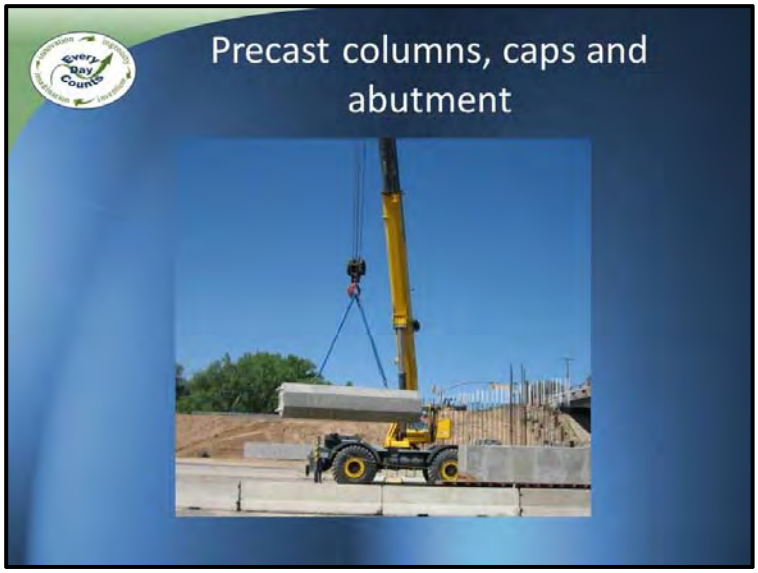


Slide 15:
Mid-scale PBES pieces using owned equipment and potential for self-fabrication

Slide 16:
Photo Courtesy Michael Baker Corp/Granite Construction

CM/GC Design Build Riverdale Rd over I-84 Salt Lake City Utah

Small piece size, cast at the project, conventional equipment and techniques used for erection



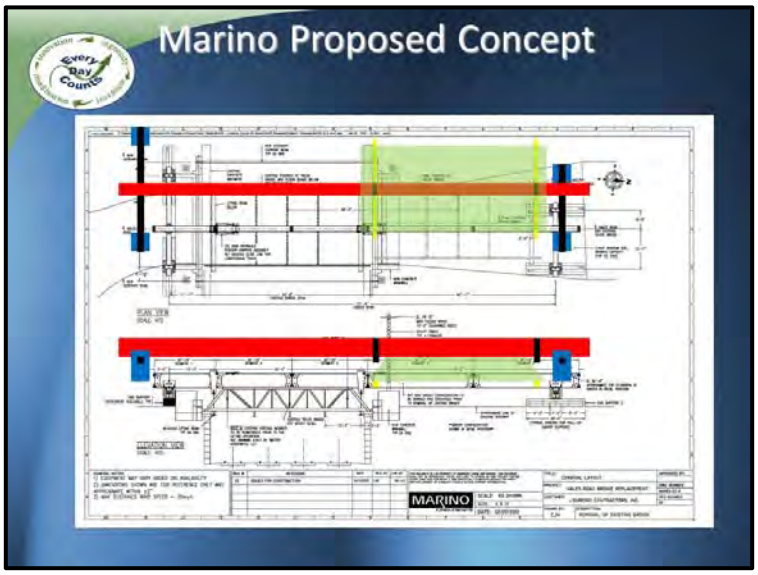
Slide 17:
Photo courtesy Michael Baker Corp/Granite Construction

CM/GC Design Build Riverdale Rd over I-84 Salt Lake City Utah

Slide 18:
Mill Street Bridge Epping New Hampshire designed and constructed using local resources

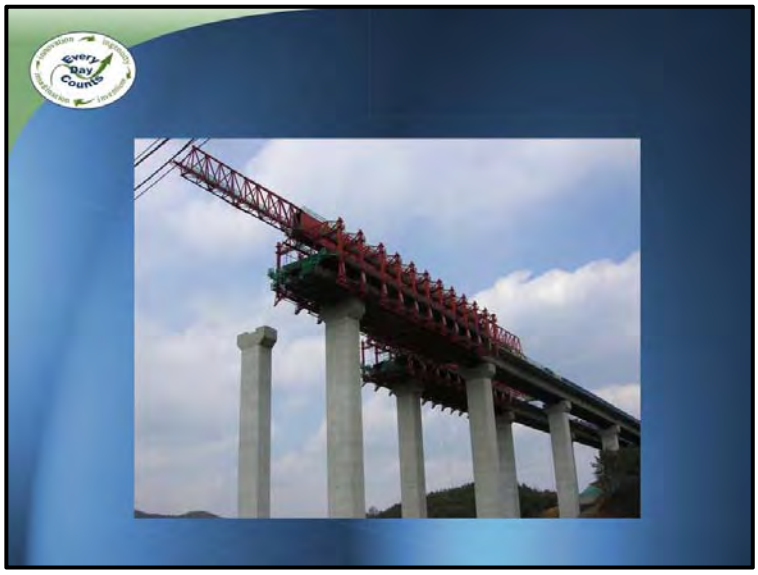
Slide 19:
All the way to small scale light pieces where access, distance, remoteness or other constraints are present
Photos courtesy HCB Bridge

Slide 20:
Photos Courtesy Barnhart Crane

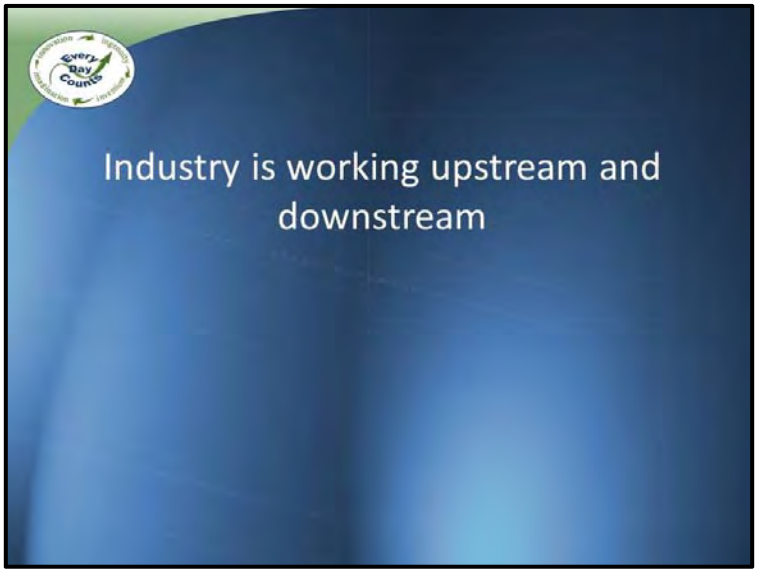


Slide 21:
Proposed method courtesy Barnhart-Marino Crane/Hake Rigging

Slide 22:
The MMS (Moveable Scaffold System) underslung modular deck forming, span by span cast in place self-launching form traveler, when there is insufficient room for casting yards or transport of segments is improbable. Photo Courtesy of Harsco Infrastructure Americas



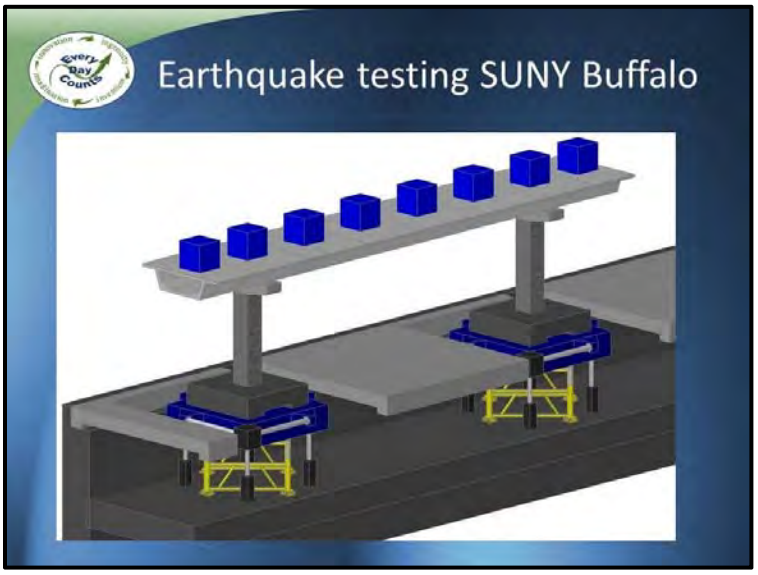
Slide 23:
The MMS Over slung system, span by span cast in place self-launching traveler, photo courtesy of Harsco Infrastructure Americas



Slide 24:
By working with Universities and assisting in research, Industry is exposed to the latest thinking and is on the ground floor with academia, research organizations and the FHWA is finding new solutions to our transportation issues

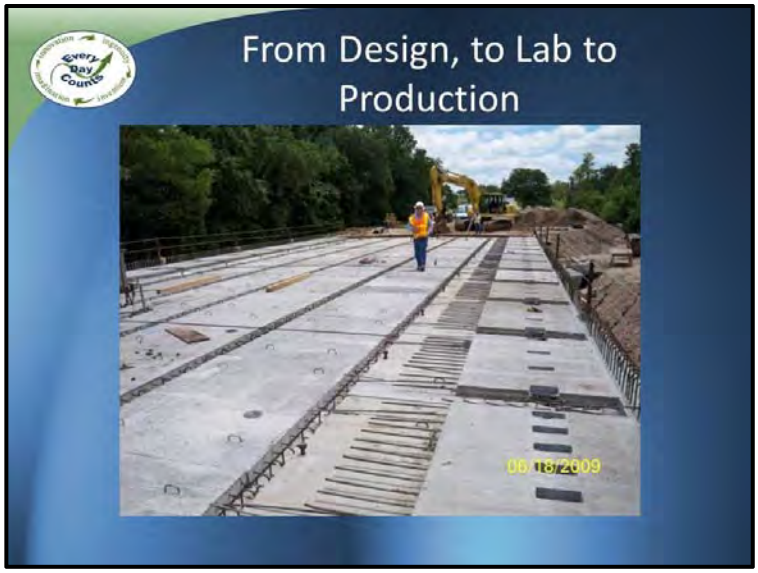
Slide 25:
Photo courtesy of University of Washington Newsletter: "*The Bridge*". Quote from Professor John Stanton. Several different research focus topics have been successfully implemented, including a cap beam connection that is very easy to construct, a bridge bent system that uses unbonded pre-tensioned columns

Slide 26:
Lab testing of HCB beams, photo courtesy HCB Bridge, prototype being tested at the AEWC Lab at the University of Maine



Slide 27:
Photo courtesy SUNY Buffalo SEESL - Structural Engineering and Earthquake Simulation Laboratory

Slide 28:
Precast overhangs undergoing testing
Photo courtesy Austin Prestress, Texas A&M, Oklahoma Transportation Center and Tyler Ley, PE, Ph.D. – Assistant Professor, Oklahoma State University

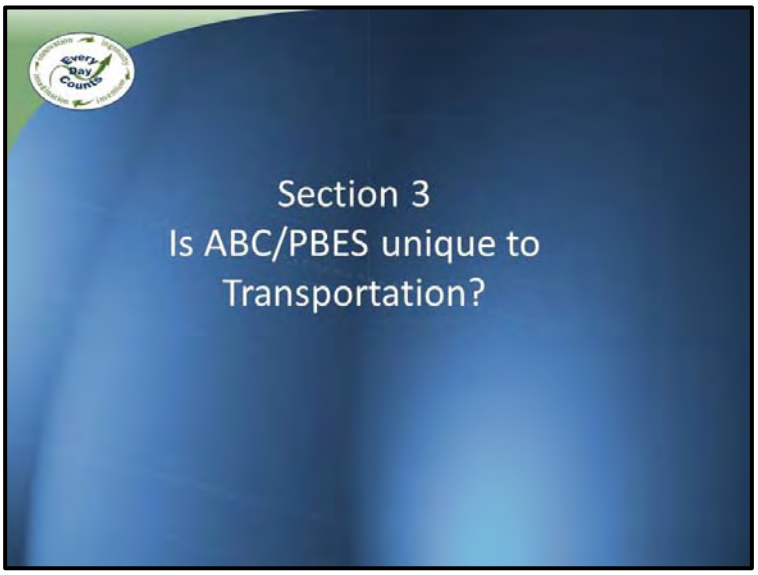


Slide 29:
Photo courtesy SUNY Buffalo SEESL - Structural Engineering and Earthquake Simulation Laboratory

Slide 30:

Photo courtesy Austin Prestress, Texas A&M, Oklahoma Transportation Center and Tyler Ley, PE, Ph.D. – Assistant Professor, Oklahoma State University

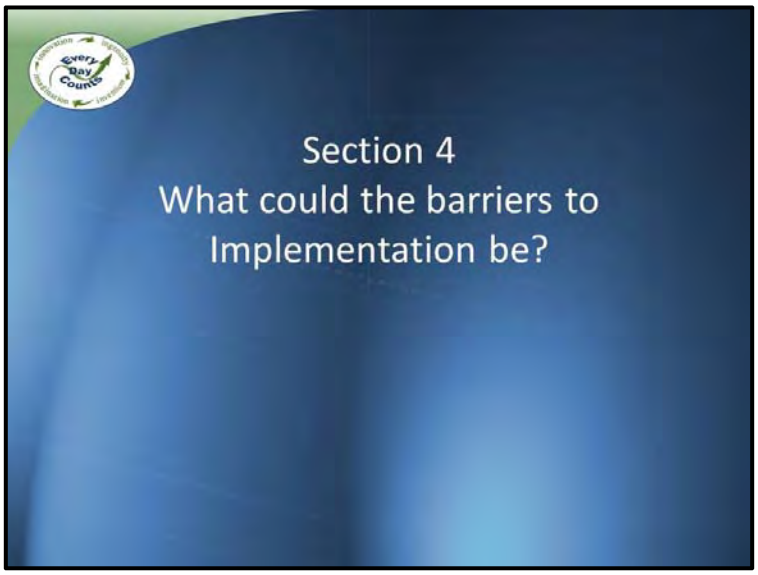
Rock Creek Bridge, in Parker County just north of Cool, Texas



Slide 31:

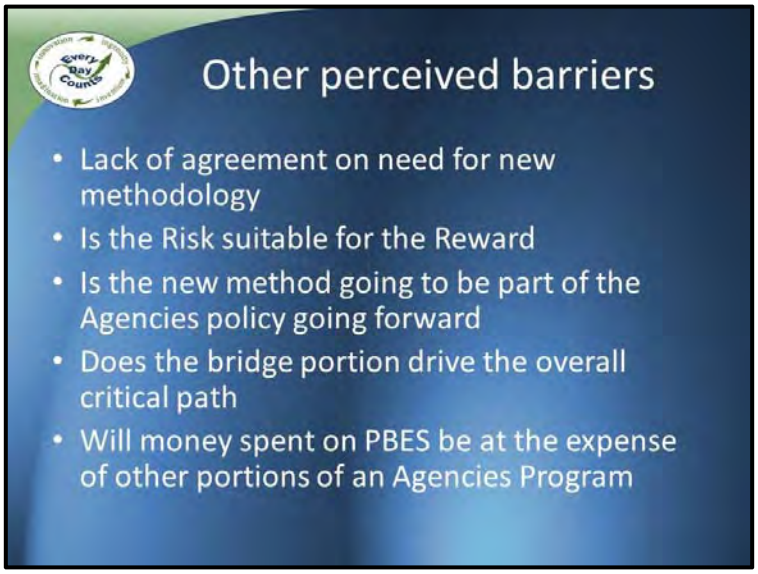
Slide 32:

Many industries value time and quality over initial cost. Newer project financing options also stress delivery time and the opening of facilities to generate revenue.



Slide 33:

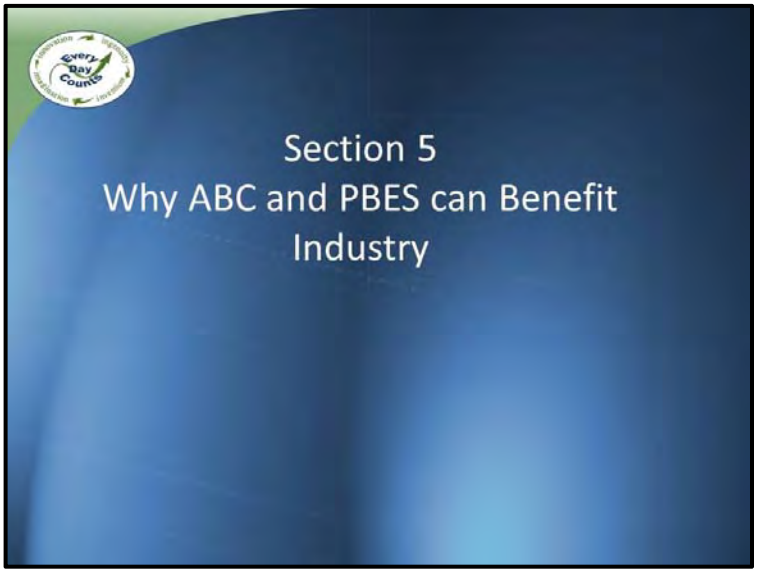
Slide 34:



Slide 35:

Slide 36:

Slide 37:



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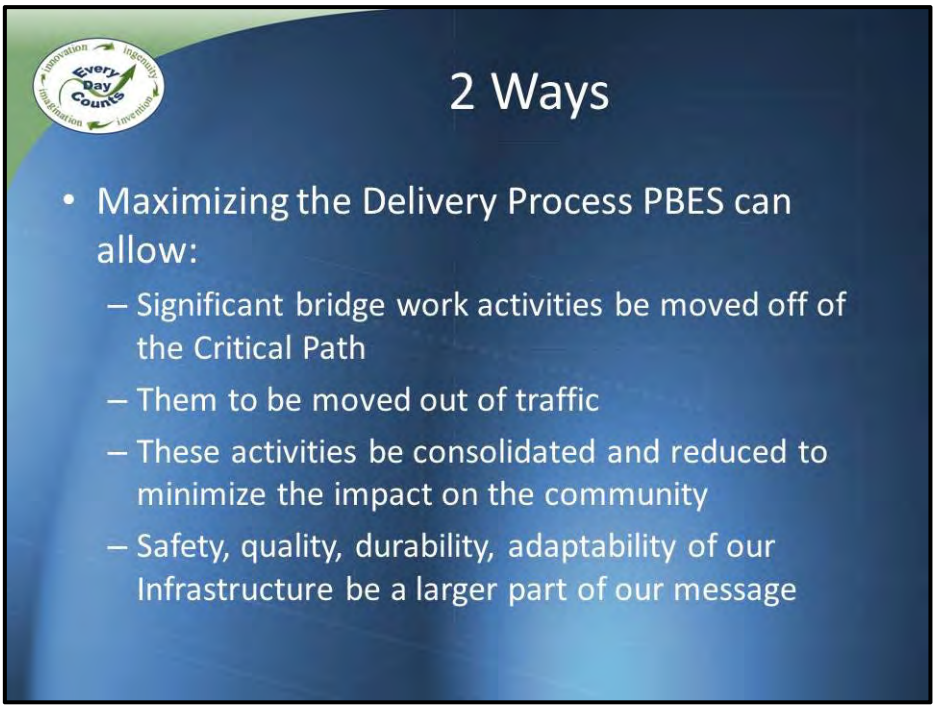
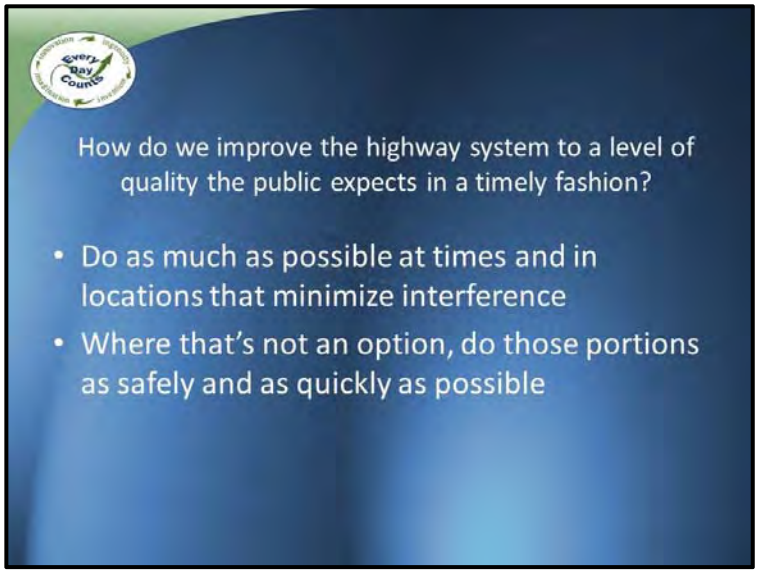
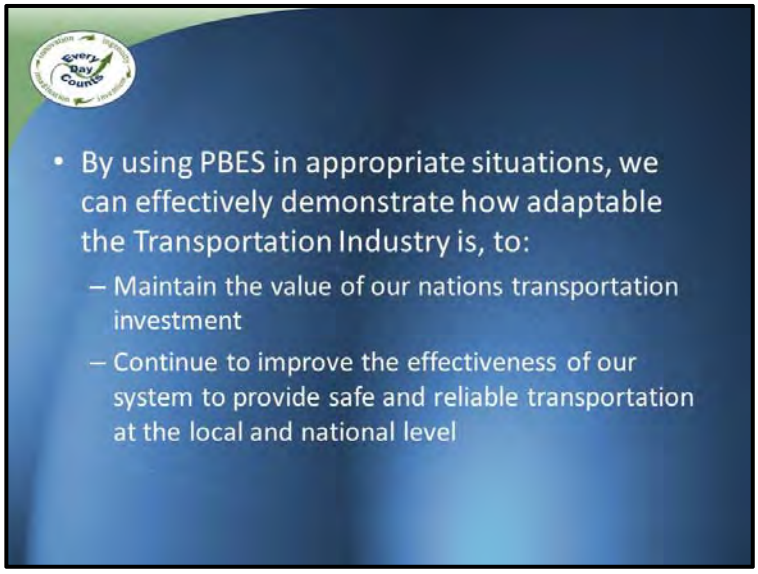


1) Bridge elements can be fabricated at a time convenient to the contractor instead of as dictated by the linear schedule of in place construction
2) Working in and around traffic continues to be one of the most hazardous portions of highway construction for both the public, the Agency and the Contractor, working outside of the final location may minimize added congestion due to construction activities and lessen the economic impact to adjacent businesses
3) PBES can reduce the truck traffic from deliveries in the work zone, move them to other project locations and smooth equipment and labor demands on the project
4) Our Infrastructure when treated as an investment needs to last longer

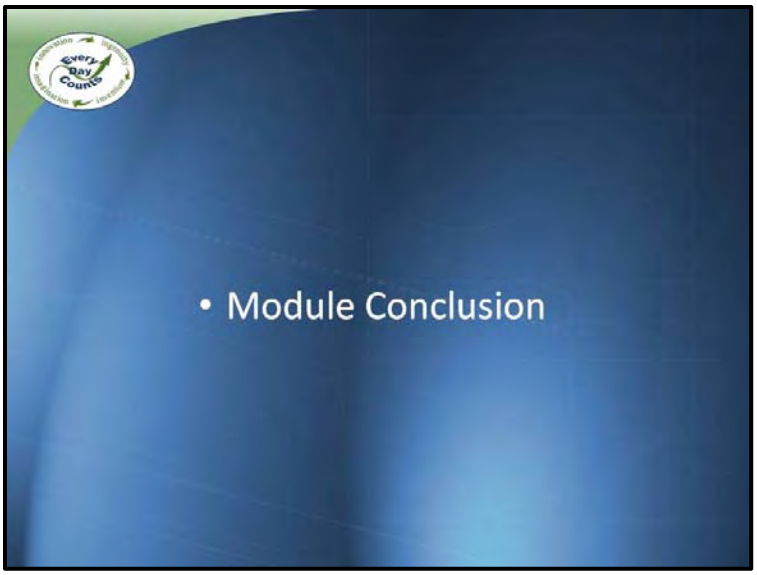
Slide 39:



Slide 40:
The public's perception of "timely" can be based on congestion caused by construction



Slide 41:
The Construction Industry, along with our engineering firms and vendors are working on PBES in many ways each and every day. We're working hard to provide appropriate and innovative solutions to our transportation issues; and the AGC and our partners will continue to work to implement the best technology available to support the FHWA's Every Day Counts Initiative

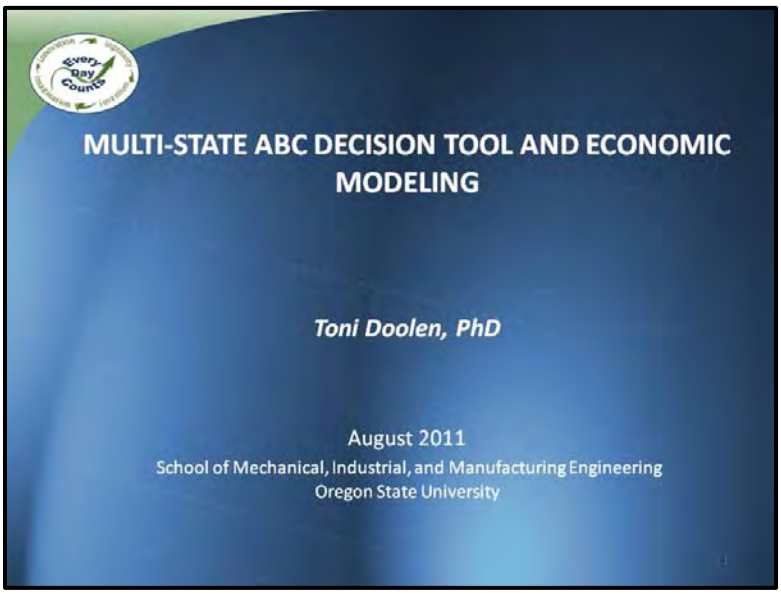


Slide 42:

Slide 43:

Accelerated Bridge Construction Decision Making & Economic Development Modeling Tool: Oregon led Pooled Fund Study

MODULE SLIDES & NOTES



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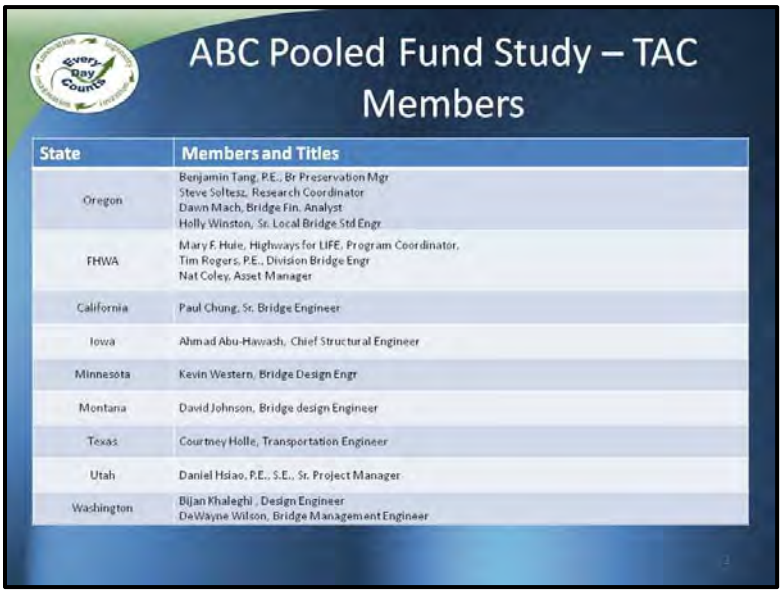


State	Members and Titles
Oregon	Benjamin Tang, P.E., Br Preservation Mgr Steve Soltesz, Research Coordinator Dawn Mach, Bridge Fin. Analyst Holly Winston, Sr. Local Bridge Std Engr
FHWA	Mary F. Hule, Highways for LIFE, Program Coordinator, Tim Rogers, P.E., Division Bridge Engr Nat Coley, Asset Manager
California	Paul Chung, Sr. Bridge Engineer
Iowa	Ahmad Abu-Hawash, Chief Structural Engineer
Minnesota	Kevin Western, Bridge Design Engr
Montana	David Johnson, Bridge design Engineer
Texas	Courtney Holle, Transportation Engineer
Utah	Daniel Hsiao, P.E., S.E., Sr. Project Manager
Washington	Bijan Khaleghi , Design Engineer DeWayne Wilson, Bridge Management Engineer

Slide 2:
8 states + federal highways

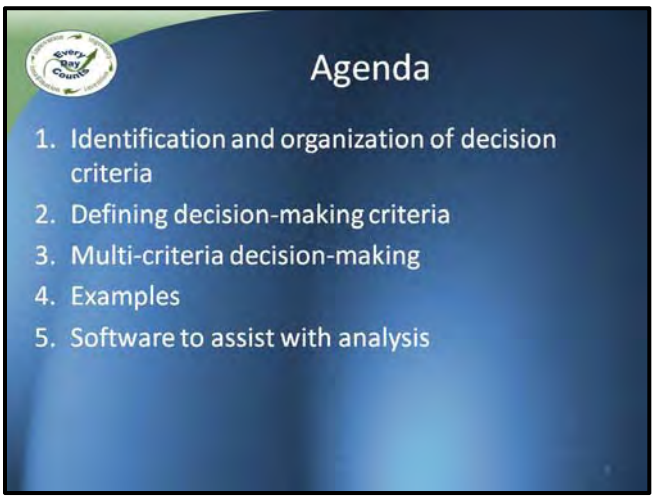
Slide 3:

Account for characteristics of bridge project, e.g. bridge length, complexity, road user characteristics, environmental requirements, traffic levels, existing levels of congestion, and construction site attributes

Slide 4:

User-friendly and flexible to accommodate a range of construction situations, transparent as to the method of calculation, and customizable to maintain future relevance.

Engineers who can use the tool to create detailed estimates for recommendations



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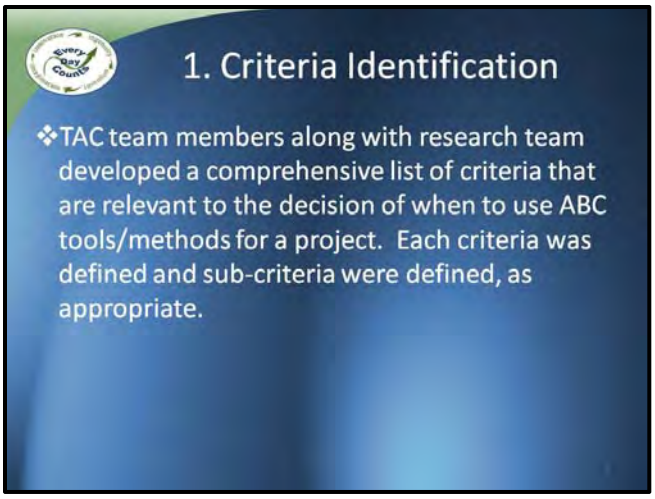

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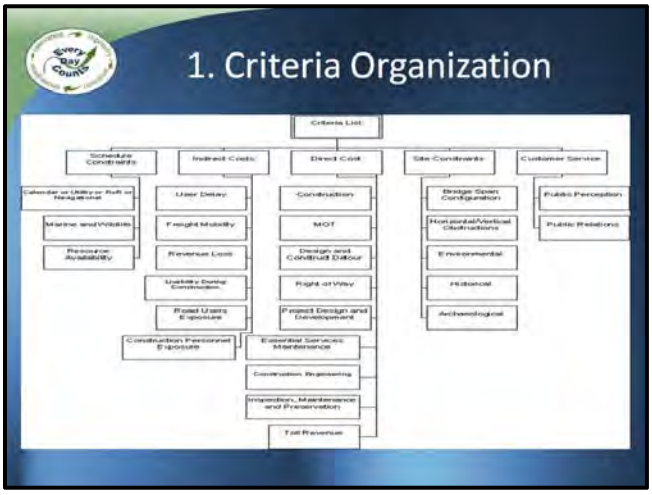

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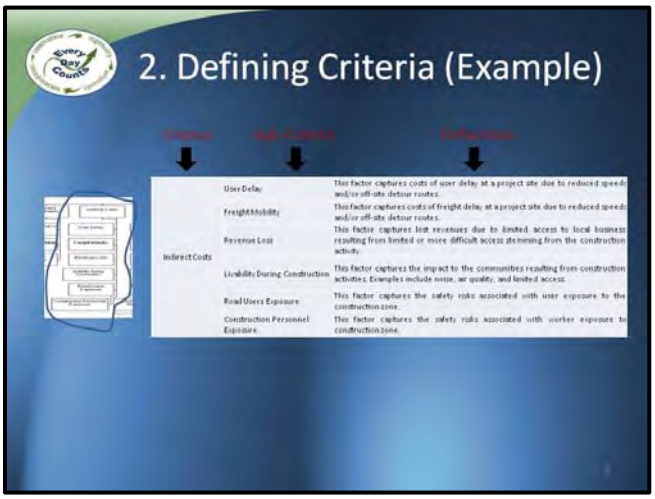


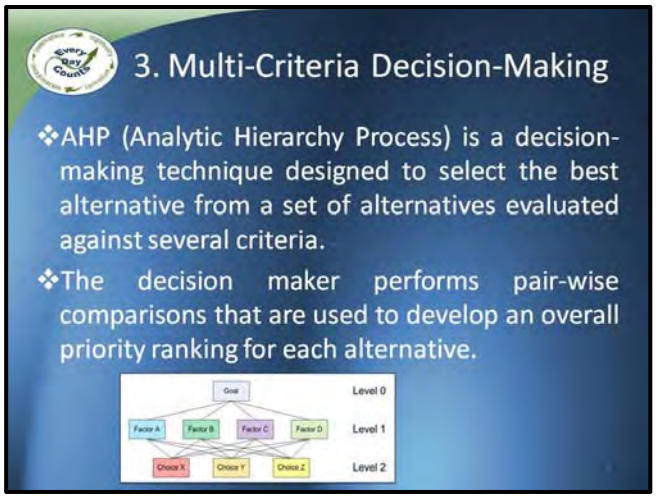
Slide 8:

Slide 9:

Key Resources on AHP:

Saaty, T.L. (1980) *The Analytic Hierarchy Process*, McGraw Hill.

Saaty, T.L. and Vargas, L.G. (1984). Comparison of eigenvalue, logarithmic least squares and least squares methods in estimating ratios. *Mathematical Modeling*, 5, 309-324.



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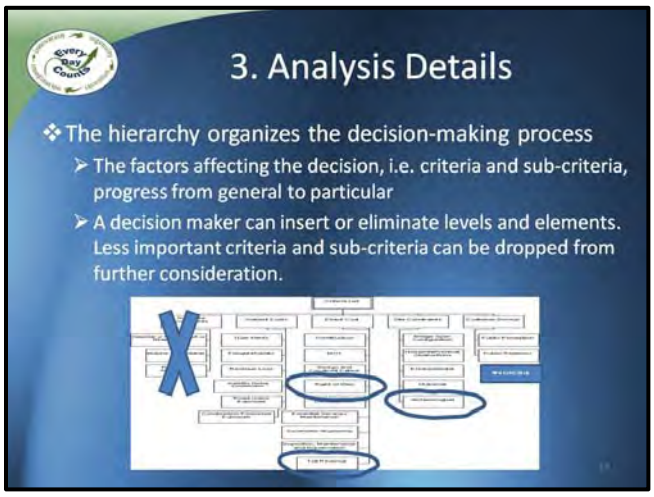

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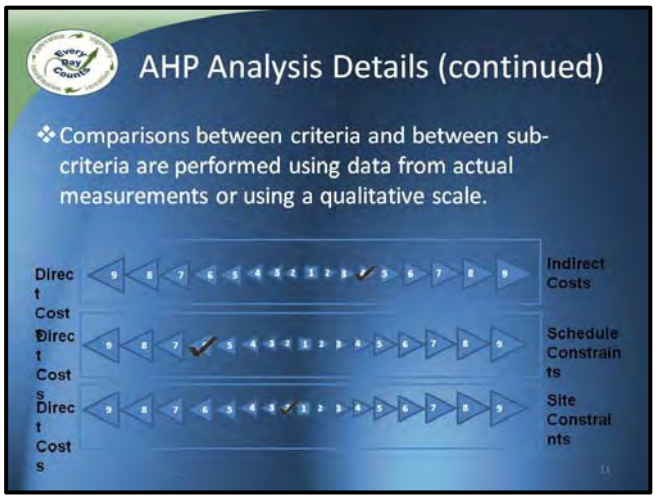

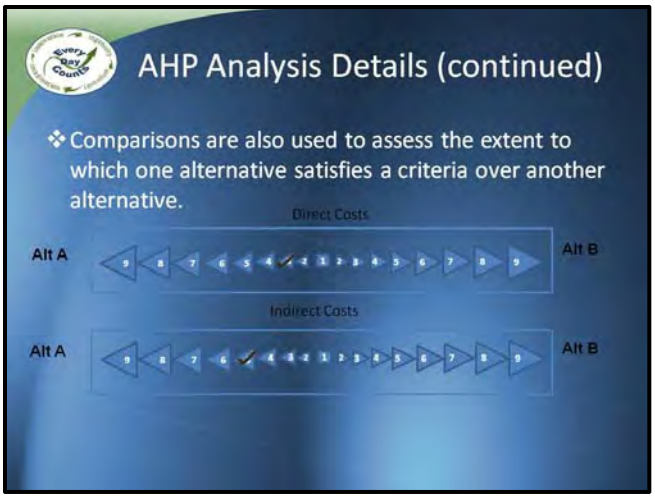

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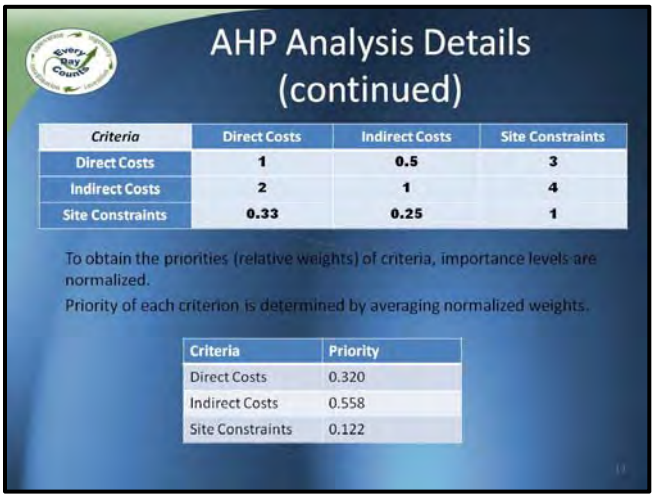
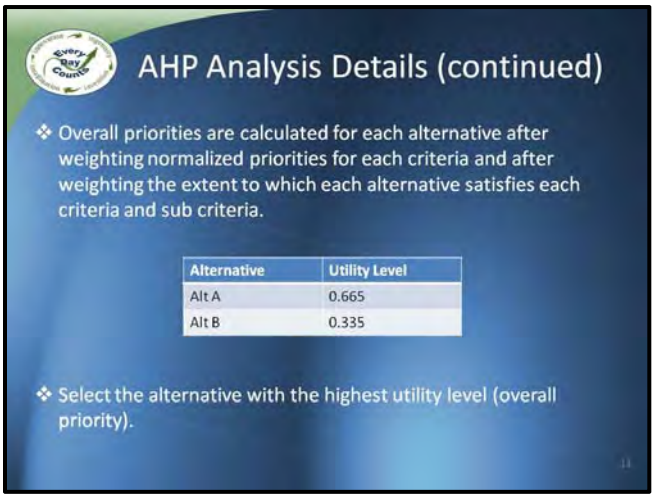


Criteria	Direct Costs	Indirect Costs	Site Constraints
Direct Costs	1	0.5	3
Indirect Costs	2	1	4
Site Constraints	0.33	0.25	1

Criteria	Priority
Direct Costs	0.320
Indirect Costs	0.558
Site Constraints	0.122

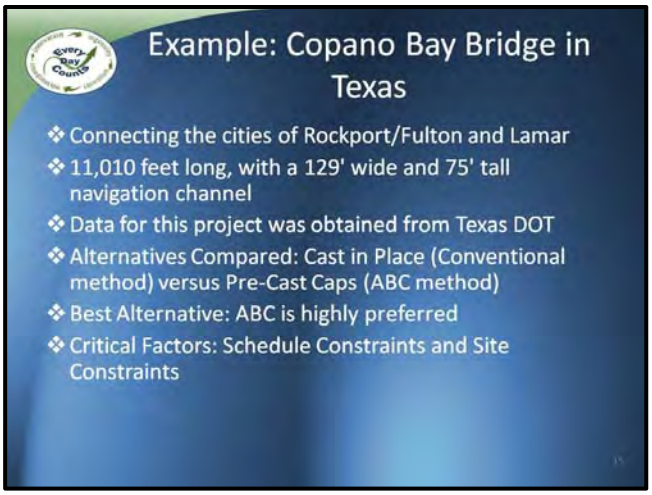
Slide 13:



Alternative	Utility Level
Alt A	0.665
Alt B	0.335

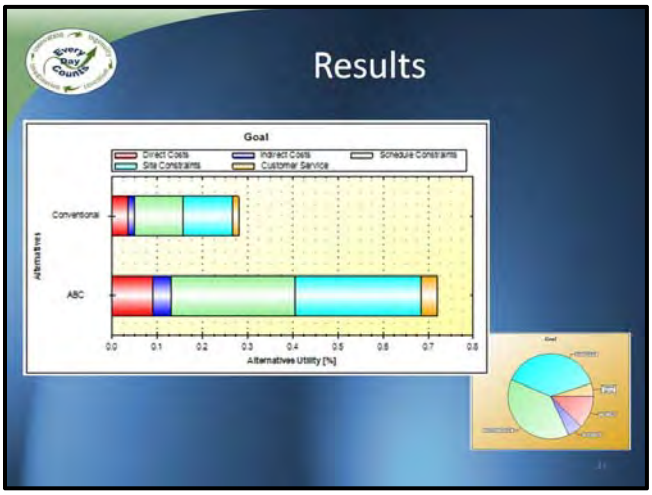
Slide 14:

Slide 15:



The Copano Bay Bridge: The Copano Bay Bridge replaces the existing causeway on SH 35 at the mouth of Copano Bay. The bridge connects the cities of Rockport/Fulton and Lamar, on the Gulf Intracoastal Waterway. Copano Bay is home to oyster colonies and migratory birds, attracting birdwatchers year-round. Two peninsulas frame the bay opening, limiting ROW and dictating phased construction. The bridge is 11,010 feet long, with a 129' wide and 75' tall navigation channel. The existing structure suffers severe corrosion from marine exposure, such that some piling members have failed and required extensive repair. As such, providing corrosion protection - in the form of high-performance concrete, stainless reinforcing steel, and cylinder pile foundations - was of high importance. The superstructure is 100', 120', and 150' long prestressed concrete girders. A majority of the piers consist of cast-in-place caps on trestle piles, with the tallest piers around the navigation channel being CIP bent caps on CIP columns and waterline pile caps. Contractors may elect to propose precast bent caps as alternate construction, thus reducing the duration of construction activities over open water.

Slide 16:

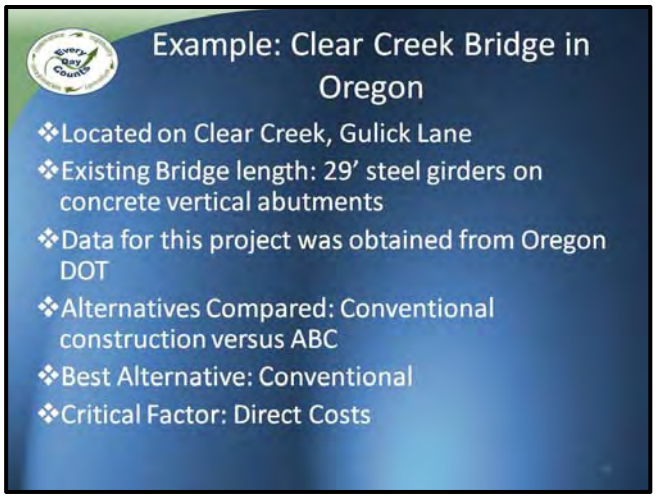


Slide 17:

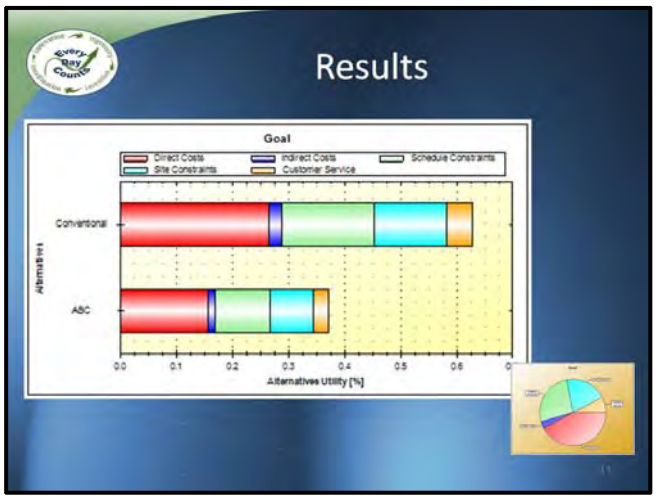
Slide 18:

Bridge info:

- Existing Bridge is on Clear Creek, Gulick Lane
- Existing Bridge length: 29ft steel girders on concrete vertical abutments
- The bridge is on a rural local road.
- ADT: 90
- Detour length: 1 mile
- The new bridge will be 80-100 ft in length



Slide 19:



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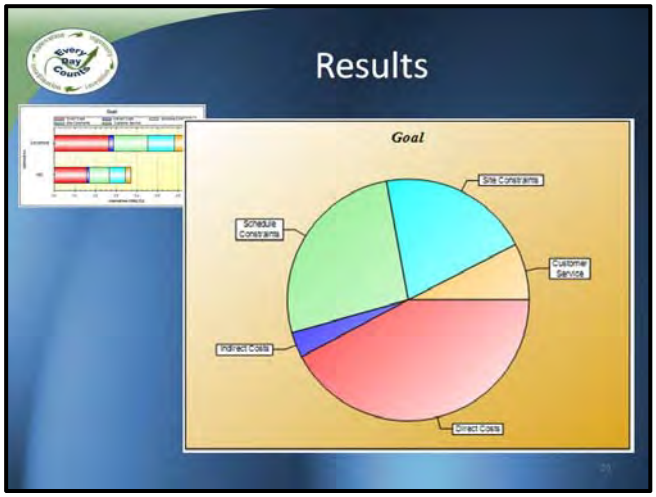
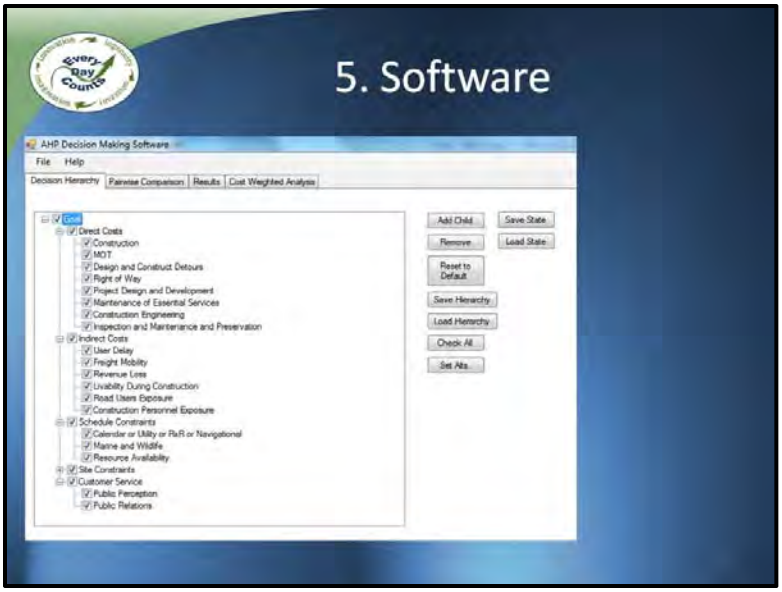
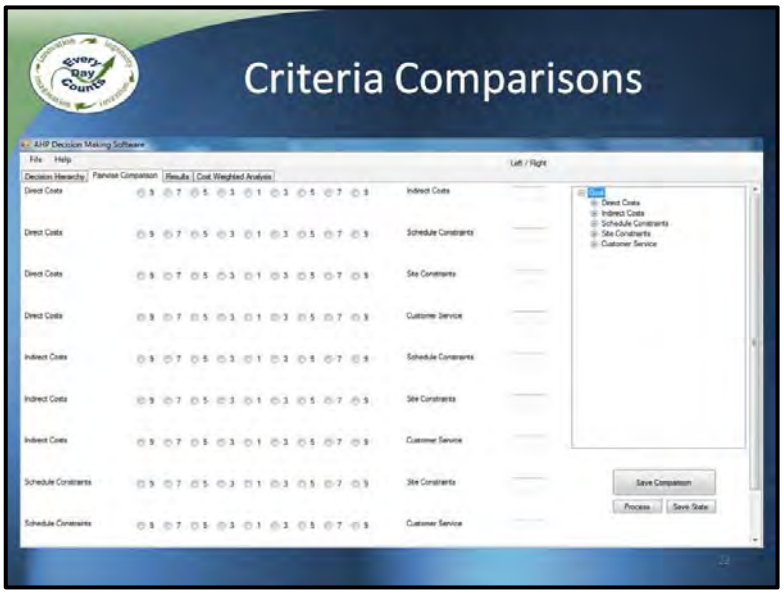




Slide 21:

The first tab is associated with constructing a decision hierarchy. In this tab, the user has access to all necessary functions to support loading, saving, and modifying a decision hierarchy. The user has the option to disable a decision category either temporarily or permanently for every hierarchy. The second tab is associated with conducting pairwise comparisons. The user can save the state of an analysis at anytime and later return to that specific position, without losing any data. After finishing all pairwise comparisons, the user can review the results in the third tab.

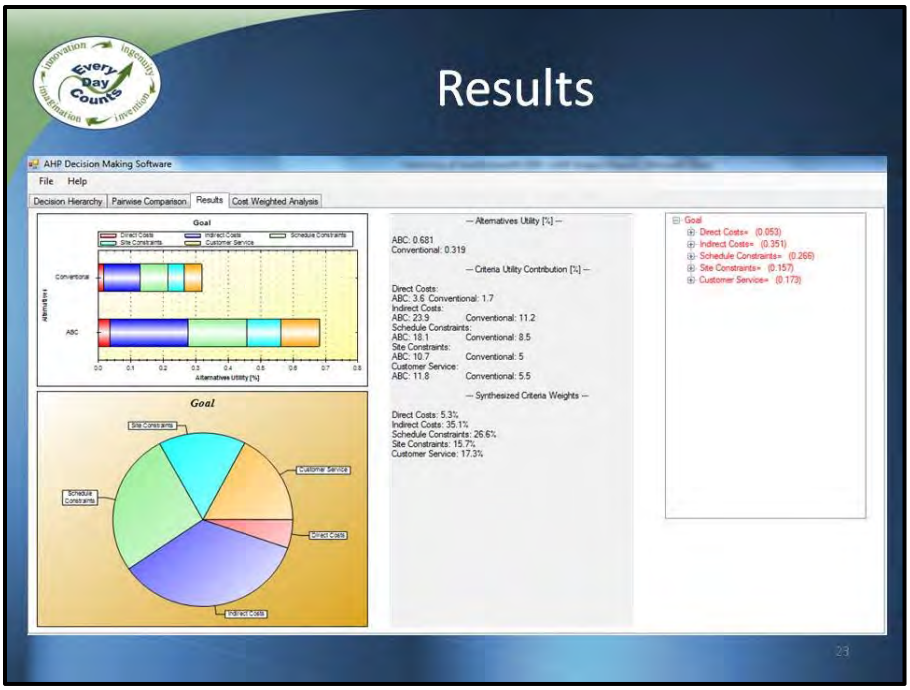
For each node, existing in the decision model, the tool will generate a set of two plots: a bar chart indicating the utility levels of the two alternatives being compared and a pie chart showing the weights for each of the sub-categories. The last tab provides the user with the option of completing an additional cost-weighted analysis. This tab may be used only after all cost criteria have been eliminated from the decision model constructed using the first (left most) tab.



Slide 22:

Pairwise comparisons are used to determine the relative importance of each criterion and the preference for each alternative when a set of criteria is considered. Each choice is a linguistic phrase. Some examples of linguistic phrases that can be used are: "A is more important than B", or "A is of the same importance as B", or "A is a little more important than B", and so on. In the pairwise comparison window, the user still has visibility to the decision hierarchy (in read-only mode) on the right hand side of the window. By clicking on each item in the hierarchy listing on the right, all pairwise comparisons associated with that level of the hierarchy will be displayed. Prior to viewing the results, the user must save the entire sets of comparisons by clicking on the “Save Comparison” button at the bottom of the window.

The user can compare criteria in two ways. For qualitative criteria, the user can use the scales provided on the form to rate the relative importance of criteria. If the criteria are quantitative (and accurate values or estimations are available) or the user wishes to use even scale numbers, text entry boxes are provided next to each comparison. The value entered in this box will represent the relative importance of the criterion on the left, over the criterion on the right. If the user uses both the radio buttons and manually enters a rating or a ratio in the text box, the value entered in the text box has the priority and will override the value entered using the scale.



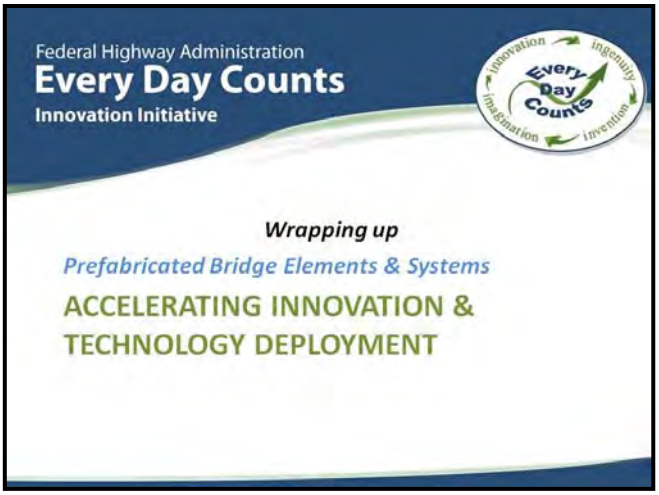
Slide 23:

From the results tab, the user can review the results of the AHP analysis completed using the pairwise comparisons or ratios entered by the user. At the center of the page, the overall preference for the two alternatives being compared is presented using percentages. The alternative with higher percentage value has the highest preference (i.e. utility).

These plots are dynamically generated for each hierarchy node. In other words, every time the user selects a node or category from the decision hierarchy on the right, the associated plots are drawn automatically. The bar chart represents the preference or utility level, calculated for the alternatives, by only considering the criteria within that specific node. In other words, when the user selects the “Schedule Constraints” node from the hierarchy, the stacked plot will show the utility level by only considering the weights and preferences associated with calendar and schedule constraints. By default, the software will display the plots for the overall results (plots associated with the “Goal” node) when the user moves on to the results tab. At the “Goal” node level, every generated bar is aggregated based on the utility values calculated using every subcategory. The pie chart shows the synthesized weight for every sub-criterion in a selected category. If the user selects a third-level criterion, the pie chart will show the user entered preference for different alternatives. The criterion with the highest weight in pie chart has the greatest contribution towards the total utility displayed in the stacked bar chart.

Slide 24:

Conclusion



Slide 1

Slide 2

PBES are innovative methods to decrease bridge construction time by allowing elements to be built off-site, outside the traffic area, and then transported to the site and installed rapidly.

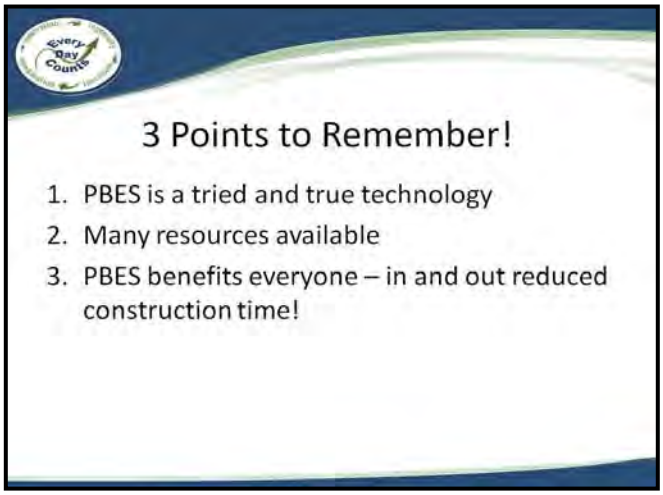
Slide 3

Some of the benefits of employing Prefabricated Bridge Elements & Systems are that they minimized traffic

disruption, improved work zone safety improved worker safety, improved product quality, controlled environment, cure times, and easier access.

Slide 4

Slide 5



1. Transitioning from traditional construction to PBES bridge construction is not an insurmountable task. There are many project examples in the webinar that were presented, and specific case studies are constantly posted on our website. PBES is a tried and true technology that will move bridge construction to the next level.

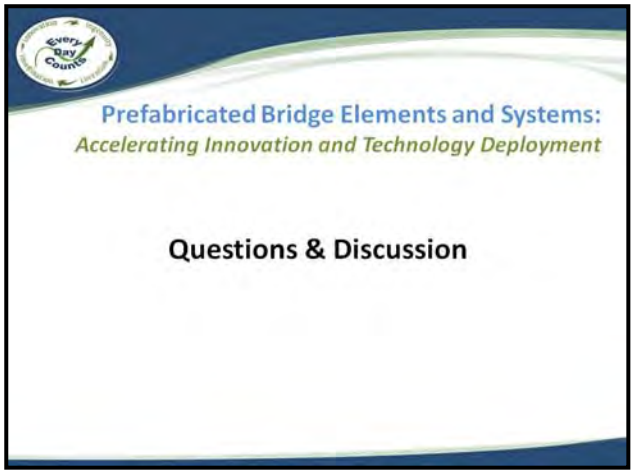
2. There are many resources available to help the States implement PBES. The workbook and the presentation highlighted many of these resources. Everything from specifications, to drawings, to engineering, to process. The important considerations in the decision-making framework for PBES should be incorporated into the States' project development process to determine if PBES is the most effective course of action to accelerate a bridge construction effort.

3. PBES benefits everyone: PBES reduces project time and cost, while increasing safety for both workers and the motoring public. (VERY strong VERY positive message).

Slide 6

Wrap Up:

PBES is a clear winner. Positive public perception and feedback received on accelerating bridge construction through the use of PBES leads to greater funding opportunities, political/leadership support, and confidence for Federal, State, and local transportation agency projects.



V. APPENDICES

APPENDIX A: Every Day Counts PBES Technology Deployment Team

General Information:
EDC POCs: Bob Richard, EDC (202) 493-3163; John Moulden (202) 493-3470; & Angel Correa (ABC Team Representative) (404) 562-3907

Accelerated Bridge Construction

Stakeholders / Positions	Team Member(s)	Email	Telephone	Title	Location
Point of Contact Co-technical Lead PBES	Claude Napier	Claude.Napier@dot.gov	(804) 775-3327	Sr. Structural Engineer	RC-STST Richmond
Technical Lead PBES	Lou Triandafilou	Lou.Triandafilou@dot.gov	(410) 962-3648	Sr. Structural Engineer	RC-Baltimore
Project/Funds Manager	Chris Marston	Chris.Marston@dot.gov	(804) 775-3363	Assistant Structural Engineer	VA Division
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Marketing Specialist	Deborah Vocke	Deborah.Vocke@dot.gov	(410) 962-3744	Marketing Specialist	RC-Baltimore
Evaluation Lead	Rajkumar Ailaney	Raj.Ailaney@dot.gov	(202) 366-6749	Structural Engineer	HIF/ HIBT-1
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Federal Lands Highway Division	Gary Jakovich	Gary.Jakovich@dot.gov	(703) 404-6233	FLH Chief Bridge Engineer	EFLH
	ALT. Arvind Patel	Arvind.Patel@dot.gov	(703) 948-1413	Project Manager	EFL-P&D
	Roger Surdahl	Roger.SURDAHL@dot.gov	(720) 963-3768	Highway Engineer, Technology Deployment	CFLH
Division Offices	Helene Roberts	Helene.Roberts@dot.gov	(609) 637-4230	Bridge Engineer	NJ Division
	Tim Rogers	Timothy.Rogers@dot.gov	(503) 587-4706	Bridge Engineer	Oregon Division
	Russell Robertson	Russell.Robertson@dot.gov	(801) 963-0078 x229	ITS Engineer	Utah Division
	Barry Brecto	Barry.Brecto@dot.gov	(360) 753-9482	Bridge Engineer	WA Division

Stakeholders / Positions	Team Member(s)	Email	Telephone	Title	Location
Stakeholders AASHTO	Bruce Johnson ALT. Benjamin Tang	Bruce.V.Johnson@odot.state.or.us Benjamin.M.Tang@odot.state.or.us	(503) 986-4200 (503) 986-3318	State Bridge Engineer Bridge Preservation Managing Engineer	Oregon DOT Oregon DOT
	Joshua Sletten ALT. Carmen Swanwick	jsletten@utah.gov cswanwick@utah.gov	(801) 965-4879 (801) 965-4981	Bridge Design Manager Chief Structural Engineer	Utah DOT Utah DOT
	Shoukry Elnahal	shoukry.elnahal@state.ma.us	(617) 973-7995	Director, Accelerated Bridge Program	Mass DOT Highway Division
Stakeholders AGC	Bill Duguay	WDuguay@jdabrams.com	(713) 734-6499	Houston Area Manager	J.D. Abrams L.P.
Stakeholders NACE					
	Eugene (Gene) Calvert	EugeneCalvert@colliergov.net	(239) 252-5791	Traffic Operations Department	Collier County Transp. Division
Stakeholders NCBC	Sue Lane	SLane@cement.org	(202) 408-9494, Ext. 126	Director, Transportation Structures	Portland Cement Assoc.
Stakeholders AISC/NSBA	Brian Raff	Raff@steelbridges.org	(312) 670-5415	Marketing Director	NSBA/ AISC
Stakeholders ARTBA	**TBD**				

APPENDIX B: Prefabricated Bridge Elements & Systems Resources

Publications:

Title: Prefabricated Bridge Elements and Systems Cost Study: Accelerated Bridge Construction Success Stories
Publisher: Federal Highway Administration, Washington DC
Topics: Prefabricated Bridge Elements and Systems, Accelerated Bridge Construction
Abstract: The prefabricated bridge elements and systems (PBES) cost study documents the details related to savings in time and money on nine PBES projects in states across the country. All nine projects are replacement projects, and as such reducing the impact of onsite construction to motorists was a priority. Each project is an example of how various combinations of prefabrication and effective contracting strategies were used to achieve the accelerated onsite construction timeline.
Full Text URL: http://www.fhwa.dot.gov/bridge/prefab/successstories/
Publication Type: Print Document; Web Document

Title: ***Connection Details for Prefabricated Bridge Elements and Systems***
Publisher: Federal Highway Administration, Washington DC
Topics: Prefabricated bridges, connection details
Abstract: Prefabricated components of a bridge produced off-site can be assembled quickly, and can reduce design time and cost, minimizing forming, minimize lane closure time and/or possibly eliminate the need for a temporary bridge. This document has been developed to promote the use of prefabricated elements and systems in bridges and focuses on "Connection Details" as part of accelerated construction projects. Accelerated Bridge Construction is one of the prime focus areas of the Office of Infrastructure of Federal Highway Administration. It focuses on a need to create awareness, inform, educate, train, assist and entice State DOT's and their staff in the use of rapid construction techniques. This document represents the "State of the Practice" at this time with respect to connections between prefabricated elements in accelerated bridge construction projects. Most of the details were obtained from State Departments of Transportation, industry organizations, and private consultants. This information contained herein should be used to develop designs and determine which details would be appropriate for accelerating bridge construction projects.
Full Text URL: http://www.fhwa.dot.gov/bridge/prefab/if09010
Publication Type: Print Document; Web Document

Title: ***Framework for Prefabricated Bridge Elements and Systems (PBES) Decision-Making***
Author: Mary Lou Ralls Newman
Publisher: FHWA
Topics: Prefabricated Bridge elements and Systems, decision-making framework
Abstract: This report presents a framework for the consideration to employ PBES technology on bridge projects. As such, the framework is a decision-making tool to help answer the ultimate question of whether a prefabricated bridge is achievable and effective for a specific bridge location. The anticipated users of this framework are the representatives of the owner agency and the contractor: the decision makers for the bridge type and the implementers, including designers and project managers.
Full Text URL: http://www.fhwa.dot.gov/bridge/prefab/if06030.pdf
Publication Type: Print Document; Web Document

Title: ***Manual on Use of Self-Propelled Modular Transporters to Remove and Replace Bridges***

Publisher: Federal Highway Administration, Washington DC
Topics: Prefabricated bridges
Abstract: This manual contains information on the equipment, benefits, costs, project selection criteria, planning, design, contracting issues, and example contract documents for using self-propelled modular transporters to move bridges. It also includes case studies and lessons learned from previous projects. The manual is intended for use by bridge owners, construction contractors, suppliers, and other professionals involved in bridge design and construction.
Full Text URL: http://www.fhwa.dot.gov/bridge/pubs/07022/
Publication Type: Print Document; Web Document

Title: ***MnDOT/FHWA Precast Slab System Workshop Summary Report***
Publisher: Federal Highway Administration, Washington DC
Topics: Prefabricated bridges
Abstract: Increasing traffic volumes, an aging highway bridge infrastructure, and dwindling resources are increasing the need for State DOTs and the Federal Highway Administration (FHWA) to look for innovative ways to more quickly construct longer-lasting bridges while minimizing traffic disruption.
Full Text URL: http://www.fhwa.dot.gov/bridge/prefab/slab.cfm
Also See: Mn/DOT Precast Slab System
Publication Type: Print Document; Web Document

Title: ***Prefabricated Bridge Elements and Systems in Japan and Europe Summary Report***
Publisher: Federal Highway Administration
Publication Date: 2004
Abstract: Summary of the scanning tour
Full Text URL:
- Summary PDF Version: http://www.fhwa.dot.gov/bridge/prefab/pbesscan.pdf (1.4 mb)
- Summary HTML Version: http://www.fhwa.dot.gov/bridge/prefab/pbesscan.cfm
- Full Report: http://international.fhwa.dot.gov/links/pub_details.cfm?id=495
- Implementation Plan: http://www.fhwa.dot.gov/bridge/prefab/stip.cfm

Publication Type: Print Document; Web Document

Title: ***Prefabricated Bridges 2004***
Author: AASHTO Technology Implementation Group (TIG) and Federal Highway Administration (FHWA)
Publisher: FHWA and American Association of State Highway and Transportation Officials, Washington DC
Publication Date: 2004
Number of Pages: 16
Topics: Prefabricated bridges
Abstract: This brochure highlights best-practice applications of bridge prefabrication across the United States.
Full Text URL:
- PDF Version: http://www.fhwa.dot.gov/bridge/prefab/2004best.pdf (0.3 mb)
- HTML Version: http://www.fhwa.dot.gov/bridge/prefab/2004best.cfm

Publication Type: Print Document; Web Document

Additional publications can be accessed at:
http://www.fhwa.dot.gov/bridge/prefab/pubs.cfm
Prefabricated Bridge Elements & Systems Web and Video Links:

Prefabricated Bridge Elements and Systems: __

http://www.fhwa.dot.gov/bridge/prefab
Offers information on how using PBES facilitates meeting public needs. It also includes innovative projects, associated publications, and video links.

PBES Fact Sheet: http://www.fhwa.dot.gov/crt/lifecycle/prefab.cfm
Provides information on how prefabricated bridge construction can help minimize traffic delays and community disruptions by reducing onsite construction time and improving quality, traffic control and safety.

PBES Advantages: http://www.fhwa.dot.gov/bridge/prefab/advantag.cfm
Explains the advantages prefabricated bridge elements and systems offer bridge designers and contractors in terms of construction time, safety, environmental impact, constructability and cost.

PBES Research: http://www.fhwa.dot.gov/bridge/prefab/research.cfm
Provides a listing of relevant research articles and publications related to PBES technologies and deployment including:

- *Precast Structural Elements for Bridge Construction*
- *Behavior of Cast-in-Place Slabs Connecting Precast Slab and Steel Girder Assemblies*
- *Development of Precast Bridge Construction Systems*

Highways for LIFE Homepage: http://www.fhwa.dot.gov/hfl
Provides an overview of the Highways for LIFE program and website, along with related links pertinent to prefabricated bridge elements and systems.

Accelerated Constructions Technology Transfer (ACTT):
http://www.fhwa.dot.gov/construction/accelerated
Provides an overview of the ACTT program and related links pertinent to prefabricated bridge elements and systems including:

- *Prefabricated Bridges Deliver Quality, Safety and Savings* (**Publication Number: FHWA-HRT-05-022)** *http://www.fhwa.dot.gov/publications/focus/04dec/01.cfm*
- *850 Ton Bridge Lifted Into Place by World's Largest mobile Crane – Connecticut Project STP-1092(110), SP 92-526 http://www.fhwa.dot.gov/bridge/crane.cfm*
- *Accelerated Bridge Repairs: Meeting the Challenge in Oklahoma (***Publication Number: FHWA-RD-02-013)** *http://www.fhwa.dot.gov/publications/focus/02aug/01.cfm*
- *ALDOT's Interchange Emergency High Traffic Bridge Rebuilt in Record Time http://www.fhwa.dot.gov/resourcecenter/success/successstories/vol1iss10.cfm*
- *Innovative Technology for Accelerated Construction of Bridge and Embankment Foundations in Europe http://international.fhwa.dot.gov/links/pubs.cfm?link_ID=2#G*
  The following links are to articles included in the Bridges and Structures section:
  1. *http://international.fhwa.dot.gov/pubs/pl08016/pl08016.pdf Bridge Evaluation Quality Assurance in Europe, 2008*
  2. *http://international.fhwa.dot.gov/pubs/pl05002/pl05002.pdf Bridge Preservation and Maintenance in Europe and South Africa, 2003*
  3. *http://international.fhwa.dot.gov/Pdfs/conc_seg_cabstay_euro.pdf Performance of Concrete Segmental and Cable Stayed Bridges in Europe, 2002*

Video Links:
All of these links can be accessed at http://www.fhwa.dot.gov/bridge/prefab/videos.cfm

Introduction to Prefabricated Bridge Elements and Systems (.wmv, 4.2 mb)

Superstructure: Partial-Depth Decks (Texas' SH 249/Louetta Road Overpass, Texas' Pierce Elevated) (.wmv, 3.6 mb)
Superstructure: Full-Depth Decks (Kentucky's US 27 over Pitman Creek Bridge, New York's Tappan Zee Bridge, Virginia's Dead Run and Turkey Run Bridges, Illinois' Route 29 Bridge over Sugar Creek) (.wmv, 6.0 mb)
Total Superstructure System: Preconstructed Composite Units (Virginia's I-95/James River Bridge) (.wmv, 4.3 mb)
Total Superstructure System: Truss Spans (Virginia's George P. Coleman Bridge) (.wmv, 3.3 mb)
Substructure: Bent Caps (Texas' SH 66/Lake Ray Hubbard Bridge) (.wmv, 2.4 mb)
Total Substructure System: Piers (Texas' SH 249/Louetta Road Overpass, Texas' US 183 Elevated) (.wmv, 2.7 mb)
Total Prefab Bridges (Puerto Rico's Baldorioty de Castro Avenue Overpasses, New York's Route 9/Metro North Pedestrian Bridge, New York's I-287 Viaducts in Westchester County, North Carolina's Linn Cove Viaduct) (.wmv, 4.6 mb)
Graves Avenue Prefabricated Bridge Project
Time lapsed video showing the moving of a complete bridge superstructure carrying Graves Avenue over I-4 near DeLand, Florida (.wmv, 3 mb). The bridge was moved into place in less than an hour while traffic was temporary slowed using a gang of highway patrol "rolling road block" to interrupt traffic flow for less than 30 minutes. Courtesy of Florida DOT.
Nemo Bridge (.wmv, 44 mb)

Prefabricated Bridge Elements & Systems Projects:
Using the FHWA link: http://www.fhwa.dot.gov/bridge/prefab/projects.cfm you can access information about bridge projects throughout the United States that used prefabricated bridge elements and systems. The following information is included for most of the projects listed:

- Project name and location
- Project description
- Project contact information, including email address and telephone number
- Prefabricated elements or systems used and specific advantages produced
- Specific contractual aspects, if applicable
- A photograph
- Related documents, if available, including special specifications, detail drawings, or other engineering resources specific to the project

You can also search using the following parameters:

By State and/or Project Name: http://www.fhwa.dot.gov/bridge/prefab/all.cfm

By Elements and Systems: http://www.fhwa.dot.gov/bridge/prefab/elements.cfm

A. Superstructure

- **Decks (partial or full-depth):** *Provides an explanation of the advantages prefabrication offers for deck construction and definitions for partial and full-depth decks. The following link provides examples of bridge projects using this technology:* http://www.fhwa.dot.gov/bridge/prefab/elements.cfm?elems=Decks
- **Total Superstructure Systems:** *Provides insight into total superstructure systems and their use. The following link provides examples of bridge projects using this technology:* *http://www.fhwa.dot.gov/bridge/prefab/elements.cfm?elems=Superstructure*

B. Substructure

- **Bent Caps:** *Provides the advantages for using precast bent caps over cast-in-place bet caps. The following link provides examples of bridge projects using this technology: http://www.fhwa.dot.gov/bridge/prefab/elements.cfm?elems=Bent%20Caps*
- **Columns:** *Explains how precast columns can greatly reduce construction time. The following link provides examples of bridge projects using this technology: http://www.fhwa.dot.gov/bridge/prefab/elements.cfm?elems=Columns*
- **Total Substructure Systems:** *Explains what total substructure systems are. The following link provides examples of bridge projects using this technology: http://www.fhwa.dot.gov/bridge/prefab/elements.cfm?elems=Substructure*

C. Total Prefab Bridges: *Explains the maximum advantages for using total prefabricated bridge systems. The following link provides examples of bridge projects using this technology: http://www.fhwa.dot.gov/bridge/prefab/elements.cfm?elems=Total%20Prefab*

By Advantages:

- **Reduced Traffic Disruption:**
  http://www.fhwa.dot.gov/bridge/prefab/advantag.cfm?ad=traffic%20disruption
- **Construction Zone Safety:**
  http://www.fhwa.dot.gov/bridge/prefab/advantag.cfm?ad=zone
- **Environmental Sensitivity:**
  http://www.fhwa.dot.gov/bridge/prefab/advantag.cfm?ad=environment
- **Improved Constructability**
  http://www.fhwa.dot.gov/bridge/prefab/advantag.cfm?ad=constructibility

By Key Words at: http://www.fhwa.dot.gov/bridge/prefab/keyword.cfm

APPENDIX C: Prefabricated Bridge Elements & Systems Fact Sheet

Prefabricated Bridge Elements and Systems

Offsite manufacture of bridges offers many onsite advantages

2004 WSDOT Lewis and Clark Bridge full-depth deck replacement

Prefabricated bridge elements and systems (PBES)—bridge components or entire bridges built offsite and transported to their final location for quick installation—offer a number of advantages over cast-in-place bridge construction.

- PBES components can be built offsite while earthwork and foundation construction is underway, shortening onsite construction time that impacts traffic from months to weeks, days, or just hours.
- Bridge components are manufactured in a controlled environment where the use of consistent materials and methods contributes to uniform quality in the end product.
- Flexible start times for manufacturing components ensures adequate time for proper concrete curing for good long-term performance.
- Less time in the work zone reduces safety risks, especially when working over water or near power lines or other hazardous site conditions.
- PBES construction minimizes site impact, a necessity when working over wetlands or other environmentally sensitive locations.

PBES have been used in new construction and in rehabilitation or replacement of existing bridges. Materials used for PBES are primarily concrete and steel. Lightweight and corrosion-resistant fiber-reinforced polymer has been used in applications such as full-depth deck panels.

Bridges installed using PBES with durable field connections can have a service life of 75 to 100 years. Prefabricated bridge elements include partial and full-depth deck panels, girders, pier caps, columns, footings, and foundations. Prefabricated bridge systems include complete superstructures, complete substructures, and entire bridges.

Fabrication plants build most prefabricated elements and transport them directly to the bridge site for assembly or to an adjacent site for assembly of the larger prefabricated systems.

Although prefabricated elements, such as pretensioned concrete beams, have been used by most states for half a century or more, larger and more complete prefabricated systems are becoming more common, such as entire superstructures moved into position with self propelled modular transporters (SPMTs). The next step in the United States is multispan superstructure units and multispan bridges complete with substructures, moved into position with SPMTs as is now done in Europe.

2004 NYCDOT Belt Parkway Bridge replacement over Ocean Parkway

Contact

Reggie Holt
Senior Bridge Engineer
Office of Infrastructure
FHWA
202-366-4596
reggie.holt@dot.gov

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

Continued on backside

Prefabricated Bridge Elements and Systems, Continued

2007 UDOT 4500 South Bridge removal over I-215

2007 UDOT 4500 South Bridge installation over I-215

2002 VDOT I-95 James River Bridge superstructure replacement

A number of recent projects show the diversity of PBES. These projects range from deck replacements to superstructure replacements to complete bridge replacements, many with no impact on rush hour traffic.

- In 2002, the Virginia Department of Transportation (DOT) replaced the superstructure of its Interstate 95 James River Bridge in Richmond with prefabricated superstructure segments. More than 100 superstructure spans were replaced in nighttime closures using high-capacity cranes and conventional flatbed trailers, with all lanes remaining open to traffic from 6 a.m. to 7 p.m. The superstructure replacement was completed in just 137 nights over 17 months, versus 24 to 36 months using conventional methods. Project costs came in at 11 percent below the engineer's estimate.
- In 2004, the Washington State DOT replaced the deck of the Lewis and Clark Bridge on State Route 433 that crosses the Columbia River between Washington and Oregon during 124 nighttime closures plus three weekend closures, versus the 4 years it would have taken using conventional construction methods. This allowed the steel through-truss bridge to be kept open to traffic during rush hour, eliminating the need for a long detour. More than 100 36-foot-wide full-depth lightweight concrete deck panels, totaling 3,900 linear feet, were installed using a special frame mounted on SPMTs. Every night an existing deck segment was removed and a new panel installed. Installation costs were 38 percent below the engineer's estimate.
- Also in 2004, the New York City DOT replaced the Belt Parkway Bridge over Ocean Parkway in Brooklyn while completely reconfiguring the interchange and parkways, and did so without reducing traffic lanes during rush-hour traffic. Prefabricated components included the piles, T-walls, cap beams, superstructure, parapets, barriers, and approach slabs. Bridge assembly required only a few nights over several weeks. The entire project was constructed in 14 months, including a 3-month winter shutdown, rather than the 3 to 4 years conventional construction would have required. The project came in at 8 percent below the engineer's estimate.
- In October 2007, the Utah DOT replaced the four-span deteriorated 4500 South Bridge that crosses I-215 East near Salt Lake City with a one-span steel girder bridge in just one weekend. The old bridge was removed and the new bridge installed using SPMTs. The 4500 South Bridge was reopened to traffic in 10 days, and I-215 was detoured for just 2 days.

Various prefabricated bridge resources are available. Completed projects with contacts and some plan details and specifications are available on the FHWA prefabricated bridges Web site. A decisionmaking framework helps bridge owners determe whether PBES provide benefits for a specific project is also available there. A new publication, *Manual on the Use of Self-Propelled Modular Transporters to Remove and Install Bridges*, is available at www.fhwa.dot.gov/bridge/pubs/07022. A compilation of PBES connection details used across the country is at https://knowledge.fhwa.dot.gov/cops/ep.nsf/home.

For more information

- "Brooklyn's Memorable Season: New bridge features 100-year life and will be completed in less than a year," *Roads & Bridges*, July 2004, Vol. 42, No. 7, pp. 19-23 and 64, http://roadsbridges.com/Brooklyns-Memorable-Season-article5329
- *"Prefabricated Bridge Elements and Systems in Japan and Europe,"* FHWA -PL-05-003, Federal Highway Administration, March 2005, http://international.fhwa.dot.gov/links/pub_details.cfm?id=495
- FHWA prefabricated bridges Web site, www.fhwa.dot.gov/bridge/prefab/
- "Framework for Prefabricated Bridge Elements and Systems (PBES) Decision-Making," www.fhwa.dot.gov/bridge/prefab/framework.cfm

Appendix D: Self-Propelled Modular Transporters Fact Sheet

Self-Propelled Modular Transporters

Specialized vehicles dramatically reduce onsite construction time and user impact

Vehicles that can remove existing bridges and install new bridges with minimal traffic disruption are helping the United States grapple with the dual challenges of an aging bridge inventory and increasing bridge congestion.

Self-propelled modular transporters (SPMTs) are computer-controlled multiaxle platform vehicles that can move prefabricated bridge spans weighing several thousand tons and position them accurately within a fraction of an inch. Precise placement is possible because the SPMT's electronic steering capability drives multiple axles and allows pivoting about a point. Bridge construction that formerly shut down traffic for months can now be completed with closures of a few minutes to a few hours.

Conventional bridge construction follows sequential processes that require significant onsite construction time. Onsite superstructure construction, for example, involves erecting beams and deck forms, tying deck reinforcement, placing deck concrete, curing deck concrete, removing temporary formwork, and placing traffic railing and appurtenances such as signs. With SPMT technology, this sequence is collapsed to one onsite step—moving the prefabricated superstructure from the staging area to its final position—thus minimizing onsite construction time and traffic disruption.

Continued on backside

Contact

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Self-Propelled Modular Transporters, Continued

Prefabricating bridge components offsite under controlled conditions and installing them onsite with SPMTs provides unprecedented flexibility to remove and replace existing bridges quickly. The use of SPMTs for bridge moves was the top recommendation of the 2004 Prefabricated Bridge Elements and Systems International Scan sponsored by the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the Transportation Research Board's National Cooperative Highway Research Program. The scan researched how other countries use prefabricated bridge components to minimize traffic disruption, improve work zone safety, reduce environmental impact, improve constructability, enhance quality, and lower life-cycle costs. The scan team learned that European countries frequently use SPMTs to lift and drive bridges to their final location in just minutes.

SPMTs should be considered for all bridge projects for which reduced onsite construction time is a priority, and also when other site requirements justify their use.

A number of U.S. projects have used this technology successfully:

- A 111-foot (ft) long steel truss replacement span was installed on Wells Street crossing Wacker Drive in downtown Chicago for the Chicago Transit Authority in 2002.
- SPMTs with special framing were used in 2004 to remove the 36-ft-wide existing deck segments and install new precast deck segments in the Lewis and Clark Bridge on SR 433 over the Columbia River between Washington and Oregon, with no impact to rush-hour traffic and with savings of $10 million .
- Existing spans were removed and new longer and wider spans installed on Graves Avenue over Interstate 4 northeast of Orlando, FL, in 2006.
- Damaged spans were removed and new spans installed on I-10 over LA 35 near Lafayette, LA, in 2006.
- SPMTs on barges were used in 2006 to install the new 400-ft-long steel network arch main span of the Providence River Bridge in Rhode Island.

For more information

manuals

- *Manual on Use of Self-Propelled Modular Transporters to Remove and Replace Bridges,* www.fhwa.dot.gov/bridge/pubs/07022
- "Framework for Prefabricated Bridge Elements and Systems Decision-Making." www.fhwa.dot.gov/bridge/prefab/framework.cfm

videos

- Video clips on use of PBES on U.S. bridge projects, www.fhwa.dot.gov/bridge/prefab/videos.cfm
- Video clips on Graves Avenue Bridge project in Florida, http://trans4mation.org/Videos

W W W . F H W A . D O T . G O V / H F L

APPENDIX E: Framework for Prefabricated Bridge Elements and Systems (PBES) Decision-Making

Executive Summary

Prefabricated bridges offer significant advantages over onsite cast-in-place construction. Among these advantages are a substantial reduction in onsite time required to construct or rehabilitate a bridge, lowest costs resulting from offsite manufacturing and standardized components and improved safety due to reduced exposure time in the work zone. The controlled environment of offsite fabrication also ensures quality components for good long-term performance.

Careful planning, design, and implementation are required to realize the significant advantages of prefabricated bridge construction. Decision makers must consider if the job should be fast tracked, the applicability of the design, the abilities of contractors and suppliers in the target market, access to the project site, and how the construction requirements affect cost and schedule. Other important factors for success of an accelerated bridge project include the owner's and contractor's commitment to see the job through; willingness to share responsibility, control, and risk; and understanding that time is money for all players. Owners should be able to expect inexpensive, durable, and fast construction, allowing them to get more projects within available budgets, whereas contractors should be able to make a reasonable profit and have more bidding opportunities.

This report presents a framework for the objective consideration of the above-mentioned issues. As such, the framework is a decision-making tool to help answer the ultimate question of whether a prefabricated bridge is achievable and effective for a specific bridge location. The anticipated users of this framework are the representatives of the owner agency and the contractor: the decision makers for the bridge type and the implementers, including designers and project managers.

The framework can be used at various levels of detail to assist decisions. The second section of this report is a flowchart to guide a high-level assessment of whether a prefabricated bridge is an economical and effective choice for the specific bridge under consideration. The matrix in the third section provides the users with a different format and more detail than the flowchart. The fourth section consists of considerations in various categories corresponding to those in the flowchart and matrix, with discussion and references for use in making a more in-depth evaluation on the use of prefabrication. The flowchart, matrix, and considerations section may be used independently or in combination, depending on the user's desired depth of evaluation.

Full document can be accessed at:
http://www.fhwa.dot.gov/bridge/prefab/if06030.pdf

APPENDIX F: *DRAFT* UTAH Department of Transportation Framework for Prefabricated Bridge Elements and Systems (PBES) Decision Making

UTAH Department of Transportation

Accelerated Bridge Construction Decision Making Process 2010

Introduction

In the past, the Department had used an Accelerated Bridge Construction (ABC) Decision Chart during project scoping to determine if ABC was appropriate for the site. This chart was based on the Federal Highway Administration Manual entitled "Decision-Making Framework for Prefabricated Bridge Elements and Systems (PBES), May 2008". This process was based on a set of questions regarding specific constraints of each project. If certain thresholds were met, ABC was recommended.

A new approach has been developed for the decision-making process for accelerated bridge construction. This guide outlines the approach to the new process and how it is used during project development. A spreadsheet has been developed to assist project planners in the implementation of this new process.

Approach

ABC is standard practice for the project delivery, efficiency and fast construction. The Department has recently adopted themes that are now used as the basis of all projects in Utah. The themes are as follows:

- Accelerate Delivery – Design and Construction
- Decrease and Minimize MOT (Reduce User Costs)
- Encourage Innovation
- Get a good price

ABC can be used as a tool for the incorporation of these themes. In an effort to make the ABC decision making process more in line with these themes, the Department has developed a new process. The previous chart was based on a series of go/no-go decisions. In reality, many of these decisions are more measured. A definitive answer on whether or not to use ABC based on individual factors is not always appropriate.

In the past one project factor out of the eleven selected factors could drive the decision process. The new approach involves measured responses to each factor. The individual factors are weighted in order to be consistent with the Department themes. The weighted factors are then used to calculate an ABC rating, which is used to provide direction on the use of ABC for the project. If the Department policies and direction change in the future, the weighting factors can be adjusted to coincide with the changes.

The result of this new approach is that a bridge with one significant control factor may actually rate lower than a bridge with several moderate control factors.

This approach will not change the decision-making process outcomes for projects that are on the outlying boundaries of the controls. Bridges where ABC was an

Page 1

UTAH Department of Transportation

obvious choice before will remain as such. Conversely, bridges where ABC was not appropriate before will also remain as such. This new process will be helpful for bridges between these extremes where the use of ABC is in question.

ABC Measures

Ten measures of project constraints have been identified as being applicable to the ABC decision process. The following is a brief description of each measure and how they apply to the current Department themes:

Average daily traffic:

This is a measure of the amount of traffic traversing the bridge site. Use a value equal to the total of the number of vehicles on the bridge and on the roadway under the bridge (if applicable). The value of maintaining the interstate highway network is accounted for in the measure by assigning the maximum score for this situation. This measure addresses the Department theme of **Decrease and Minimize MOT**.

Detour time:

This is a measure of the time impact that a project has on vehicles passing through the construction site. Account for the detour time delays due to congestion caused by construction. If detours are required for the both the roadway on and under the bridge, enter the worst case scenario. This measure addresses the Department theme of **Decrease and Minimize MOT**.

Evacuation route:

This measure is used to account for bridges that are on or over a designated evacuation route. Accelerated bridge construction can be used to minimize time of impact for these are important roadways. This is the only measure that is a go or no-go decision, resulting in a score of zero or five. This measure addresses the Department theme of **Decrease and Minimize MOT**.

User costs:

This is a measure of the financial impact of a construction project on the traveling public. The Department has instituted standard methods for calculating user costs. Use these methods to calculate user costs for each project. This measure addresses the Department theme of **Decrease and Minimize MOT**.

Economy of scale:

This measure accounts for the repetition of the elements and processes, and how they relate to the overall cost of a project. The total number of spans is used in place of the length of the bridge, in order to account for repetition of substructure elements as well as superstructure elements. This measure addresses the Department theme of **Get a Good Price**.

Use of standards:

This is a measure of the potential to make use of Department standards. The use of standards will lead to more repetition of elements and reduced prices. This measure addresses the Department theme of **Get a Good Price**.

UTAH Department of Transportation

Worker safety:

This is a measure of the relative safety provided to the work force at the construction site. Work behind concrete barriers is considered safer than work behind signs, crash trucks, traffic cones, and barrels. The percentage of work accomplished without the protection of concrete barriers is used for this measure. Accelerated bridge construction and the use of prefabricated elements will reduce the exposure time of workers to these dangerous environments. This measure addresses the Department theme of **Accelerate Delivery.**

Environmental issues:

This is a measure of the project's impact to the surrounding environment. Accelerated bridge construction can be used to minimize the overall impact of a project by reducing the construction time on site. This measure addresses the Department theme of **Accelerate Delivery.**

Railroad impacts:

This is a measure of the impact of the project on railroad traffic. The number of trains and type of train are used to measure this impact. This measure addresses the Department theme of **Decrease and Minimize MOT**.

Weather limitations:

Severe weather can have a significant impact on construction schedules. Accelerated bridge construction can be used to minimize the construction time on site, thereby limiting exposure of the structure to the environment. This is especially useful for locations with short construction seasons. This measure addresses the Department theme of **Accelerate Delivery.**

The department theme of **Encourage Innovation** is not listed in these measures. It has been demonstrated that the use of ABC in itself requires innovative designs. A rating procedure has been developed to determine where the use of ABC is appropriate. This procedure is described below. This procedure is based on the department theme of **Encourage Innovation.** The threshold for ABC use has been set to ensure that innovative designs will be commonplace.

ABC Rating Procedure

A procedure has been developed to calculate an ABC rating factor that accounts for all of the project measures defined in the previous section. Weighting factors have been assigned to each measure to coincide with the current Department policies and goals. Do not change the weighting factors for individual projects, since these values have been assigned by the Department.

The values assigned to each project decision measure are multiplied by the corresponding weight factor. The weighted values are then totaled and divided by the maximum possible score for each measure. This results in an ABC rating of between zero and one hundred.

The rating scores have been categorized into three rating scales. Do not use ABC on bridges with a rating of between zero and twenty. Consider ABC on bridges with a rating of between twenty and sixty. Use ABC on bridges with a rating between sixty and one hundred.

UTAH Department of Transportation

Final ABC Decision Process

The ABC rating process is one step in the determination of whether accelerated bridge construction is appropriate for each project. A decision process has been developed that is similar to the previous process used by the Department. This process can be used to make a final determination on the appropriate construction methods for each project. Part of this process addresses the potential increase in costs due to the use of accelerated bridge construction methods.

The following pages depict the decision making process. Values for each ABC measure have been included for a hypothetical bridge project.

Utah Department of Transportation 4501 South 2700 West Salt Lake City, UT 84114	Project:	Hypothetical Bridge Project		
	By:	MPC	Checked:	BLB
	Date:	5/11/2010		5/11/2010
	Sheet No.	1	of	3

Utah ABC Decision Process **June 2010**

ABC Rating procedure

Enter values for each aspect of the project. Attach back-up data if applicable

Average Daily Traffic	5	1	Less than 5000
Combined on and under		2	5000 to 10000
Enter 5 for Interstate Highways		3	10000 to 15000
		4	15000 to 20000
		5	More than 20000
Detour Time	2	1	Less than 5 minutes
		2	5-10 minutes
		3	10-15 minutes
		4	15-20 minutes
		5	More than 20 minutes
Evacuation Route?	0	0	No
		5	Yes
User Costs	4	1	Less than $5000 per day
		2	$5000 to $7000
		3	$7000 to $10000
		4	$10000 to $12000
		5	More than $12000
Economy of Scale	2	1	1 span
(total number of spans)		2	2 to 3 spans
		3	4 to 5 spans
		4	6 to 7 spans
		5	More than 7 spans
Use of Standards	1	1	Custom Bridge
		2	25% of elements are applicable to standards
		3	50% of elements are applicable to standards
		4	75% of elements are applicable to standards
		5	Majority of elements are applicable to Standards
Worker Safety	5	1	Majority of work behind concrete barriers (out of traffic)
		2	25% of work behind signs/barrels/cones (exposed to traffic)
		3	50% of work behind signs/barrels/cones (exposed to traffic)
		4	75% of work behind signs/barrels/cones (exposed to traffic)
		5	Majority of work behind signs/barrels/cones (exposed to traffic)
Environmental Issues	1	1	Minimal to no environmental impacts
		2	
		3	Moderate impact site
		4	
		5	High Value Site

Utah Department of Transportation 4501 South 2700 West Salt Lake City, UT 84114	Project:	Hypothetical Bridge Project	
	By:	MPC	Checked: BLB
	Date:	5/11/2010	5/11/2010
	Sheet No.	2 of	3

Utah ABC Decision Process **June 2010**

Railroad Impacts 0

0	No Railroad
1	Freight Siding (Less than 1 train per week)
2	Light Freight (1 Train per week to 1 Train per day)
3	Heavy Freight (More than 1 Train per day)
4	Commuter rail
5	Electrified Commuter Rail

Weather Limitations 1

1	Arid environment
2	
3	Normal weather (valleys)
4	
5	Extreme weather (mountains, limited construction season)

ABC Rating

	Score	Weight Factor	Adjusted Score
Average Daily Traffic	5	10	50
Detour Time	2	10	20
Evacuation Route?	0	4	0
User Costs	4	10	40
Economy of Scale	2	3	6
Use of Standards	1	3	3
Worker Safety	5	8	40
Environmental Issues	1	3	3
Railroad Impacts	0	5	0
Weather Limitations	1	3	3
		Total Score	165
		Maximum Score	295

ABC Rating	**56**

ABC Rating Scale	
60-100	Use ABC
20-60	Consider ABC
0-20	Do not use ABC

Note: Weight factors determined by UDOT. Do not adjust factors without prior consultation

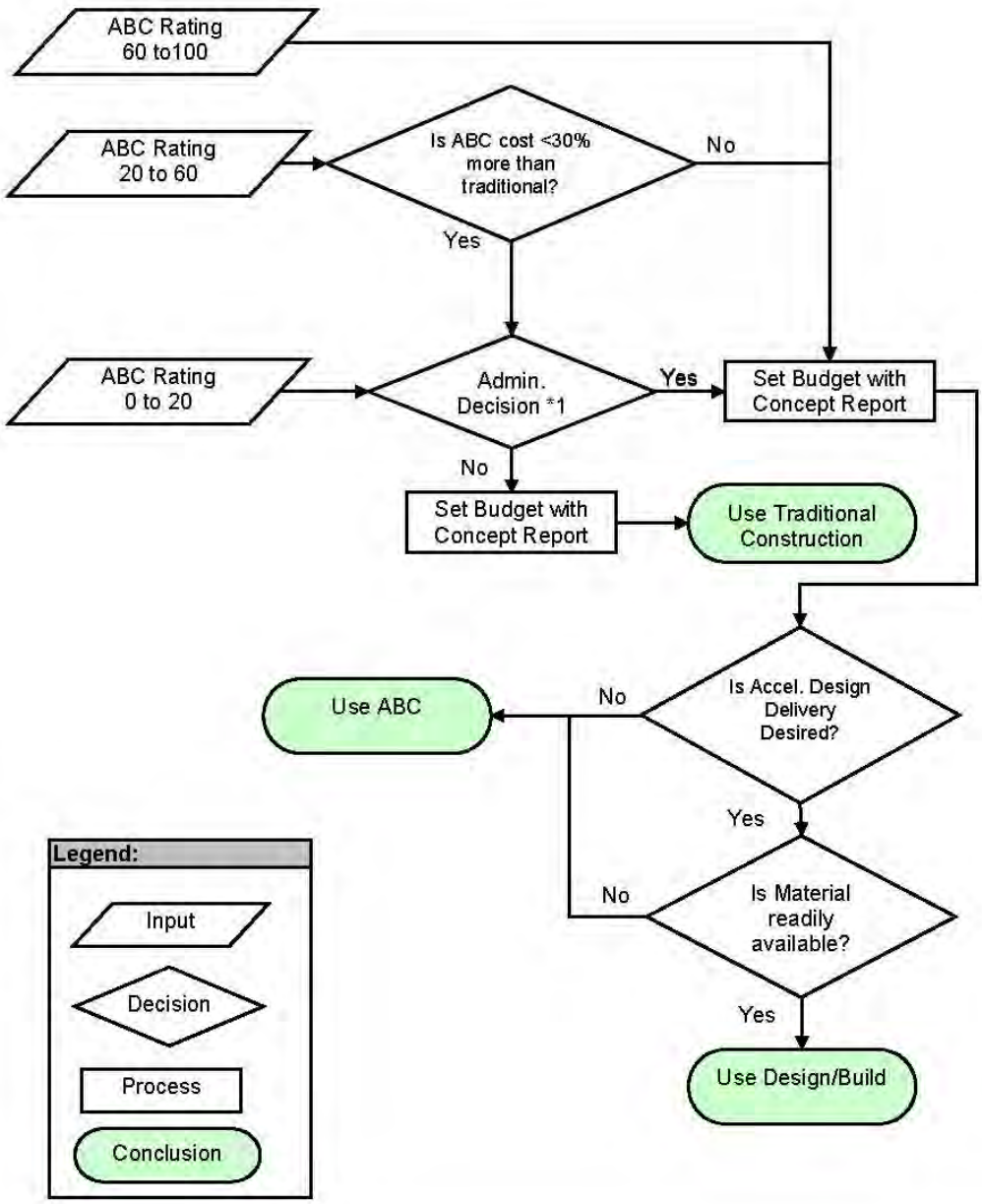
Utah Department of Transportation 4501 South 2700 West Salt Lake City, UT 84114	Project:	Hypothetical Bridge Project	
	By:	MPC	Checked: BLB
	Date:	5/11/2010	5/11/2010
	Sheet No.	3 of	3

Utah ABC Decision Process **June 2010**

Final ABC Decision Process

ABC Decision Flowchart

Note: *1 = Region/PD Directors



Memorandum UTAH DEPARTMENT OF TRANSPORTATION

DATE: December 9, 2009

TO: Region Four

FROM: Traffic Management Division

SUBJECT: Performance Cost - S-I-15-1(84)6; Dixie Drive Interchange

Analysis Summary

The following are results of this analysis:

1) Two lanes open in each direction, reduction in lane width to 11 foot lanes and a speed reduction to 55 mph. This calculation includes areas where traffic shifts from existing configuration to the work zone.

   a) Southbound
      i) Average weekday (Mon-Thurs) = $1,800/day
      ii) Average Friday = $1,900/day
      iii) Average weekend = $2,200/day
      iv) Holiday = $1,900/day
      v) Holiday weekend = $2,400/day

   b) Northbound
      i) Average weekday (Mon-Thurs) = $1,800/day
      ii) Average Friday = $2,300/day
      iii) Average weekend = $1,900/day
      iv) Holiday = $2,400/day
      v) Holiday weekend = $2,400/day

2) Reduce the number of lanes to one in each direction for eight hours at night.

   a) Southbound (11 pm until 7:00 am)
      i) Average weekday (Mon-Thurs) = $200/day
      ii) Average Friday = $225/day
      iii) Average weekend = $200/day
      iv) Holiday = $250/day
      v) Holiday weekend = $200/day

   b) Northbound (11 pm until 7:00 am)
      i) Average weekday (Mon-Thurs) = $200/day
      ii) Average Friday = $250/day
      iii) Average weekend = $250/day
      iv) Holiday = $200/day

v) Holiday weekend = $200/day

3) Full closure of I-15 for eight hours at night.

a) Southbound (11 pm until 7:00 am)
   i) Average weekday (Mon-Thurs) = $10,000/day
   ii) Average Friday = $10,600/day
   iii) Average weekend = $9,400/day
   iv) Holiday = $12,000/day
   v) Holiday weekend = $9,600/day

b) Northbound (11 pm until 7:00 am)
   i) Average weekday (Mon-Thurs) = $10,000/day
   ii) Average Friday = $11,800/day
   iii) Average weekend = $12,200/day
   iv) Holiday = $14,600/day
   v) Holiday weekend = $8,700/day

Background

This memorandum provides results for the roadway user cost analysis that was completed for a bridge structure replacement project on Interstate 15 (I-15) for the Dixie Drive project. Three options for the maintenance of traffic include:

1) Two lanes open in each direction, reduction in lane width to 11 foot lanes and a speed reduction to 55 mph. Including areas where traffic shifts from existing configuration to the work zone.
2) Reduce the number of lanes on I-15 to one in each direction for eight hours at night.
3) Full closure of I-15 for eight hours at night. The detour route includes exiting the freeway at Brigham Road, heading east to River Road and then back to I-15 at St. George Boulevard. The same detour would be in operation in the southbound direction of travel.

Data Collection

Automatic traffic recorder 400 maintained by Systems Planning and Programming provide twenty-four hour traffic counts for the month of July 2009. This count station is located south of the project site on I-15 and provides the following information.

1. July is 12% higher than the yearly average
2. AADT of 32,200
3. 72% passenger vehicles
4. 10% box trucks
5. 18% heavy trucks with trailers

The July 2009 Urban Mobility Report published by Texas Transportation Institute defined the following cost constants that have been used in this analysis:

- Average cost of time per person is $15.47/hr
- Commercial vehicle operation cost
  - $51.06/hr for large box trucks
  - $102.12/hr for heavy trucks with trailers

Internal Revenue Service standard mileage reimbursement of $0.55/mile.

Table 1 outlines the count data. Cells highlighted in yellow show volumes that are over capacity for a one lane construction project.

Table 1 - July 2009 Average Traffic						
Time of Day	Southbound			Northbound		
	Weekday	Weekend	Holiday	Weekday	Weekend	Holiday
12:00 AM	155	178	188	223	310	306
1:00 AM	126	120	107	173	242	271
2:00 AM	106	86	82	152	187	235
3:00 AM	115	86	91	128	176	219
4:00 AM	146	98	101	120	169	191
5:00 AM	205	129	149	138	165	161
6:00 AM	293	189	209	204	185	263
7:00 AM	378	293	311	342	333	374
8:00 AM	494	450	461	523	529	594
9:00 AM	615	687	667	646	713	811
10:00 AM	709	887	875	775	905	1,019
11:00 AM	765	990	1,006	915	992	1,223
12:00 PM	802	1,075	1,148	978	1,013	1,346
1:00 PM	840	1,201	1,290	937	1,097	1,205
2:00 PM	908	1,219	1,418	900	899	1,177
3:00 PM	937	1,295	1,425	862	888	1,137
4:00 PM	895	1,213	1,436	796	760	1,039
5:00 PM	851	1,095	1,346	741	744	959
6:00 PM	742	972	1,198	681	665	873
7:00 PM	609	797	987	558	524	745
8:00 PM	488	622	791	471	471	668
9:00 PM	410	523	624	416	405	524
10:00 PM	321	367	438	341	317	429
11:00 PM	255	232	294	270	278	399

Analysis Method

The Traffic Management Division used Delay Enhanced 2.0 for this analysis. This program provides several benefits to this project. It's simple to use, and the program provides a cost component to develop roadway user costs.

For the closure alternative, the difference in distance between travel on I-15 and travel on Brigham Road was measured. An estimate of 25 mph was used for travel speeds on the detour routes. This reduced speed is expected to account for stop and signal control along the detour route.

Participants can refer to the UTAH DOT Website for the final version for the Utah DOT Framework for PBES Decision Making.

APPENDIX G: Connection Details for Prefabricated Bridge Elements and Systems

Introduction

The Federal Highway Administration (FHWA) has undertaken a program called Highways for LIFE. The word "LIFE" in this program title is an acronym for:

L = Long lasting
I = Innovative
F = Fast construction
E = Efficient and safe

The thrust of this program is to change the way we design and build our highways. A former Deputy Secretary for the US Department of Transportation put it best when he stated:

"Change the way we build highways. We need to build them faster, have them last longer, have them be safer and at a lesser cost. Be BOLD and AUDACIOUS in your thinking."

The Highways for LIFE program motto is: "Get In, Get Out, and Stay Out". The first two portions of the motto are self-explanatory. The "Stay Out" portion refers to the inherent lasting quality of prefabricated components that are produced in the controlled environment of a fabrication site. Just because something can get built fast does not mean that we need to sacrifice quality. In fact, the exact opposite is true. We can build highways faster and better.

The focus of this Manual is on connections used in prefabricated bridge construction. Prefabrication is not a new concept. The vast majority of bridges built today employ some form of prefabrication. Steel and pretensioned concrete beams are two of the most common prefabricated components. Using prefabrication, large portions of the structure are manufactured off site before construction begins. There are many benefits to the use of prefabricated components; however, this Manual will focus on prefabrication as a means of accelerating bridge construction.

Numerous agencies have experimented with rapid construction techniques when bridges needed to be constructed quickly. There have been many successes, and a few failures. The next logical step in the evolution of this process is to make accelerated construction more commonplace and effective.

This type of evolution is not unprecedented. Forty years ago, parking garage structures were constructed primarily with cast-in-place concrete (either all concrete or concrete on steel framing). Today, in most parts of the country, total precast concrete parking structures are the norm and construction times for these structures have been dramatically reduced as a result. The fact that structures using prefabricated elements and systems are common in a competitive construction market also indicates the economies of this type of construction.

Accelerated Construction Technology Transfer Program (ACTT) The FHWA has sponsored numerous three-day workshops under their Accelerated Construction Technology Transfer Program (ACTT). During each workshop, a team of national experts visited a state highway agency to brainstorm on a particular project proposed for accelerated construction techniques. Each workshop provided the state agency with a wealth of information to be used as the building blocks for a successful accelerated construction project. During these workshops, the

following were identified as common needs for successfully implementing accelerated bridge construction:

- Quality details
- Long-term performance and durability
- Design methodologies and training
- Construction methodologies

Full document can be accessed at:
http://www.fhwa.dot.gov/bridge/prefab/if09010/intro.cfm

APPENDIX H: PBES Orientation Brochure (*updated version*)

FAQs

What makes PBES a good choice?

Rapidly expanding technologies associated with materials and equipment have made it possible for components of bridges and assembled composites of bridge components-sometimes even entire bridges-to be prefabricated. Bridge engineers are increasingly turning to prefabrication of bridge elements and systems to save money to solve project-specific challenges, and to increase the quality of bridges by conducting fabrication in a controlled environment.

What are the advantages of PBES for bridge construction?

Prefabricated bridge elements and systems offer bridge designers and contractors significant advantages in terms of construction time, safety, environmental impact, constructability, and cost.

- Minimized traffic disruption – months to days
- Reduced onsite construction time
- Reduced Environmental impact
- Improved work zone & worker safety
- Lower initial and Life-Cycle Costs
- Improved product quality - controlled environment, cure times, easier access, etc.

Contact Information

For training or more information on this Every Day Counts initiative, please contact your local FHWA Division Office.

To learn more about EDC, visit:
http://www.fhwa.dot.gov/everydaycounts

About Every Day Counts

Every Day Counts (EDC) is designed to identify and deploy innovation aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment.

innovation ingenuity Every Day Counts imagination

PBES

Prefabricated Bridge Elements & Systems (PBES) Technology

U.S. Department of Transportation
Federal Highway Administration

What is PBES?

With prefabricated bridge elements and systems (PBES), many time - consuming construction tasks no longer need to be done sequentially in work zones. Generally, PBES are manufactured off the bridge alignment to reduce on-site construction time relative to conventional practice. An old bridge can be demolished while the new bridge elements are built at the same time off-site, under controlled conditions, then brought to the project location ready to erect. This form of accelerated bridge construction (ABC) benefits budget-challenged Federal, State, and local transportation agencies, by:

- Reducing on-site construction time
- Reducing environmental impacts
- Improved work zone & worker safety
- lowering initial and Life-Cycle Costs
- Improved product quality - controlled environment, cure times, easier access, etc.

Traffic and environmental impacts are reduced, constructability is increased, and safety is improved because work is moved out of the right of way to a remote site, minimizing the need for lane closures, detours, and use of narrow lanes. Prefabrication of bridge elements and systems can be completed in a controlled environment without concern for job-site limitations, which increases quality and can lower costs. Prefabricated bridge elements especially tend to reduce costs where use of sophisticated techniques would be needed for cast-in-place work, such as in long water crossings or higher structures, like multi-level interchanges.

Self-propelled modular transporters (SPMTs) move bridge superstructure into place in hours, minimizing traffic disruption.

How Does It Work?

The use of prefabricated bridge elements and systems (PBES) allows Federal, State and local agencies to build new (and replace exisitng) bridges in a faster, simpler way. The lion's share of the construction work is done off-site, usually in a nearby staging area, and the new bridge is "rolled" into place. This method takes advantage of precast elements to minimize the impact of the project on motorists by reducing the time needed for roadway workzones.

After old bridge was rolled out, new one is rolled in place using self-propelled modular units at the Groves Avenue Bridge in Florida.

Case Study: Pioneer Crossing Bridge

Motorists and news crews were curious about the huge concrete structure they'd seen from I-15 at Pioneer Crossing in Utah. It is part of Utah's **Cor**ridor **E**xpansion (CORE) effort aimed at restoring and renovating I-15 in Utah County. As part of this effort, the Utah Department of Transportation is raising the bar in using self-propelled modular transporters (SPMTs) to move bridge spans into place. The south bridge span over the I-15 northbound (NB) lanes for a new diverging diamond interchange was moved into place with SPMTs on Friday night, October 16, 2009. The span over the southbound (SB) lanes was moved into place just 2-days later on Sunday night. Then, the existing four-span bridge was dismantled without reducing the three-lane capacity in each direction on I-15. On the weekend of June 4-5, 2010, the north bridge for the interchange was moved into place from a staging area in the northwest quadrant outside the interchange SB ramp—approximately 1200-feet from the bridge. The span over the SB lanes of I-15 was moved into place on Friday night, and the span over the NB lanes of I-15 was moved into place on Sunday night. These bridges over I-15 are the largest multi-girder spans moved with SPMTs in the United States to date.

The two spans of the north bridge were constructed on temporary support piers in the staging area. On June 3, the SPMTs were moved under the span to be placed over the SB lanes. The 186-foot-long span had nine 96-inch prestressed concrete Washington State bulb tees in the cross section. The span had a 45-degree skew and also weighed 2100 tons. Two lines of SPMTs had to be configured to support the massive span at each end. At acute corners of the spans, two double rows of trailers (one row of 4-axle and one of 5-axle side-by-side) was used and at obtuse corners two double rows of 6-axle trailers were used. Each axle could carry a load of 30 tons. Special tower stand jacks raised and lowered the span off the temporary supports and onto the new substructure elements, respectively. Chains were also used to help control the distance between the double lines of SPMTs. On the top of the bridge, piano-like wire was placed at the diagonals of the span to measure any span distortion. To avoid over-stressing the deck concrete, only 3 inches of distortion was allowed.

On Friday night, traffic control for the move got underway. At 8:00 p.m., one lane (of three NB and SB on I-15) in each direction was closed and then at 9:00 p.m. another. While lanes were being closed, the heavy mover subcontractor had workers positioning the span carried by the SPMTs as close to I-15 as possible for the move to begin at 10:00 p.m. A rolling road block was completed by the Utah State Police at that time to allow the SPMTs to move the west span of the north bridge of the interchange out onto I-15 and clear of the SB off-ramp. At approximately 10:15 p.m. that traffic was stopped on the SB lanes and the SPMTs moved onto I-15 SB, turned, and began going SB toward the bridge site. After stopping the traffic for 32 minutes, the one lane of SB traffic was allowed to proceed and was detoured onto the SB ramps around the bridge site. Traffic was released to flow on the ramps at 10:47 p.m. The NB traffic was similarly detoured so that the contractor had all of I-15—both SB and NB—to perform operations without traffic influence. By 1:00 a.m. the west span of the north bridge was setting on the bearings, and the SPMTs were being readied for movement back to the staging area. By 6:00 a.m. the traffic was flowing freely on I-15 NB and SB.

On Saturday, the SPMTs were configured to support and move the east span of the north bridge off the span's temporary construction supports. Cables were installed between the lines of the SPMTs to maintain the geometry of the span being lifted and moved. The span was positioned next to I-15 for the move Sunday night. By approximately 2:40 a.m. the east span of the north bridge was in place on the substructure supports. The contractor's work was complete and I-15 was opened for the rush-hour traffic on Monday morning.

Prefabricated I-15 bridge at Pioneer Crossing in UT.

The Main Components of PBES:

Prefabricated Elements:

Superstructure:

- Deck Panels: Partial & Full-Depth
- Beams: More Efficient Shapes
- Composite Units

Substructure:

- Pier Caps, Columns, & Footings
- Abutment Walls, Wing Walls, & Footings
- Bent Caps

Prefabricated Systems:

Superstructure:

Increasingly innovative bridge designers and builders are finding ways to prefabricate entire segments of the superstructure.

Substructure:

A substructure system may consist of individual pier(s) or prefabricated bent caps supported by prefabricated column(s) and/or prefabricted abutment elements.

Total Bridge:

Total prefab bridge systems offer maximum advantages for rapid construction and depend on a range of prefabricated bridge elements that are transported to the work site and assembled in a rapid-construction process.

APPENDIX I: Glossary of Acronyms Used

AASHTO	American Association of State Highway and Transportation Officials
ABC	Accelerated Bridge Construction
ACTT	Accelerated Construction Technology Transfer
ADT	Average Daily Traffic/Annual Daily Traffic
ADTT	Average Daily Truck Traffic
ASTM	American Society of Testing and Materials
ATA	America Truckers Association
CIP	Cast-in-place
DOT	Department of Transportation
EDC	Every Day Counts
FRP	Fiber-Reinforced Polymer
FHWA	Federal Highway Administration
HfL	Highways for LIFE
LTAP	Local Technical Assistance Program/Long-Term Action Plan
MCEER	Multidisciplinary Center for Earthquake Engineering Research
MSE	Mechanically Stabilized Earth
NCHRP	National Cooperative Highway Research Program
NHI	National Highway Institute
PCSSS	Precast Composite Slab Span System
PBES	Prefabricated Bridge Elements and Systems
PT	Post-Tensioning
QA/QC	Quality Assurance and Quality Control
SPMT	Self-Propelled Modular Transporters
VE	Value Engineering

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    - *Public Roads -- A*uthor Instructions (TFHRC)
    - *http://www.fhwa.dot.gov/publications/publicroads/author.cfm*
    - FOCUS Magazine (Office of Infrastructure) *http://www.fhwa.dot.gov/publications/focus/*
    - *Centered on Service* newsletter (FHWA Resource Center) *http://www.fhwa.dot.gov/resourcecenter/success/cos.cfm*

APPENDIX K: Acknowledgements

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Every Day Counts

innovation ingenuity invention imagination