Integrated Bridge Project Delivery & Life Cycle Management

FHWA Project: DTFH61-06-D-00037

Presented By

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2008 AASHTO SCOBS Annual Meeting
Focus of Current Efforts

- Speed-Up Bridge Construction Activities
- Simultaneously Enhance the Quality and Durability of Bridges Being Constructed
Emphasis of Current Efforts

• Cost-Effective Use of Prefabrication Techniques for Bridge Components

• Advanced Materials Technologies, such as Self Consolidated Concrete

• Construction Methods, e.g. Stage Construction, Use of SPMTs and Incremental Launching for Bridge Superstructures
Project Background

What is Needed

• “Fundamental Re-Thinking” of the Antiquated Processes that are still being used to Deliver Bridge Projects

We are Nearing the End of an Era

• Relied on “Paper” for Centuries, as a Primary Representation for Engineering and Construction

• Only Industry Producing 3D Products Using 2D Drawings
Project Background

Other Industry Initiatives

• Building and Other Industries (Auto, Aerospace and Marine) have Documented Reduced Costs, Faster Delivery and Improved Quality Resulting from 3D Based Integrated Design and Manufacturing Processes.

• Recent Examples
  GM Plants, Denver Museum, Queen Mary 2
Virtual Building

General Motors’ design-build team perfects a digital design, then locks it and builds without changes. The result? Faster, better, cheaper, safer—and smiles all around.
VIRTUAL Starchitecture

Denver museum’s wild wing showcases artistry of digitally enabled construction
Queen Mary 2
American Institute of Architects (AIA)
Two new model agreements for integrated project delivery (IPD)

• Both require use of Building Information Models and a division of the project into phases

• Standard contract documents provide two (2) levels of Design and Construction integration:
  1. Transitional document for those unaccustomed to IPD
  2. Single purpose entity, offering a fully integrated way to deliver a building

* Excerpts from “AIA Issues New Docs For Integrated Delivery”, by Nadine M. Post, ENR.com
• MTA NYCT Design Managers each selected 1 project in 2008 on which to use BIM

• Implementing BIM on all MTA NYCTA projects by 2009

• BIM used to determine that the massive Fulton Street Transit Center project in New York City could proceed with construction while the station remains open to trains and passengers

* Excerpts from “Doing Business with MTA NYCT” special supplement to May 2008 NY Construction Magazine
Piecemeal Progress in the Industry

- Parametric Design Tools and TransXML Omit Detailing for Fabrication and Construction
- 3D Pre-Cast Concrete Modeling Tools are not (yet) Bridge-Oriented
- Bridge Inspection or Design/Rating (e.g.) Apps each Require their own Data (Re)Entry
- 3D Geometry Created (e.g.) Visualization is not also Leveraged for Fabrication & Construction
Project Background

Piecemeal Progress in the Industry

- 3D for Structural Analysis is also not Leveraged for Other Asset Management Purposes Needing such 3D Geometry Data

- Even when Electronic Data Exchange is Pursued, only Small Pieces of the Overall Workflow Involved in Bridge Delivery are Addressed
Project Background

- FHWA International Review Tour 1999
  - Prevalent CAD/CAM in Europe, Japan


  Established a Roadmap for Integrating Steel Bridge Design-through-Construction Processes and for Advancing the State-of-the-Art Practice in Steel Bridge Manufacturing Automation and Productivity
Project Background

“Theme Areas” Progress:

- **3D Modeling & Electronic Info. Transfer:** NCHRP 20-07 Task 149 Project (Completed Nov. 2003)
- **Standardized Specs and Approval Processes:** NSBA/AASHTO Collaboration
- **Standardized Design Details:** NSBA/ AASHTO Collaboration
- **Showcase of Benefits of Automation:**
  - AASHTO Subcommittee on Bridges and Structures Resolution (2005)
  - FHWA Project: DTFH61-06-D-00037
2D vs. 3D

2D CAD provides an Electronic “drawing board”

3D CAD enables a parametric model

2D Drawings contain the information

3D model contains the info; drawings are only reports

2D Drawings human-readable; separate manual data entry is required for analysis

3D model is computer-readable, such that direct analyses are possible

Coordination is difficult; information is scattered among different drawings and specifications clauses

Coordination is automatic: 3D model is the single source for all product information

Manual checking

Automated checking

No support for production

Potentially full support for production (via CNC codes etc.)
What This Is About

[Diagram showing Traditional Design-Bid-Build Schedule vs. 3-D Model Design-Build with timeframes]

- Traditional Design-Bid-Build Schedule:
  - Preliminary design: 4 weeks
  - Design drawings: 8 weeks
  - Bidding: 3 weeks
  - Shop drawings: 6 weeks
  - Fabrication: 4 weeks
  - Erection start: 28 weeks

- 3-D Model Design-Build:
  - Preliminary design: 4 weeks
  - Design drawings: 4 weeks
  - Fabrication: 4 weeks
  - Erection sequence: 15 weeks

- Notes:
  - Translation
  - CNC machinery
  - Erection sequence
  - 2-week overlap

[Logo: U.S. Department of Transportation, Federal Highway Administration]
Overview of Project Vision

- Develop a Prototype Integrated System Illustrating the Data Exchanges and Applications
- Addresses entire Bridge Life Cycle
- Utilize 3-D Bridge Information Modeling (BrIM) as a Technology to Accelerate Bridge Project Delivery and Enhance Life Cycle Management
Overview of Project Vision

- Demonstrate the Viability, Efficiencies and Benefits of the Integrated Bridge Project Delivery and Life Cycle Management Concept Through One-Half-Day and Two-Day Presentations of the Prototype Integrated System to Stakeholders Around the Country
Project Scope

- A Large and Complex Project
- Relates Many Data Exchanges and Stakeholders
- Involves Development of a Prototype - Not Production - Software Linking Appropriate Existing Commercial Software that Demonstrates a Viable Integrated System for Bridge Project Delivery and Life Cycle Management
Project Scope

- Implementation Will Require Initial Stakeholder Input, Mechanics for Maintenance, and Will Illustrate Economic Benefits and Improved Quality

- Presentations, Seminars, and Other Information Exchanges Address the “Stakeholder Engagement and Buy In”
Project Objectives

- Develop integration and linking software
- Demonstrate utility of an integrated approach
- Promote benefits and efficiencies of this approach
- Develop and conduct one-half and two day workshops
- Make presentations to illustrate use of the system for concrete and steel bridges
Project Approach

• Generate a *3D Architectural Blueprint for Integrating Various Phases into the Automated Processes*

• Significantly Improved 2D Design Drawings, as well as Construction Drawings, in Conjunction with Life Cycle Management Through Automation
Project Approach

• Highlight the Benefits of Automation and Communication Technologies to Achieve Rapid Coordinated Bridge Design, Construction and Subsequent Life Cycle Management

• Approach will be Implemented by Performing an Integrated Set of Overlapping Tasks
Data Ownership Issues will be Addressed with the Philosophy Espoused by the AISC Code of Standard Practice:

The Quality of the Contract Documents is the Responsibility of the Entities that Produce those Documents

Related Key Issue:

View / Approve / Edit Control and Tracking
Concept: Process Integrated around Central Data Repository

Outside Exchanges

Material suppliers

-82B exchanges

Inside Exchanges

Enterprise Applications

Materials order/ tracking app.
Scheduling and workflow app.
Logistics and production app.

Design Stage

Design application
Analysis application
Shop drawing Application

Production Stage

Process planning application
Formwork design application
Rebar bending application
Robotics applications

Formwork fabricator

Architect or contractor
Construction Support

- Visualization Staging Application
  - BrIM handles

- Construction Scheduling Application
- Tekla 4D
- Estimating Application
- Constructed Bridge

- Inherent To BrIM
- XML

- BrIM 3D Model
  - (AutoCAD Revit or Bentley Microstation)

U.S. Department of Transportation
Federal Highway Administration
Quincy Avenue Bridge
Extending Linkages

- CAD (Computer-Aided Design)
- CIM (Computer-Integrated Manufacturing)
- Construction Modeling (e.g., Erection)
- Construction Management
- Operations, Maintenance, Life Cycle Management
Example of Parameterization (Hammerhead Pier)

- Geometric Parameters
  - Column Diameter or width
  - Pier head Angle/width
  - Elevation
  - Footing Length
  - Column Height
  - Pier head Height of the head
  - Footing length
  - Footing Width
  - Pier head Thickness
  - Footing No of pile
  - Footing Spacing
  - Footing Cover
  - Column No of girders
  - Column Spacing of the girders
  - Column Roadway slope
  - Column Distance of the pier head from the CL of the girder seat
  - Column Distance from the CL of Bearing line
  - Column Add thickness to the model for the section

- Reinforcement Detailing
  - Footing Top Bars
  - Footing Bottom Bars
  - Footing Top Bars
  - Footing Bottom Bars
  - Footing Top Bars
  - Footing Bottom Bars
  - Top Bars
  - Bottom Bars
  - Spacing
  - Starting Elev
  - End Elev
  - Cover
  - Vertical Shear
  - Top Bars
  - Top Bars
  - Spacing
  - Size
  - Cover
  - Spacing
  - Starting elevation of the bars
  - Projection into footing/vert
  - Projection into Pier Cap
  - Bar No.
  - Bar No.
  - Spacing
  - Projection into footing/vert
  - Projection into Pier Cap
  - Top Bars
  - Top Bars
  - Spacing
  - Cover
  - Bottom Bars
  - Bottom Bars
  - Spacing
  - Cover

- Dependent Parameters
  - Skew Angle
  - No of girders
  - Spacing of the girders
  - Roadway slope
  - Distance of the pier head from the CL of the girder seat
  - Distance from the CL of Bearing line
  - Add thickness to the model for the section

- Hammerhead Piers
  - Footing
  - Column
  - Pier head
  - Footing
  - Column
  - Pier head
  - Footing
  - Column
  - Pier head

Example of Parameterization

- Longitudinal
  - Top Bars
  - No.
  - Spacing
  - Starting Elev
  - End Elev
  - Cover
  - Bottom Bars
  - No.
  - Cover
  - End Elev
  - Spacing

- Transverse
  - Top Bars
  - No.
  - Spacing
  - Starting Elev
  - End Elev
  - Cover
  - Bottom Bars
  - No.
  - Cover
  - End Elev
  - Spacing

- Vertical
  - Top Bars
  - No.
  - Spacing
  - Starting Elev
  - End Elev
  - Cover
  - Bottom Bars
  - No.
  - Cover
  - End Elev
  - Spacing

- Shear
  - Top Bars
  - No.
  - Spacing
  - Cover
  - Bottom Bars
  - No.
  - Spacing

- Footing
  - Top Bars
  - No.
  - Spacing
  - Cover
  - Bottom Bars
  - No.
  - Cover

- Pier Cap
  - Top Bars
  - No.
  - Spacing
  - Cover
  - Bottom Bars
  - No.
  - Spacing

- Elevation
  - Working point
  - Column
  - Tapered pier head
  - Other end of pier head
  - Pile Cut-off
<table>
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<tr>
<th>Family</th>
<th>Component</th>
<th>Description</th>
<th>Weight Unit</th>
<th>Weight (Mass)</th>
<th>Quantity</th>
<th>Unit</th>
<th>Unit Price</th>
<th>Total</th>
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<td>Deck</td>
<td>28 MPa deck concrete N</td>
<td>28 MPa concrete for N. bound bridge deck</td>
<td>kg</td>
<td>468.4</td>
<td>207.75</td>
<td>m3</td>
<td>260.00</td>
<td>$54,015.00</td>
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<td>Deck</td>
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<td>28 MPa concrete for S. bound bridge deck</td>
<td>kg</td>
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<td>260.00</td>
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<td>kg</td>
<td>4608.0</td>
<td>5760.0</td>
<td>pc</td>
<td>2.50</td>
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<td>Foundation</td>
<td>Concrete N</td>
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<td>kg</td>
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<td>Foundation</td>
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<td>kg</td>
<td>31905</td>
<td>350.0</td>
<td>m</td>
<td>110.00</td>
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<td>kg</td>
<td>1795.4</td>
<td>1795.4</td>
<td>kg</td>
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<td>$2,683.10</td>
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<td>kg</td>
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<td>kg</td>
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<tr>
<td>Superstructure</td>
<td>HPS Steel N</td>
<td>High performance weathering steel for plate girders N. bound</td>
<td>kg</td>
<td>191865.2</td>
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<td>kg</td>
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<td>Superstructure</td>
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<td>191865.2</td>
<td>191865.2</td>
<td>kg</td>
<td>$3.00</td>
<td>$575,985.60</td>
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</table>

Grand Total: $1,528,280.80
Manufacturing Too (via CNC)

- Automatic Pop-marking
- Stiffener plates etc.
- Avoid manual layout process

Multi-User Mode:
- Different people working together using a single model
- Within an organization and discipline
- Between organizations and disciplines
In continuous spans, the nominal flexural resistance of the section shall not exceed:

\[ M_{n} = 11880.6 \text{kN}\cdot\text{m} \]

where

\[ M_{p} = 1.07 \left( D_{p} \right) \]
\[ t_{s} \]
\[ D_{t} \text{ and } t_{s} \text{ have } \mu \text{ and } \phi \text{ factors applied} \]

Nominal Flexural Resistance:

\[ M_{n} \leq M_{u} \]

where

\[ M_{u} = \frac{1}{3} f_{l} S_{x} t_{w} \left( 3.76 E_{s} F_{y,c} \left( \frac{F_{y,t}}{F_{c,y}} \right) \right) \]

for the section "compact",

\[ D_{cp} t_{w} \leq 150 \text{mm} \]

otherwise

\[ D_{cp} = 126.2 \text{mm} \]

The specified minimum yield strengths of the flanges and web do not exceed 485 MPa. Sections that satisfy the following requirements shall qualify as compact sections:

- The web satisfies the requirement of Article 6.10.2.1.1.
- The section satisfies the slenderness limit:

\[ 2 D_{cp} t_{w} \leq 3.76 E_{s} F_{y,c} \]

Positive Moment Region:

Strength Limit State:

- Visualization
- Detailing
- Design Checking
- Visualization
- Inelastic Dynamic
- User Input
## Project Schedule

### Integrated Bridge Project Delivery & Life Cycle Management

**Contract DTFH61-06-D-00037**

**Project Schedule**

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>Assumed Duration</th>
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<td>2</td>
<td>Development of Half-Day Presentation</td>
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<td>AASHTO SCORS presentation</td>
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<td>3</td>
<td>Development of Two-Day Presentation</td>
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<td></td>
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<td>15 mos</td>
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<td>4</td>
<td>Integrated Software Package Dev/Demo</td>
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<td>4f-h</td>
<td>Code/Test/Debug/Demo/Revise</td>
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<td>4i-j</td>
<td>Benchmark notes, Recommendations</td>
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<td>5</td>
<td>Half-Day Presentations</td>
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<td>Two-Day Presentations</td>
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<td></td>
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</tr>
</tbody>
</table>

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**Legend**

- **a**: abstract
- **s**: submit
- **p**: present

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**ARORA and ASSOCIATES, P.C.**

Consulting Engineers

**U.S. Department of Transportation**

**Federal Highway Administration**

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Contract Issued (09/14/2006)

Kick-Off Meeting (12/20/2006)

Task Order Issued for Tasks 2, 3 and 4 (03/14/2007)

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Rev. 05/31/2007
Summary

- Complex and a Non-Typical R&D Project
- Aimed at Establishing the Viability of an Integrated Bridge Project Delivery and Life Cycle Management
- Resulting Product:
  An Integrated Prototype System, with Linking Software, that Connects Existing Commercial Software for All Major Phases of Bridge Life
Project Team

Arora and Associates, P.C.
Arun M. Shirolé, P.E., Timothy J. Riordan, P.E.

State University of New York
Stuart Chen, Ph.D., P.E.

University of Wyoming
Jay Puckett, Ph.D., P.E.

Federal Highway Administration
Krishna Verma, P.E.
THANK YOU!
New Domain to Address Project Objectives
See BrIM Details