Novel 3D Approach for the Construction Study of Africa's Longest Cable-Stayed Bridge
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Learning Objectives

- Understand how 3D Modeling can be used for the construction study of a cable stayed bridge.
- Understand how to collaborate with stakeholders on a large infrastructure project.
- Understand about interoperability between AutoCAD Civil 3D, Inventor, Vault, and Buzzsaw.

Description

This class will present the final detailed analysis and shop drawing production of Africa's longest cable stayed bridge over the river Bouregreg in Morocco. EGIS was responsible to deliver the “Shop Drawings” of the bridge based on their competences in this domain built through similar challenging projects. Autodesk products were decisive.

The complexity of the bridge and particularly of its pylons and cables was very challenging making a 3D model necessary to take into account of different details that were impossible to do in a 2D drawing. For example the diameter of the cables in 3D and their pre-stressed state was modeled to be considered to carry out clash detection between cables. Thanks to a comprehensive 3D parametric model in Inventor, anomalies were detected and corrected that would have otherwise created rework and delays during construction. The interoperability among Autodesk solutions made it easier to collaborate with other teams and respect the deadline.

Arnold LEDAN

Arnold LEDAN is a civil engineer based in France and he has worked at EGIS bridge department since 1997. Arnold has more than 20 years of experience of designing Civil Infrastructure with Autodesk products. Since 2004 he is CAD production manager and manages a team of technicians. He started his career as CAD technician and proved himself overtime by earning an engineering degree and managerial responsibilities. He develops different applications in VB.NET to connect AutoCAD Civil 3D & Inventor. He has started using Revit Structure for bridges to explore how to implement other BIM uses. He is responsible for the implantation of Vault software, Inventor at EGIS for bridges since 2007.
6 companies, 3 continents, 1 bridge:

Building Africa’s Largest Cable-Stayed Bridge across the Bouregreg

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When Morocco undertook building a bridge across the Bouregreg River, the project presented complex construction challenges and brought together six companies to collaborate across three continents.

The bridge is part of the Rabat motorway bypass in western Morocco, which connects Fes and Casablanca, allowing travelers to skip the capital city of Rabat. The bridge spans two banks of the Bouregreg River, which runs between Rabat and Salé from the Atlas Mountains to the Atlantic coast, near the Sidi Mohammed Ben Abdallah dam. Autoroutes Du Maroc (ADM), Morocco’s highway company, undertook construction of the bridge in 2010 in order to alleviate traffic, speed up commerce and transport, and increase safety in the region.

The Bouregreg bridge design actually consists of two successive bridges. The 200-meter access bridge connects from the south side of the river to the main cable bridge, which runs another 742 meters. The bridge’s total length, just under a kilometer (952 meters), makes it the longest cable-stayed bridge on the African continent, and at 200 meters high it’s also the tallest. Two striking, Islamic architecture inspired pylons consisting of four curved, reinforced caissons converging at the top and joined at the base, are spaced 376 meters apart and each is stayed by 183 meter reaching cables. The bridge’s
structure consists of two lateral ribs of prestressed concrete connected by metal crossbeams every four meters, and a reinforced concrete slab 0.25 m thick. The 30.4-meter wide deck is supported by 20 pairs of parallel cables spaced eight meters apart, and will have three lanes going in each direction.

Due to the project’s complexity, six different companies from three continents were involved: The bridge was designed by Setec TPI and STRATES Architects (France); it was constructed by China Overseas Engineering Corporation (COVEC) and Major Bridge Engineering Corporation (MBEC) (China); and final design study was done by Egis JMI (France) with the collaboration of Bridge Reconnaissance and Design Institute (BRDI) (China) The Autoroute Du Maroc (ADM) is overseeing the project.

Egis JMI (Jean Muller International, named for the original firm’s founder), part of the larger Egis Group with 12,000 employees around the world, is based in Paris with offices in Lyon, Bordeaux and Bangkok. Egis primarily operates in Europe, Africa, and Asia, handling infrastructure projects of all types—rail and transport, road, buildings, water and environmental, and aviation. Egis JMI is known for their work on the Jacques Chaban-Delmas Bridge in Bordeaux, with its unique vertically lifting middle deck. Egis JMI was the 2013 winner of “grand prix de la Construction “and FIDIC Award 2014 “Outstanding Project of the Year”
Egis was brought on board the Bouregreg project to do the final design “shop drawings” of the bridge including final calculation notes. Shop Drawings are drawings for fabrication that propose fabrication details for structural members and components.

The preparation of shop drawings is a very specialized process with its own language and methods. The drawings and data for construction are developed from information presented on the contractual drawings. These drawings contain the basic bridge geometry, pier and sub-structure locations and design, as well as the sizes of all material, and the basic connection information. These are usually prepared by a consulting engineer for the owner. Construction, thus the shop drawings, must adhere to all the applicable specifications and the information on the contract plans. With this in mind, the detailers, shop drawing producers, must have experience, knowledge and ability to translate contract information into shop drawings. Most bridge fabricators contract their shop drawing production to independent detailing offices. Detailing offices must provide shop drawings that not only meet all the contract drawings information, the controlling specifications, but also must satisfy the unique requirements of the constructor for which they are working.

The shop drawings are a significant part of fabrication and have a significant impact on the success of the project. The detailer’s experience and ability to produce a timely and accurate set of shop detail drawings will influence the success or failure of the project. During the process of producing shop drawings there are almost always questions arising about the contract documents. These problems must be resolved in a timely manner and it is the detailer’s responsibility to resolve these. The communication between detailer and owner or owner’s representative is critical in order to complete the shop drawings efficiently and on time. Another step in the process of shop drawing detailing cycle is the owner’s review of the drawings, or “approval” process. Construction cannot begin without the owner’s approval of the shop drawings. This can be a lengthy process, which delays and adds cost to the design and construction cycle. The production and approval of shop drawings therefore plays an important role in the timely completion of the entire project.

The traditional use of 2D drawings in shop drawing for a complex project like a bridge are prone to errors as they are merely disconnected 2D views of a bridge. For complex 3D geometry it’s difficult to have precise 2D representation capture the intended design. Additionally any concordance between different 2D views that report the same dimension need to be verified manually.

Due to the project’s complexity, Egis undertook creation of a 3D model in order to determine if the design was in fact feasible and determine any design or dimension error that might go undetected using 2D drawings. They used Inventor for flexible bridge modeling, and for its ability to dynamically link with Excel and share the library via Vault for collaboration purposes. They created the digital model field from the TOPO file in AutoCAD Civil 3D, with recovery of the triangulated land size in AutoCAD. They imported and triangulated surface modeling in Inventor. This approach helped them to include the specific terrain and it’s effect on the foundations. Working with the 3D global model, Egis was able to identify structural problems in both the pylon and the deck designs, and adapt the design before construction.

Each pylon consists of four legs joined at the head and foot with two curves.
Egis found that the original conception of the pylon heads, with circular prestressing cables was not optimal. To overcome this shortcoming Egis proposed a design of including a metal box with guiding tubes for the cables. The new design for the cable connection with the metal box anchor ensured that the head was able to bear the pull of the cables and the guiding tube mechanism gave the perfect alignments of the cables.

![Before](before.jpg)  ![After](after.jpg)

When they examined the bridge’s deck design, Egis found another issues. Manipulating the 3D model, they determined that the diameter of the precast cables in their pre-stressed state would create a clash, which had not been evident in the 2D design. Thanks to the global 3D approach, Egis was able to run a clash detection based on a minimum tolerance between the cables and guarantee zero clash.

Another big challenge was the collaboration side of the work as this project involved continuous information exchange between different teams dispersed on a global level. The use of a data
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Arnold LEDAN
Civil Engineer
Egis

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Customer Success Manager
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About the speaker

Arnold LEDAN
Civil Engineer / CAD Manager
- Manages the workload for CAD / BIM Technicians
- Leader and manager of CAD / BIM Technicians
- Technical support to CAD / BIM Technicians
- Develop, implement and enforce CAD / BIM Standards
- Manage Database
- Autodesk Vault, Buzzsaw
- Development in vb.net:
  - Autocad, Inventor, Autocad Civil 3D, Revit structure With dynamo for Bridges

About the co speakers

Shakeel MIRZA
- Joined Autodesk, Inc., in 2014 as Customer Success Manager, ensuring BIM Transformation of EGIS
- Engineer + Master’s in modeling & Simulation + MBA
- Previous tenure @Autodesk 2008-2012 as Technical Consultant

Bruno LAUMONDAIS
- Joined Autodesk, Inc., in 2013 as Global-Support Account Manager, ensuring Autodesk comes with EGIS on its way to operational excellence.
- 20 years IT industry
- Experience @ O-I, Dell, DHL

Class summary

Re-engineering and construction studies of the Cable Stayed Bridge over the river Bouregreg in Morocco.

The longest Cable Stayed Bridge in Africa.

A technical challenge for Egis.

Key learning objectives

At the end of this class, you will be able to:

- Understand how 3D modeling can be used for the construction study of a cable stayed bridge.
- Understand how to collaborate with stakeholders on a large infrastructure project.
- Understand about interoperability between AutoCAD Civil 3D, Inventor, Vault, and Buzzsaw.

Contents

- Company Profile
- The challenges on the Bridge Project
- The Bouregreg Cable Stayed Bridge
- Conclusion & Questions / Answers
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Company Profile

Egis - Creative for the long term

OUR MISSION
• Engineering
• Construction
• Urban planning, Architecture & Landscaping
• Infrastructure planning
• Real estate services
• Turnkey solutions

The challenges of the bridge project and the benefits of BIM

The challenges of a bridge project
• Having a complex geometry
• High risk of non compliance
• High production cost due to execution delays

Benefits of BIM
• Having a better geometry analysis.
• Avoiding non-compliance feasibility
• Reducing our production costs.
The objective is to select the most appropriate modeling software for bridges.

- Powerful
- Interoperable
- Aligned with our processes and projects

The Bouregreg cable stayed bridge

Contents
1. Project Location
2. Presentation of the bridge
3. Terrain and Axis modeling
4. Pylons modeling
5. Head of pylons modeling
6. Deck
7. Workflow

Project Location
General
- Deviation on the highway from Casablanca to the highway going to Fès.
- The Bouregreg cable-stayed bridge is located south east of Rabat, Morocco
- Project Length
  - 41.1 Km (25.54 mi)
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Project Location

Site

Bridge

Stakeholders

Strates

MTRC, TPI

Automobile du Maroc

Egis International

Covec & MREC

BRDI

External Checker

STRAETS

ETQIC

Casablanca

Fès

Bridge View from Casablanca

Bridge View from Fès

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Stakeholders

FRANCE

MOROCCO

THAILAND

MOROCCO

FRANCE

External Controller

Engineering

Engineering

Engineering

Owner

Companies

Assistance to Owner

Engineering

Engineering

Engineering

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A quite huge structure!

Bridge Description

- 2 major parts:
  - A cable-stayed bridge 742 m (2434 ft) long.
  - A viaduct in prestressed beams 200 m (656 ft) long.

Bridge Description

- Cable Stayed Bridge
  - Total width: 30.4 m (99 ft)
  - Structure: Two side beams of reinforced concrete connected by metal beams spaced out every 4 m (13 ft)
  - A reinforced concrete slab 0.25 m (0.82 ft) thickness
  - The deck is supported by 2 x 20 pairs of cable stay, spaced 8 m (26 ft)

Bridge Description

- Approach spans
  - 5 independent spans, each consisting of 2 x 5 prestressed precast beams 40 m (131 ft) long.

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modeling a 3D terrain with Inventor

1. Creating DTM (Digital Terrain modeling) from the TOPO file.
2. Recovering the triangulated surface from Civil 3D to AutoCAD
3. Importing the triangulated surface from AutoCAD for modeling in Inventor
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Creating an 3D axis with Inventor

1. Creating the horizontal alignments and longitudinal profiles.
2. Exporting alignments and profiles in an LandXML file
3. Creating of a 3D axis from LandXML file, or AutoCAD Civil 3D native file.

How to modeling a 3D axis with Inventor ?

- Importing Information
  - Listing, LandXML Files, etc...
  - Retrieving information directly from alignments and longitudinal profiles of AutoCAD Civil 3D
- Defining the area of studies.
  - Type the name of the Excel file.
  - Select an alignment and a longitudinal profile
  - Type the beginning of the axis
  - Type the axis length

modeling - Axis

- Importing Information
  - Listing, LandXML Files, etc...
  - Retrieving information directly from alignments and longitudinal profiles of AutoCAD Civil 3D
- Defining the area of studies.
  - Type the name of the Excel file.
  - Select an alignment and a longitudinal profile
  - Type the beginning of the axis
  - Type the axis length
Pylons Description

- Each pylon has four legs joined at head and foot with two curves.
- The pylons are 185 m (607 ft) and 197 m (647 ft) high.
- The Foundation dimension:
  - 30.0 m (98 ft) × 25.0 m (82 ft) × 5.0 m (16 ft)

Pylons formwork complexity
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Pylons formwork complexity

Pylons formwork complexity

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Pylons formwork complexity

Pylons formwork complexity

Pylons formwork complexity

Pylons formwork complexity

General Assembly

Assembly

Segment 1

Segment 2

Segment 3

Segment n

Construction of Pylon

Geometric definition of Pylon

Part file
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Earthwork preparatory work
Pylon P2
- Nailed walls
- Hydraulic Deviation

Earthwork preparatory work
Pylon P2
- Nailed walls
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Head of Pylons
Initial Conception
- Challenges
  - Cable stabilization during construction.
  - Horizontal prestressing cables

Head of Pylons
Final Conception
- Metal box proposed by Egis JMI

Head of Pylons
Final Conception
- Elements of the metal box
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Deck Construction
- Built by Balance cantilever from both side of the towers.
  - Installation of lateral beams
  - Installation cable stayed
  - Installation of metal beams spacers every 4 m / 13 ft
  - Concreting slab

Deck
- Prestressing cable
  - Geometric definition
  - Clash detection directly in Inventor
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Calculation Software
- Software PCP from CEREMA
  - Software dedicated to the bridge from the french government
- Software for Structural Analysis
  - local FE Model

CAD / BIM Software

General Documents Workflow

Produced documents
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**Internal Organization by Vault EGIS**

- Secure vault for all documents revisions with reference files.
- Ensure revision availability at any time.

**Workflow with Vault EGIS**

- Benefits
  - Secure vault for all documents revisions with reference files.
  - Ensure revision availability at any time.

**Workflow with Vault EGIS**

- History revision of documents

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**External Organization by Buzzsaw EGIS and BRDI**
Conclusions

- Few figures about this project
  - Engineering: 4 Years (from July 2010 to July 2014)
  - Construction: 5 Years (from January 2011 to March 2016)

- We successfully used Inventor to answer technical needs for the construction study of this complex bridge

Conclusions

- Inventor helped us to respond to the challenges of complex bridge design being:
  - Powerful - Handles complex 3D geometry through rich modeling tools
  - Interoperable — easy transfer of data from other software (C3D, Vault)
  - Consistent with our processes and projects