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1 Description

This tutorial presents a linear analysis of a prestressed reinforced concrete box girder bridge.

The characteristics of the model are presented in the following list and the material and geometry properties in Table 1.

- three-dimensional model
- linear static analysis
- model characteristics:
  - units: N, m
  - isotropic elastic materials
  - reinforcement elements
  - solid element
- load & boundary conditions
  - body force
  - pressure
  - prestress for reinforcement
  - constraints
- result evaluation
  - deformations
  - reinforcement stresses

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2 Finite Element Model

For the modeling session we start a new project. We set the gravity load direction in global $Y$ direction, for this we change the value of "direction of gravity" in the property panel.

![Figure 1: New project Dialog](https://dianafea.com)

![Figure 2: Property panel - definitions](https://dianafea.com)
2.1 Geometry

2.1.1 Box Girder

We create a polygon sheet for the box girder cross-section with the $X$, $Y$, $Z$ coordinates (in m): $(2, 0, 0), (2.7, 2.4, 0), (5, 2.6, 0), (5, 3, 0), (-5, 3, 0), (-5, 2.6, 0), (-2.7, 2.4, 0), (-2, 0, 0)$. We change the viewpoint to a top view and fit the shapes in the workspace window.

![Add polygon sheet - outer contour box girder](image)

Figure 3: Add polygon sheet - outer contour box girder

![Geometry view](image)

Figure 4: Geometry view
We create a polygon sheet for the contour of the inner box.

Main menu ➔ Geometry ➔ Create ➔ Add polygon sheet  [Fig. 5]

Figure 5: Add polygon sheet - contour inner box girder

Figure 6: Geometry view
We subtract the two sheets to get the hole in the box girder.

Figure 7: Subtract shapes

Figure 8: Geometry view
We extrude the box girder sheet to get a 3D body shape.

Figure 9: Extrude shape

Figure 10: Geometry view
2.1.2 Reinforcement

We create a line for the reinforcement bar located in the top flange. This line is copied and translated 6 times over 1.5 m in positive X direction to get 7 reinforcement bars in total.

Figure 11: Add line for reinforcement bar

Figure 12: Array copy shape

Main menu → Geometry → Create → Add line  
Main menu → Geometry → Modify → Array copy
We add a reinforcement set rebars and move the lines rebar 1 to rebar 7 in the geometry browser into this reinforcement set [Fig. 13].

Tip: an alternative way to create the reinforcement sets is to select the respective lines in the geometry browser, right-click in the selection and choose the option ‘New reinforcement shapeset from selection’.
2.1.3 Support Blocks

We create a polygon sheet for the support block.

Main menu ➔ Geometry ➔ Create ➔ Add polygon sheet  [Fig. 15]

![Add polygon sheet](image1.png)

**Figure 15:** Add support block

![Geometry view](image2.png)

**Figure 16:** Geometry view
We copy the sheet of the support block three times and translate it to get four support blocks in total. The distance between the support blocks are 3.6 m in X and 8.5 m in Z direction.

Figure 17: Array copy support block

Figure 18: Array copy support blocks
Figure 19: Geometry browser

Figure 20: Geometry view
We project and imprint the sheets of the support blocks on the box Girder.

Main menu ➔ Geometry ➔ Modify ➔ Shape projection  

[Fig. 21]

Figure 21: Projection support blocks on box Girder
2.2 Properties

2.2.1 Reinforcement

We assign the reinforcement properties to the reinforcement set \textit{rebars}. Therefore we need a new material model and geometry properties for the steel.

\texttt{DianaIE}

\texttt{Select the correspondent reinforcement set in the Geometry browser >}

\texttt{Main menu $\rightarrow$ Geometry $\rightarrow$ Assign $\rightarrow$ Reinforcement properties $\rightarrow$ [Fig. 22]}

\texttt{Reinforcement properties $\rightarrow$ Material $\rightarrow$ Add material $\rightarrow$ [Fig. 23] $\rightarrow$ Edit material $\rightarrow$ [Fig. 24] $\rightarrow$ Geometry $\rightarrow$ Edit geometry $\rightarrow$ [Fig. 25]}

\texttt{Figure 22: Reinforcement property assignment}

\texttt{Figure 23: Add new material - tendon}
Figure 24: Linear material properties - tendon

Figure 25: Geometry properties - bars
2.2.2 Box Girder

We create a linear material model for the concrete box girder. For a solid shape it is not necessary to define geometry properties. We assign the properties to the box girder.

Main menu ➔ Geometry ➔ Assign ➔ Shape Properties ➔ [Fig. 26]
Shape Properties ➔ Material ➔ Add material ➔ Edit material ➔ [Fig. 27, 28]

Figure 26: Property assignment - box girder
Figure 27: Add linear material - concrete
Figure 28: Linear material properties - concrete
2.3 Boundary Conditions

The support blocks are supported.

Figure 29: Attach support

Figure 30: Boundary conditions support blocks
2.4 Loads

We apply the self-weight of the box girder.

**Main menu ➔ Geometry ➔ Assign ➔ Add global loads 🌇 [Fig. 31]**

![Edit global loads window](https://dianafea.com)

**Figure 31: Self-weight**
A distributed load of 20000 N/m$^2$ in negative Y direction is applied to the top surface of the box girder.

Figure 32: Attach load

Figure 33: Top pressure load
We prestress the reinforcement bars (we select all the rebar(s)).

Figure 34: Prestress load reinforcement
We create four load combinations.

Main menu → Geometry → Loads → Open geometry load combinations table 📊 [Fig. 35] [Fig. 36] → Add geometry load combination 📊

Figure 35: Geometry browser - Load combinations

Figure 36: Load combinations
2.5 Mesh

We create the mesh of a box girder with its reinforcements. First we set the mesh properties with an element size of 0.2 m.

Figure 37: Set mesh properties

Figure 38: Finite element mesh
3 Structural Linear Static Analysis

3.1 Commands

We setup a structural linear static analysis with default properties and we run the analysis.

![Main menu](https://dianafea.com)

**Main menu**  ➔ Analysis  ➔ Add analysis  
**Analysis browser**  ➔ Analysis1  ➔ Add command  ➔ Structural linear static
**Analysis browser**  ➔ Analysis1  ➔ Rename  ➔ Linear  
**Main menu**  ➔ Analysis  ➔ Run all analyses

![Analysis browser](https://dianafea.com)

Figure 39: Analysis browser
3.2 Results

We create a contour plot for the total displacement $D_{tXYZ}$ on deformed shape for load combination 4.
We create a line diagram for the reinforcement cross section Forces $N_x$ for load combination 4. We right-click on $N_x$ and select line diagram.

**Results browser** ➔ Load combination 4 ➔ Output linear static analysis ➔ Reinforcements results ➔ Reinforcement Cross-section Forces ➔ $N_x$  

**Figure 42:** Results browser - $N_x$

**Figure 43:** Reinforcement Cross-Section Forces $N_x$ for load combination 4
Appendix A Additional Information

Folder: Tutorials/BoxGirder

Number of elements $\approx 11856$

Keywords:
- **ANALYS**: linear static.
- **CONSTR**: support.
- **ELEM**: bar hx241 reinfo solid tp18l.
- **LOAD**: elemen face force prestr reinfo weight.
- **MATERI**: elasti isotro.
- **OPTION**: direct.
- **POST**: binary ndiana.
- **PRE**: diana.
- **RESULT**: cauchy displa extern force green reacti strain stress total.
Disclaimer: The aim of this technical tutorial is to illustrate various tools, modelling techniques and analysis workflows in DIANA. DIANA FEA BV does not accept any responsibility regarding the presented cases, used parameters, and presented results.