Bridging Your Innovations to Realities

Integrated Solution System for Bridge and Civil Engineering
Contents

- Overview
- Introduction to midas Civil
- Part 1. Modeling
- Part 2. Analysis
- Part 3. Design
- Project Applications

midas Civil
Overview

Integrated Solution for Bridge and Civil Engineering

Bridging Your Innovations to Realities

Distributed worldwide & Leader in high profile projects

A partial list of Users

- T Y Lin
- Hyder
- URS Corp.
- Parsons Corp.
- Michael Baker Jr.
- Figg Bridge Engineers
- Burgess & Niple
- Akins
- Arup
- Maunsell AECOM Group
- OTAK
- Halcrow
- Parsons & Brinckerhoff
- HNTB Corp.
- Roughan & O’Donovan
- McCormick Rankin Corp.
- WSP
- Delcan
- Royal Haskoning
- Scott Wilson
- Strasky, Husty
- PennDOT
- COWI
- Scott Wilson
- Ministry of Transportation of Ontario
- Figg Bridge Engineers
- OTAK
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- HNTB Corp.
- Roughan & O’Donovan
- McCormick Rankin Corp.
Part 1. Modeling

Graphic User Interface

Rendering Window

Main menu

Works Tree

Context menu

Task Pane

Table Window

Message Window

Command Line
Part 1. Modeling

View Control

Various model display methods

- Wire Frame
- Remove Hidden line
- Perspective
- Shrink
See-through Effect of Composite Bridge by Blending (Transparency) effect
Visualization options for Elements / Load / Boundary Conditions
3 separate data files merged into one total model
Part 1. Modeling

Various Section Properties

Prestressed & Post-tension Concrete Box Sections

Section Data

Section Properties

Joint On/Off

Section Size

PSC Viewer

Bridging Your Innovations to Realities
Part 1. Modeling

Various Section Properties

AASHTO/Caltrans PC Section DB

Section Data

Section Name: AASHTO TYPE 1

Symmetry: Left

Section Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Area</td>
<td>1.12E+04</td>
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<td>4.65E+04</td>
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<tr>
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<td>s2</td>
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</tr>
<tr>
<td>s4</td>
<td>3.73E+01</td>
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</table>
Part 1. Modeling

Various Section Properties

Italy & UK PC Section DB
Tapered Sections

midas Civil

Part 1. Modeling

Various Section Properties

Bridging Your Innovations to Realities

Show Calculation Results...
Composite Sections

Various Section Properties

Section Data

Section ID: 1
Name: Bulb T-60
Section Type: Composite

Sub: 7.5 ft
h: 0.046933 ft
Hv: 0 ft

Girders:
- JR3
- JR4

Size 1: Import

H1: 5.000 ft
HL1: 0.167 ft
HL2: 0.333 ft
HL2-2: 0.167 ft

Material:
- Select Material from DB...

Offset: Center-Top
- Change Off

Show Calculation Results...

Import PSC Section

Select PSC Section:
- AASHTO Type 1
- 88T-72

Section Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value (Before)</th>
<th>Value (After)</th>
<th>Unit</th>
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<td>5.4170e+5</td>
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<td>ft⁴</td>
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<td>2.0625e+4</td>
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<td>2.0625e+4</td>
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<td>1.2358e+6</td>
<td>ft²</td>
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<td>0.0000e+0</td>
<td>ft²</td>
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<td>-1.0625e+4</td>
<td>ft</td>
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</table>

Close
Part 1. Modeling

Various Section Properties

Composite Sections
Section Property Calculator (SPC)

User Defined Section

Draw sections of arbitrary shapes

Section Property Calculator (SPC)

Draw sections of arbitrary shapes

Result List

<table>
<thead>
<tr>
<th>Value [Unit:mm]</th>
<th>Scale Factor</th>
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Part 1. Modeling

User Defined Section

Importing CAD Files

1. Draw section shape using CAD
2. Import CAD file through SPC
3. Import section properties
Part 1. Modeling

Tendon Profile Generator

Importing Tendon Profile from AutoCAD DXF file

- Draw Tendon Profile using CAD
- Import DXF file through Tendon Profile Generator
- Import Tendon Profile
# Part 1. Modeling

## Revit Interface

### Data Transfer for BrIM (Bridge Information Modeling) Workflow

<table>
<thead>
<tr>
<th>Functions</th>
<th>Revit &lt;&gt; Civil</th>
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<td><strong>Linear Elements</strong></td>
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<tr>
<td>Structural Column</td>
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<tr>
<td>Beam</td>
<td>&lt;&gt;</td>
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<tr>
<td>Brace</td>
<td>&lt;&gt;</td>
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<tr>
<td>Curved Beam</td>
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<td>Beam System</td>
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<td>Truss</td>
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<tr>
<td><strong>Planar Elements</strong></td>
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<tr>
<td>Foundation Slab</td>
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<tr>
<td>Structural Floor</td>
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<tr>
<td>Structural Wall</td>
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<tr>
<td>Wall Opening &amp; Window</td>
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<tr>
<td>Door</td>
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<td>Vertical or Shaft Opening</td>
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<tr>
<td><strong>Boundary</strong></td>
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<tr>
<td>Offset</td>
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<td>Rigid Link</td>
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<td>Cross-Section Rotation</td>
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<td>End Release</td>
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<td>Point Boundary Condition</td>
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<td>Material</td>
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</table>
Creep/Shrinkage

**Add/Modify Time Dependent Material (Creep / Shrinkage)**

- **Name:** C270
- **Code:** CEB-FIP(1990)

**CEB-FIP(1990)**
- Characteristic compressive strength of concrete at the age of 28 days (fck):
  - 30000 kN/m²
- Relative Humidity of ambient environment (40 - 99):
  - 70%
- Notational size of member:
  - h = 2 * A / p (A: Section Area, p: Perimeter in contact with atmosphere)
  - 0

**Type of cement**
- Rapid hardening high strength cement (HS)
- Normal or rapid hardening cement (N, R)
- Slowly hardening cement (SL)

**Age of concrete at the beginning of shrinkage:**
- 3

**Show Result...**

**Show Time Dependent Material Function**

- Creep Function Data Type:
  - Creep Coefficient
  - Shrinkage Strain

- **Graph Options**
  - X-axis log scale
  - Y-axis log scale

**Creep Coefficient**

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<td>0.6789</td>
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**Shrinkage Strain**

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<td>7</td>
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<tr>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>
Part 1. Modeling

Time Dependent Material Properties

Compressive Strength

Add/Modify Time Dependent Material (Comp. Strength)

Name: C270
Type: Code

Development of Strength
Code: CEB-FIP
Mean compressive strength of concrete at the age of 28 days ($f_{cd}$):
30000 kN/m²

Cement Type(s):
$N_r = 0.25$

Scale Factor: 1.0
Graph Options: X-axis log scale, Y-axis log scale

Redraw Graph

Options:
- ACI
- CEB-FIP
- Ohzagi
- INDIA (IRC: 18-2000)
- European
- CEB-FIP (1978)
Drag & Drop system

Drag & Drop material, section properties & supports
Part 1. Modeling

Bridge Model Wizards

- Suspension Bridge Wizard
- Transverse Analysis Model Wizard
- Cable Stayed Bridge Wizard
- RC Slab Bridge Wizard
- RC Frame/Box Culvert Wizard
- Segmental Bridge Model Wizard
- ILM Bridge Wizard
- FCM Bridge Wizard
- MSS Bridge Wizard
- FSM Bridge Wizard
- PSC Bridge Wizard
- Rail Track Analysis Wizard
- Grillage Model Wizard
Beam Model Wizard

Input/Edit: Insert

Input Type

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<td>2</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Type 1: Add
Type 2: Delete
Auto Bound. Condition
Show Element No.

Material: 2 (Grade C3000)
Section: 1 (AASHTO 5)

Redraw & Update Data

OK  Close  Apply
Truss Model Wizard

- **Type**: Truss
- **Number of Panels**: 4
- **L**: 6 m
- **D1**: 0 m
- **H1**: 0 m
- **D2**: 2.4 m
- **Option**: Symmetric

The image shows a truss model with a diagram indicating the dimensions and options available in the Truss Model Wizard.
## Suspension Bridge Model Wizard

### Bridge Layout

#### Input Bridge Configuration

- **Bridge Model Wizards**
- **Select Material & Section Properties**
- **Bridge layout can be checked in real time**

### Suspension Bridge Wizard

<table>
<thead>
<tr>
<th>Node Coordinates &amp; Heights</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>A</td>
<td>5.207148</td>
</tr>
<tr>
<td>A1</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>128.0015</td>
</tr>
<tr>
<td>C</td>
<td>274.9997</td>
</tr>
</tbody>
</table>

### Asymmetric Bridge

- **D**: Coordinate (x, y, z)
- **E**: Coordinate (x, y, z)
- **E1**: Coordinate (x, y, z)

### Deck System

- **Width**: 28.57016 m
- **Unit Weight**: 249.5566177 kN/m

### Distance from Dock to Pylon

- **G1**: Distance (m)
- **G2**: Distance (m)
- **G3**: Distance (m)
- **G4**: Distance (m)

### Shape of Deck

- **Left Slope**
- **Arc Length**
- **Right Slope**

### View option

- **View Plane**
- **Bitmap**
- **Drawings**
- **Update List**

### Horizontal Force

- **0**
- **0**
Construction sequence of Suspension Bridge
## Cable Stayed Bridge Model Wizard

### Input Bridge Configuration

- **Node Coordinates & Heights**
  - **Type**
    - Symmetric Bridge
    - Asymmetric Bridge
  - **A**
    - X: 0, Z: 25
  - **B**
    - X: 100, Z: 90
  - **C**
    - X: 0, Z: 0
  - **D**
    - X: 0, Z: 0
  - **Height**
    - H1: 90, H2: 0
  - **Depth of Deck (H3)**
    - H3: 0

### Select Material & Section Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Q370xD</td>
<td>1: A</td>
</tr>
<tr>
<td>2: Q345xD</td>
<td>2: E1</td>
</tr>
<tr>
<td>3: C50</td>
<td>3: E2</td>
</tr>
</tbody>
</table>

### Bridge layout can be checked in real time

**Distance from Deck to Tower**

- **G1**
  - Dist(m): 0
- **G3**
  - Dist(m): 0
- **G4**
  - Dist(m): 0

**Shape of Deck**

- **Left Slope(%)**
  - 0
- **Arc Length(m)**
  - 0
- **Right Slope(%)**
  - 0

**Cable Distances & Heights**

- **Left**
  - Dist(m): 3, 8@10, 14
  - Height(m): 1.2, 3@1.5, 3@2, 2@2.3, 45
- **Center**
  - Dist(m): 14, 9@10, 12, 9@10, 14
- **Right**
  - Dist(m): 0
  - Height(m): 0

**Bridge Model Wizards**

- **Select Material & Section Properties**
- **Bridge layout can be checked in real time**

---

**Part 1. Modeling**

**Bridge Model Wizards**

**Bridging Your Innovations to Realities**
Construction sequence of Cable Stayed Bridge
ILM Bridge Model Wizard – 1st Step: Nose & Post-tension Input, Define Each Segment and Input Support Conditions

Compression-only Support Points
ILM Bridge Model Wizard – 2nd Step: 1st and 2nd Stage of Tendon Input

3-D Tendon Placement Check
ILM Bridge Stage Wizard – Definition of Launching Distances & Construction Stages

ILM Model with Defined Construction Stages
FCM Bridge Model Wizard – 1st Step: Model Tab, Type 1 & 2

Select Material Properties & Pier Sections

Input No. of Days for Constructing each Segment

Input Bridge Configuration & Division of Segments

Input Initial Maturity for each Member
FCM Bridge Model Wizard – 2nd Step: Section Tab, Type 1 & 2

- **Input Section Dimensions**
  - Select sections defined

- **Check Sectional Configuration**

- **Input Form Traveler Load**
FCM Bridge Model Wizard – 3rd Step: Tendon Tab, Type 1

- Input Tendon Placement
- Input Tendon Properties & Jacking Forces
- Input No. of Tendons
- Input No. of Anchors for Each Segment
FCM Bridge Model Wizard – 3rd Step: Tendon Tab, Type 2

Input number of tendons belonging to each tendon group

Tendon layout can be checked in real time
FCM Bridge Model Wizard – *Completed Construction Stage Model with 3-D Tendon Layout*
PSC Bridge – *Effective Width calculation*

The Effective Width Scale Factor window is shown with various input fields and options. The calculation results are displayed in a table format with the following columns:

- Span No
- b1
- b2
- b3
- b4
- b5
- b6
- b7
- b8
- b9
- b10
- Envelope

The table contains rows for each span with calculated values for effective widths and other parameters. The calculation results are shown in the table.
# PSC Bridge – *PSC Section (Reinforcing steel)*

## Display of longitudinal rebars input

<table>
<thead>
<tr>
<th>Number</th>
<th>Distance</th>
<th>Dia.</th>
<th>Area (in²)</th>
<th>Rot.Y</th>
<th>Y (in)</th>
<th>Rot.Z</th>
<th>Z (in)</th>
<th>Spacing</th>
<th>Spacing</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.6</td>
<td>40</td>
<td>4.4</td>
<td>Center</td>
<td>0.00</td>
<td>Top</td>
<td>0.13</td>
<td>✓</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>25</td>
<td>2.75</td>
<td>Center</td>
<td>0.00</td>
<td>Top</td>
<td>0.13</td>
<td>✓</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Longitudinal Reinforcement**

- **Start Point**: Use Start Point
- **Ref. Point**: Sup1
- **Distance**: 200 in

**Section Information**

- **Division Tolerance**: 0.36 in
- **Type 1**: ✓
- **Type 2**: □
- **Development Length**: □
Section Manager—PSC Section (Reinforcing steel)
PSC Bridge – Tendon template *(Quick Tendon Profile Generation)*

![Tendon template wizard](image)
Transverse Analysis Model Wizard – 1st Step: Model configuration

- Desired PSC member
- Select I or J section
- Input model configuration
Transverse Analysis Model Wizard – 2\textsuperscript{nd} & 3\textsuperscript{rd} Step: Load, Tendon/Reinforcement Profile definition

Load definition including Live Load

Define Tendon and Reinforcement profile
Part 1. Modeling

Bridge Model Wizards

RC Slab Bridge Wizard

Step 1: Longitudinal configuration

Step 2: Transverse configuration

Step 3: Load definition
Part 1. Modeling

Bridge Model Wizards

RC Frame / Box Culvert Wizards

Step 1: Longitudinal configuration

Step 2: Transverse configuration

Step 3: Load definition
Part 1. Modeling

Bridge Model Wizards

Grillage Model Wizard – customization for CALTRANS

Step 1: Define Bridge Alignment

Step 2: Define Span Configuration
Step 3: Define Section and Division

Step 4: Define Transverse Configuration
Grillage Model Wizard – customization for CALTRANS

Step 5: Define Loads and Traffic Lanes
Step 6: Define Tendon Profiles

Step 7: Define Reinforcement Profiles
Grillage Model Wizard – *customization for CALTRANS*

**Completed Model with Boundary Conditions**

**Completed Model with Tendon Profile**
### Rail Track Analysis Model Wizard

- **Model with Temperature Load**
- **Model with train load (gravity direction)**
- **Model with train acceleration and braking force**

**Construction Stage model with all load cases**

**Auto-generation of multi-linear type elastic link**

**Generation of additional moving load analysis models with referring to the most critical position**

**Additional model**

**Additional model**

**Additional model**

**Most Critical Position**
Rail Track Analysis Model Wizard

Longitudinal displacement of deck due to acceleration and breaking force

- Longitudinal Displacement Due to deck rotation

- Relative Disp. Check
- Rotational Angle Check
- Expansion Joint Check

Complete Model

CS1: Unloaded Stage
Temperature Load only

CS2: Loaded Stage
Temp. + Train Vertical/Starting/Break
Birder Bridge Wizard

- Automatic generation of steel composite girder bridge model
  - Straight, curved, or skewed bridge
  - 3D bridge model with piers, abutments, cross frames
  - Automatic generation of construction sequence with composite action
- Automatic calculation of effective width for composite section
- Cracked section option to ignore concrete deck stiffness in negative flexure region
- 3D Cross frame modeling for accurate design
Part 1. Modeling

Train Load Generator

Train load for Time History Analysis

Train Dynamic Load Function

Import TGS file in Time History Function
## Concurrent Forces

<table>
<thead>
<tr>
<th>Elem</th>
<th>Load</th>
<th>Part</th>
<th>Axial (kN)</th>
<th>Shear-y (kN)</th>
<th>Shear-z (kN)</th>
<th>Torsion (kN·m)</th>
<th>Moment-y (kN·m)</th>
<th>Moment-z (kN·m)</th>
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</thead>
<tbody>
<tr>
<td>332</td>
<td>MVL1</td>
<td>172</td>
<td>0.00</td>
<td>0.00</td>
<td>-153.57</td>
<td>-16.58</td>
<td>1625.04</td>
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<td>MVL1</td>
<td>172</td>
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<td>0.00</td>
<td>159.12</td>
<td>15.38</td>
<td>1676.10</td>
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<td>MVL1</td>
<td>172</td>
<td>0.00</td>
<td>0.00</td>
<td>167.55</td>
<td>12.35</td>
<td>1660.23</td>
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</tr>
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<td>0.00</td>
<td>185.14</td>
<td>-12.05</td>
<td>1623.46</td>
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<td>172</td>
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<td>-12.02</td>
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</tr>
<tr>
<td>346</td>
<td>MVL1</td>
<td>172</td>
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</tr>
<tr>
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<td>MVL1</td>
<td>172</td>
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<td>0.00</td>
<td>359.35</td>
<td>14.79</td>
<td>746.46</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Moving Load Optimizer

- **Copy**
- **Find...**
- **Sorting Dialog**
- **Style Dialog**
- **Show graph**
- **Activate Records**
- **Export to Excel**
- **View by Load Cases**
- **View by Max Value Item**
- **Dynamic Report Table**
Exporting frame model to solid/plate model to readily perform Detail Analysis

midas Civil: line beam model

midas FEA: Solid model

midas FEA: Imported tendons
Calculating Resultant Forces for 3D FE model

**Local Direction Force Sum**

- **Mode**: Polygon Select
- **Type of Element**: Beam, Plate, Solid
- **Load Case/Combination**: Summation
- **Step**: Last Step
- **Tolerance**: 0.000000
- **Coordinate Input**:
  - Position: 1659.99, 363.725
- **Result**:
  - At X=1659.99, Y=162, Z=0
  - Fx: -6.073e-007, Mx: -6.954e-001
  - My: -6.017e-001, Mz: -6.018e+004

**Plate + Beam Model**

**All Plate Model**

<table>
<thead>
<tr>
<th>Name</th>
<th>Load</th>
<th>Length (m)</th>
<th>Fx (kN)</th>
<th>My (kNm)</th>
<th>Mz (kNm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Beam</td>
<td>10.21</td>
<td>17.17</td>
<td>-3.15</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
<td>Beam</td>
<td>10.21</td>
<td>17.17</td>
<td>-3.15</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
<td>Beam</td>
<td>10.21</td>
<td>17.17</td>
<td>-3.15</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
<td>Beam</td>
<td>10.21</td>
<td>17.17</td>
<td>-3.15</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
<td>Beam</td>
<td>10.21</td>
<td>17.17</td>
<td>-3.15</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
<td>Beam</td>
<td>10.21</td>
<td>17.17</td>
<td>-3.15</td>
<td>0.00</td>
</tr>
</tbody>
</table>
General Sections Design

Moment-Curvature Curve
Axial load = 1000
Neutral Axis Angle = 45

Nonlinear properties

Design Code

Midas Civil
General Section Design – cracked section stresses

\[
x\{Ac + (n - 1)As' + nA\} = Ac \cdot xc + (n - 1)As'd' + nAsd
\]

\[
x = \{Ac \cdot xc + (n-1) As' d' + nAs d\}/\{Ac + (n-1)As' + nA\}
\]
Part 1. Modeling

Dynamic Report Generator

Register data
- Register images, tables, and graphs to insert into the report.
- Registered data can be verified in the Report Tree.

Generate a report
- Generate a report in MS Word format.
- Insert data by Drag & Drop from the Report Tree.

Modify model data
- Modify model data.
- Re-perform analysis and design.

Re-generation
- Automatic re-generation of the report with updated analysis results.

Menu | Tables | Group | Works Report

Dynamic Report
- Setup
- Reference DB
- Images
  - User Defined Images
  - Image Files
- Tables
  - User Defined Tables
  - Special Tables
  - Table Templates
- Charts
  - STDMFunc
  - TDMComp
- Texts
  - Defined Texts
  - User Defined Texts
FX+ modeler for complex geometric FE modeling

Geometry modeller
- Geometry modelling and clean-up

Mesh generators
- Auto, mapped and manual meshing

CAD data exchange (STEP, IGES)
- Imported CAD geometry
- Generated mesh

FX+ pre-processor
- Constraint

Graphic display
- Spatially varying pressure
- Wireframe
- Shading & transparency

FX+ modeler
- Convert 1D frame to planer / solid elements
Part 2. Analysis

Analysis Capabilities

**Construction Stage analysis**

**Moving Load Analysis**
- Influence Line & Influence Surface

**Modal Analysis**
- Eigen Value & Ritz Vector

**Dynamic Analysis**
- Static Seismic Analysis
- Response Spectrum Analysis
- Time History Analysis

**Buckling Analysis**

**Large Displacement Analysis**

**P - Delta Analysis**

**Thermal Stress Analysis**

**Nonlinear Analysis**
- Nonlinear Geometric Analysis
- Nonlinear Material Analysis
- Pushover & Fiber Model Analysis
- Inelastic Time History Analysis
- Boundary Nonlinear Analysis

**Heat of Hydration Analysis**

**Integral Bridge Analysis**
PSC Bridge – *Tendon Prestress Loss*

**Construction Stage Analysis**

<table>
<thead>
<tr>
<th>Tendon Coordinates…</th>
<th>Tendon Elongation…</th>
<th>Tendon Arrangement…</th>
<th>Tendon Loss…</th>
<th>Tendon Approximate Loss…</th>
<th>Tendon Weight…</th>
<th>Tendon Stress Limit Check…</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Tendon Group [Top-P 1-1] at the stage of [CS15]**

```
<table>
<thead>
<tr>
<th>Stage</th>
<th>CS15</th>
<th>Apply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top-P 1-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>110587.5790</td>
<td>-1593.1204</td>
<td>0.9864</td>
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<td>-3059.8470</td>
<td>0.9877</td>
</tr>
</tbody>
</table>

Effective Num. 1.0000

**Tendon Time-dependent Loss Graph**

- Tendon: Top01-02
- Stage: CS1
- Step: First Step

**Graph Details:**
- Tendon Loss (Stress)
- Tendon Loss (Force)
- Distance (mm)
- Tendon Percent (Ctrl+F)

midas Civil

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Part 2. Analysis

Construction Stage Analysis

PSC Bridge – *Approximate Tendon Prestress Loss*

![Approximate Estimate of Time Dependent Tendon Losses](image)

- **Design Code**: AASHTO-LRFD 06
- **Estimation Method**: Rational Approximate Method
  - PCI Bridge Design Manual 04
  - JSCCE 02
- **Rational Approximate Method (AASHTO-LRFD06)**
  - Ambient Relative Humidity (0-100) %
  - Compressive Strength of Concrete at time of Initial Loading (f'c)
    - 0 kips/in²
- **Relaxation Loss**
  - Per Code
  - User Defined
  - Tendon Type: Low-relaxation Strand
  - Relaxation Loss: 0 kips/in²

**Tendon Load**
- Load Case: P5

**Dead Load (Self Weight)**
- Load Case: Self

**Additional Dead Load (Superimposed Load)**
- Load Case: Self
### Construction Stage Analysis

**PSC Bridge – Tendon Stress Limit Check**

<table>
<thead>
<tr>
<th>Tendon</th>
<th>FDL1 (N/mm²)</th>
<th>FDL2 (N/mm²)</th>
<th>FLL (N/mm²)</th>
<th>Immediately after anchor set</th>
<th>At service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bot1</td>
<td>867.122</td>
<td>1008.605</td>
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**Tendon Stress Limit**

- **At anch.**
  - fpu: 0.7
  - fpy: 0.74
- **Away from anch.**
  - fpu: 0.74
  - fpy: 0.8
- **At service**
  - fpu: 0.8
**Part 2. Analysis**  

**Construction Stage Analysis**

**PSC Bridge – Stress output locations on PSC section**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
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<tbody>
<tr>
<td>Sig-xx</td>
<td>Sum of axial stresses in ECS x-direction</td>
</tr>
<tr>
<td>Sig-zz</td>
<td>Sum of axial stresses in ECS z-direction</td>
</tr>
<tr>
<td>Sig-xz (shear)</td>
<td>Sum of shear stresses due to shear force and prestressing shear bars</td>
</tr>
<tr>
<td>Sig-xz (torsion)</td>
<td>Shear stress due to torsion</td>
</tr>
<tr>
<td>Sig-xz (bar)</td>
<td>Shear stress due to prestressing shear bars</td>
</tr>
<tr>
<td>Sig-Is (torsion)</td>
<td>Diagonal Tensile Stress excluding torsional shear stress</td>
</tr>
<tr>
<td>Sig-Is (shear + torsion)</td>
<td>Diagonal stress due to torsion and shear force</td>
</tr>
<tr>
<td>Sig-Ps1</td>
<td>Max. principal stress</td>
</tr>
<tr>
<td>Sig-Ps2</td>
<td>Min. principal stress</td>
</tr>
</tbody>
</table>
Part 2. Analysis

Construction Stage Analysis

PSC Bridge – Stress output locations on PSC section

Sig-xx, Position 1
Max: 80.6
Min: -85.5

Sig-xx, Position 9
Max: 38.5
Min: -40.8
Part 2. Analysis

Construction Stage Analysis

FCM Bridge – *Camber Control, Table and Graph*
ILM Bridge – *Contour & Graph of Nose Tip Deflection*
Construction Stage Analysis

ILM Bridge – *BMD for Each Construction Stage*

**Minimum Bending Moment Envelope upon Completion**

**Maximum Bending Moment Envelope upon Completion**
Part 2. Analysis

Construction Stage Analysis

Cable-stayed Bridge – *Finding Unknown Load Factors by Optimization*

Definition of Unknown Load Factors

Completed Structure Model

midas Civil
Cable-stayed Bridge – **Geometric nonlinearity and tangential displacements**

Nonlinear analysis is performed by accumulating the results.

Time dependent effects (Creep/Shrinkage)

Maximum of 3 load cases distinguished from Dead Load (CS)

Tangential displacements (Lack of Fit Force included)

Camber for Construction Stage included in staged analysis
Cable-stayed Bridge – *Geometric nonlinearity and tangential displacements*
Cable-stayed Bridge – Forward stage analysis step1: calculate initial tension forces at completed state

Analysis results of initial equilibrium state (completed optimized state)
Construction Stage Analysis

Cable-stayed Bridge – *Forward stage analysis step2: calculate construction stage pretension forces*

**Construction stage pretension force**

\[ \text{Construction stage pretension force} = \text{Initial pretension force (from step 1)} + \text{Lack of Fit Force (additional tension required to install a cable)} \]

**Displacements of forward stage analysis at the last stage using Lack of Fit Force**

\[ \text{Max.} - 0.000426 \]

**Displacements at the completed state**

\[ \text{Max.} - 0.00043 \]
Construction Stage Analysis

Cable-stayed Bridge – *General Camber Output*
Suspension Bridge – *Initial configuration analysis*

Select the analysis method for initial configuration analysis

Select load cases, which need to be equilibrated with cable tensions
Suspension Bridge – **Nonlinear backward construction stage analysis**

Equilibrium Element Nodal Forces calculated from the second accurate analysis.

![Construction Stage Analysis Control Data](image)

<table>
<thead>
<tr>
<th>Type</th>
<th>Elem</th>
<th>Fx(1) (kN)</th>
<th>Fy(1) (kN)</th>
<th>Fz(1) (kN)</th>
<th>Mx(1) (kN·cm)</th>
<th>My(1) (kN·cm)</th>
<th>Mz(1) (kN·cm)</th>
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Part 2. Analysis

Construction Stage Analysis

Bridging Your Innovations to Realities
Suspension Bridge – *Nonlinear backward construction stage analysis*
Part 2. Analysis
Moving Load Analysis

Influence Line Analysis
Moving Load Tracer + Vehicle Load Conversion to Static Load
Eigen Value Analysis – *Mode 1 Vibration Shape + Contour*
Time History Analysis – Displacement & Moment

Graph 1: Time history of displacement and moment for different sections.

- **Displacement Graph**
  - X-direction
  - Y-direction
  - Graph showing maximum displacement in cm over time in seconds.

- **Moment Graph**
  - Top in Pier (Element-9)
  - Bottom in Pier (Element-1)
  - Graph showing maximum moment (tonf-m) over time in seconds.

- **Maximum Displacement**
  - Middle in Pier (Node-6) = 4.055 cm

- **Maximum Moment**
  - $M_{max} = 1128$ (tonf-m)
Time History Analysis – Shear vs Displacement Graph

- Shear in Middle (tonf) vs Displacement in Middle (cm)
- Top Displacement vs Base Shear
- $V_{max} = 64.48$ (tonf)
- $D_{max} = 4.01$ (cm)
- Node-6
Dynamic Boundary Nonlinear Analysis – *Lead Rubber Bearing Definition*

**Define General Link Properties**

- **Name**: LRB1
- **Application Type**: Force
- **Property Type**: Lead Rubber Bearing Isolator
- **Description**:

**Linear Properties**

- **DOF**: Dx: 50000, Dy: 200, Dz: 200
- **Effective Stiffness**: 0 tonf/in
- **Effective Damping**: 0 tonf sec/in

**Nonlinear Properties**

- **Shear Spring Location**:
- **Distance Ratio Properties**:

**Lead Rubber Bearing Definition**

\[
\begin{align*}
\sigma &= k \cdot \left(1 - \frac{\dot{\gamma}}{\dot{\gamma}_v}\right) \tau_v \\
\dot{\gamma} &= \frac{1}{2} \left[1 - \left(\frac{\sigma}{\tau_v} - \frac{k}{\tau_v}\right)^2\right] \dot{v}
\end{align*}
\]
Dynamic Boundary Nonlinear Analysis – *Built-in Earthquake Acceleration Record*

**Generate Earthquake Acceleration Record**

- **Earthquake:** 1940, El Centro Site, 270 Deg
- **Amplitude Scale:** 1
- **Time Scale:** 1

**Import**

- 1940, El Centro Site, 270 Deg
- Peak, 0.3569 g, Duration, 53.72 sec
Dynamic Boundary Nonlinear Analysis – *Bridge behavior with the base isolators*
Pushover Analysis — *Performance Based Seismic Design*

- Static Analysis and Member Design
- Select Load or Displacement Control
- Define Inelastic Hinge Properties
- Pushover Analysis
- Review Capacity of Structure
- Performance Point by CSM
- Evaluation of Structure to Resist Earthquake
Part 2. Analysis

Nonlinear Analysis

Pushover Analysis – Export Moment-Curvature Idealized Model from midas GSD to Civil

midas GSD

midas Civil
Pushover Analysis – *Capacity Curves*

- **Yield Point**
- **Maximum Capacity**

**Demand Spectrum**
- Define Elastic Spectrum...
- Demand Spectra at Damping Ratios (%)
- 5, 10, 15, 20
- Constant Period lines at Period (sec)
- 0.5, 1, 1.5, 2

**Evaluation of Performance Point**
- Procedure A
- Procedure B

**Performance Point**
- Displ. Control Mode: 11. Dir.: DX
- Load Pattern: Mode Shape
- U,0
- S,a,Ed
- T,eff,Diff

**Graph Display Option**
- Background Color
- Black, White
- Change Graph Tilt
- Change Graph Range
- Save Window As *.bmp

**Pushover Curve**
- Plot Type
  - Capacity Curve (MDOF)
  - Base Shear vs. Displacement
  - Shear Coefficient vs. Displacement
  - Yield Point vs. Displacement
- Additional Curves at Other Nodes
  - Nodes 2, 3, 4, 5
Part 2. Analysis

Nonlinear Analysis

Pushover Analysis – *Evaluation of Structure by Design Spectrum*

![Pushover Curve and Generate Design Spectrum](image)

- **Pushover Curve**
  - Pushover Load Case: Acc_Y
  - Plot Type: Capacity Curve (EDOF)
    - Base Shear vs. Displacement
    - Shear Coefficient vs. Displacement
    - Shear Coefficient vs. Drift
    - Load Factor vs. Displacement
  - Additional Curves at Other Nodes: 0 0 0 0 0
  - Capacity Spectrum (EDOF)
    - For Performance Point (FEMA)

- **Demand Spectrum**
  - Define Elastic Spectrum: 0.5 1 1.5 2
  - Demand Spectra at Damping Ratios (%): 5 10 15 20

- **Evaluation of Performance Point**
  - Procedure A

- **Damping Parameters**
  - Inherent + Additional Damping (%): 5
  - Structural Behavior Type: 1

- **Performance Point**
  - Displ. Control Nodes: 34
  - Dir.: DY
  - Load Patterns: Acceleration
    - V,D: Elastic
    - Sa,Sd: Elastic
    - Teff,Def: 0.591, 8

- **Graph Display Option**
  - Background Color: Black
  - Change Graph Title
  - Change Graph Range
  - Save Window As *.bmp

- **Generate Design Spectrum**
  - Site Class: A
  - Peak Ground Acceleration (PGA): Korea (Bridge)
  - Spectral Acceleration
    - Period 0.2 sec (Ss): Korea (Arch. 2000)
    - Period 1.0 sec (S1): China (JTJ 2004-89)
  - Response Modification
    - China (GB 50011-2001)
    - Shanghai (DG 208-9-2003)
  - Max. Period: Japan (Arch. 2000)
    - Japan (Bridge 2002)
Part 2. Analysis

Nonlinear Analysis

Material Nonlinear Analysis

Element types
- Truss
- Plane Stress
- Plane Strain
- Axisymmetric
- Solid

Hardening Models
- Isotropic
- Kinematic
- Mixed

Plastic Material Models
- Tresca
- Von Mises
- Mohr-Coulomb
- Drucker-Prager
Response Spectrum Analysis

Multiple spectrums input
reflecting modal damping ratios
Nonlinear Analysis

Nonlinear / Inelastic Time History Analysis

- Kinematic Hardening
- Clough
- Takeda
- Modified Taketa
Inelastic Time History Analysis results
Nonlinear Analysis

Inelastic dynamic analysis using Fiber Model
Part 2. Analysis

Nonlinear Analysis

Inelastic dynamic analysis using Fiber Model – *Defining hysteretic model of concrete*

**Inelastic Material Model**

- **Name:** Concrete
- **Material Type:** Concrete
- **Hysteresis Model:** Kent & Park Model

**Skeleton Curve**

- \( f_c' := 0 \) (kips/ft²)
- \( e_{cc} := 0 \)
- \( K := 1 \) (a number)
- \( z := 0 \)
- \( e_{cu} := 0 \)

\[ e_{cu} > e_{cl} = 0.82e + e_{cc} \]

---

**Kent & Park Model**

- Stress-compression graph
- Hysteretic model of concrete

**Japan Concrete Standard Specification Model**

- Stress-compression graph

**Japanese Roadway Specification Model**

- Stress-compression graph

**Trilinear Concrete Model**

- Stress-compression graph

---

*Midas Civil*
Inelastic dynamic analysis using Fiber Model – *Defining hysteretic model of steel*

**Inelastic Material Model**

- **Name**: D14
- **Material Type**: Steel
- **Hysteresis Model**: Menegotto-Pinto Model

**Fiber Model Parameters**

- $f_y = 50000$ ksi
- $E = 1312069$ ksi
- $b = 0.1$

**Graphical Representations**

- **Menegotto-Pinto Model**
- **Bilinear Model**
- **Asymmetric Bilinear Steel Model**
- **Trilinear Steel Model**
Inelastic dynamic analysis using Fiber Model – *Section division for Fiber Model definition*
Inelastic dynamic analysis using Fiber Model – *Fiber Cell Result Plotting*
Part 2. Analysis

Heat of Hydration Analysis

Temperature Contour with / without Cooling Pipes

Without Cooling Pipes

With Cooling Pipes
Part 2. Analysis

Heat of Hydration Analysis

Time History Curve For Temperature Difference Between Inside and Outside

**Without Cooling Pipes**

**With Cooling Pipes**
Multi-span integral bridge example – *Elevation & Cross-section at piers*

**Figure 2.1** *Integral Bridge Elevation*

**Figure 2.2** *Cross-section at piers*
Multi-span integral bridge example – *Soil profile*

*Figure 2.3  Soil profile: undrained shear strength and elastic modulus*
Multi-span integral bridge example – *Auto-generation of abut springs and pile springs*
Multi-span integral bridge example – *Moment Diagram (Dead Load)*
Multi-span integral bridge example – *Moment Diagram (Thermal expansion)*

![Moment Diagram](image-url)
Multi-span integral bridge example – Reactions (Thermal expansion)
Multi-span integral bridge example – *Influence Line*
Maximum Principal Stresses

Stress time history due to jet fan vibration
Plate Moment – Cutting Diagrams

Cutting Diagram Mode:
- Cutting Line
- Cutting Plane

Defined Cutting Lines:
- Cut-Line #1
- Cut-Line #2
- Cut-Line #3
- Cut-Line #4

Cutting Line Detail:
Name: Cut-Line #5
Pnt1: -1.5, -0.4, -1
Pnt2: 1.5, 0.1, -1
Options:
- Normal
- In Plane
Scale Factor: 1
- Reverse
- Graph
- Value Output
- MinMax Only

-64.1269
-34.9563
47.1527
41.7438
-46.5524
46.6832
-34.9563
-46.5524
Solid Stresses — *Iso Surface*
Solid Stress – Cutting plane
Part 2. Analysis

Post-processing Features

Von Mises Stresses + Deformed Shape + Contour Annotation
### Part 3. Design

### Design Features and Standards

#### PSC Composite General Design
- Eurocode2-2:05

#### PSC Design
- AASHTO-LRFD12
- CSA-S6S1-10
- Eurocode2-2:05
- KSCE-USDO5
- JTG D62-04

#### Bridge Load Rating Design (PSC & Steel Composite Bridges)
- AASHTO-LRFR05
- AASHTO-LRFR12

#### Steel Composite Girder Design
- AASHTO-LRFD12
- EN 1994-2

#### SRC Design
- SSRC79
- AIJ-SRC01
- JGJI38-01
- AIK-SRC2K
- TWN-SRC92

#### Reinforced Concrete Design
- AASHTO-LRFD12
- AASHTO-LFD96
- Eurocode2-2
- CSA-S6-00
- JTJ023-85
- IRC:21-2000
- KCI-USD99
- KSCE-USDO5
- TWN-BRG-LSO90

#### Structural Steel Design
- AASHTO-LRFD12
- AASHTO-LFD96
- AASHTO-ASD96
- AISC-LRFD2K
- AISC-LRFD93
- AISC-ADS89
- BS5950-90
- JTJ025-86
- IS:800-2007
- Eurocode3-2
- TWN-BRG-LSO90
- TWN-BRG-LSO90
PSC Design as per Eurocode2-2:05

Select PSC Design Results

Select Tendon / Bridge / Construction types
PSC Design as per Eurocode2-2:05 – Cross section stress design results table

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<thead>
<tr>
<th>Elem</th>
<th>Part</th>
<th>Positive/Negative</th>
<th>LC orm Name</th>
<th>Design Situations</th>
<th>Type</th>
<th>CHK</th>
<th>M_Ed (in kips)</th>
<th>M_Rd (in kips)</th>
<th>M_Ed/M_Rd</th>
<th>Aps (in²)</th>
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Part 3. Design

PSC Design

PSC Design as per Eurocode2-2:05 – Design Report (EXCEL compatible)

Flexure Design

Shear Design

Torsional Design
PSC Design as per AASHTO LRFD12

- **Design Code:** AASHTO-LRFD12

**Input Parameters**
- **Tendon Type**
  - Low Relaxation Tendons
  - Stress Relieved Tendons
  - Prestressing Bars

- **Corrosive Condition**
  - Severe
  - Moderate/Mild

- **Flexural Strength**
  - Code
  - Strain Compatibility

- **Exposure Factor for Crack Width**
  - Class I (1.0)
  - Class II (0.75)
  - User

- **Construction Type**
  - Segmental
  - Non-Segmental

**Output Parameters**
- **At Construction Stage/Service Loads**
  - Stress by Construction Stage
  - Stress by Service Load Combinations
  - Stress in Prestressing Tendons
  - Principal Stress by Construction Stage
  - Principal Stress by Service Load Combinations (Max Shear)
  - Principal Stress by Service Load Combinations (Max Torsion)
  - Crack Check

- **At Factored Loads**
  - Flexural Strength Check
  - Shear Strength Check
  - Combined Shear and Torsion Check

Select Tendon / Bridge / Construction types
Select PSC Design Results
PSC Design as per AASHTO LRFD12 – *Cross section stress design results table*

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**Check stress for cross section at a construction stage...**
- Check tension stress for Prestressing tendons...
- Check stress for cross section at service loads...
- Principal stress at a construction stage...
- Principal stress at service loads (at the maximum shear force)...
- Principal stress at service loads (at the maximum torsion)...
- Check crack width at service loads...
- Tension reinforcement...
- Check Flexure Strength...
- Check Shear Strength...
- Check Combined Shear and Torsion Strength...
PSC Design as per AASHTO LRFD12 – **Shear strength design results table**

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<th>(M_u) (kgf·cm)</th>
<th>(V_N) (kgf)</th>
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<th>(V_c) (kgf)</th>
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- Check stress for cross section at a construction stage...
- Check tensile stress for Prestressing tendons...
- Check stress for cross section at service loads...
- Principal stress at a construction stage...
- Principal stress at service loads (at the maximum shear force)...
- Principal stress at service loads (at the maximum torsion)...
- Check crack width at service loads...
- Tension reinforcement...
- Check Flexure Strength...
- **Check Shear Strength**...
- Check Combined Shear and Torsion Strength...
PSC Design as per AASHTO LRFD12 – Design Report (EXCEL compatible)
Bridge Load Rating Design as per AASHTO LRFR – *Permit Vehicle & Moving Load Case*

**Define User Defined Vehicular Load**
- **Load Type**: Permit Truck
- **Vehicular Load Properties**
  - **Vehicular Load Name**: Permit Load
  - **Impact Factor**: 0

**Define Moving Load Case**
- **Load Case Name**: Permit Vehicle
- **Description**: Permit Vehicle
- **Permit Vehicle**
  - **Vehicle**: Permit Load
  - **Ref. Lane**: Lane 1
  - **Eccentricity**: 30 in
  - **Scale Factor**: 1

**Overhead View**
- **Permit Vehicle**

*Image Source: midas Civil*
Bridge Load Rating Design as per AASHTO LRFR – Rating Cases and Materials

- Define Rating Case...
- Rating Material...
- Rating Design Code...
- Rating Parameter...
- Rating Group Setting...
- Rating Design
- Rating Design Result Tables
- Rating Result Diagram...

**Static Load Combination**
- Service Limit State
  - Load Type
    - DC: max 1.00, min 1.00
    - DW: max 1.00, min 1.00
    - Temperature: max 1.00
    - T. Gradient: max 1.00
    - Secondary: max 1.00
    - Permanent: max 1.00
    - User Defined: max 1.00

**Load Cases**
- Self(ST)
- Non-Struct

**Modify Concrete Materials**

- Material List
  - ID: 1
  - Name: Grade C5000
  - f/c, f/c/kR: Grade 60
  - Grade: No-bar
  - Sub-bar: Grade 60

- Concrete Material Selection
  - Code: ASTM(RC)
  - Grade: Grade C5000
  - Specified Compressive Strength (f/c, f/c/kR): 5,000 kips/in²

- Rebar Selection
  - Code: ASTM(RC)
  - Grade of Main Rebar: Grade 60
  - f_y: 60,000 kips/in²
  - Grade of Sub-Rebar: Grade 60
  - f_y: 60,000 kips/in²

Modify Close
Bridge Load Rating Design as per AASHTO LRFR – Concrete Stress Results
## Bridge Load Rating Design as per AASHTO LRFR – *Flexural Rating Results*

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**Bridge Load Rating Design as per AASHTO LRFR – Shear Strength Results**

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## Bridge Load Rating Design as per AASHTO LRFR – Tendon Results

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<td>RC1_Service_DC(MAX), DW(MAX), T(+), A, V(My-Max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>[I]</td>
<td>Tendon1</td>
<td>RC1_Service_DC(MAX), DW(MAX), T(+), A, V(My-Min)</td>
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</tr>
<tr>
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<td>RC1_Service_DC(MAX), DW(MAX), T(-), A, V(Mz-Max)</td>
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<tr>
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<tr>
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<td>1</td>
<td>[I]</td>
<td>Tendon1</td>
<td>RC1_Service_DC(MAX), DW(MAX), T(-), A, V(My-Max)</td>
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</tr>
<tr>
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<td>1</td>
<td>[I]</td>
<td>Tendon1</td>
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</tr>
<tr>
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<td>[I]</td>
<td>Tendon1</td>
<td>RC1_Service_DC(MAX), DW(MAX), T(-), A, V(Fx-Max)</td>
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</tr>
<tr>
<td></td>
<td>1</td>
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<td>Tendon1</td>
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</tr>
<tr>
<td></td>
<td>1</td>
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<td>RC1_Service_DC(MAX), DW(MAX), T(-), A, V(Fz-Max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>[I]</td>
<td>Tendon1</td>
<td>RC1_Service_DC(MAX), DW(MAX), T(-), A, V(Fz-Min)</td>
<td>235360984</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>[I]</td>
<td>Tendon1</td>
<td>RC1_Service_DC(MAX), DW(MAX), T(-), A, V(Mx-Max)</td>
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</tr>
<tr>
<td></td>
<td>1</td>
<td>[I]</td>
<td>Tendon1</td>
<td>RC1_Service_DC(MAX), DW(MAX), T(-), A, V(Mx-Min)</td>
<td>235360984</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>[I]</td>
<td>Tendon1</td>
<td>RC1_Service_DC(MAX), DW(MAX), T(-), A, V(My-Max)</td>
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</tr>
<tr>
<td></td>
<td>1</td>
<td>[I]</td>
<td>Tendon1</td>
<td>RC1_Service_DC(MAX), DW(MAX), T(-), A, V(My-Min)</td>
<td>235360984</td>
</tr>
</tbody>
</table>
Composite PC Girder Design as per EN1992-2

Tendon template wizard

Quick generation of PSC composite section
Composite PC Girder Design as per EN1992-2

1. Design Condition
1.1 Partial factors for ultimate limit states

<table>
<thead>
<tr>
<th>Design Situations</th>
<th>γk for concrete</th>
<th>γk for reinforcing steel</th>
<th>γk for prestressing steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistive &amp; Transient</td>
<td>1.50</td>
<td>1.15</td>
<td>1.00</td>
</tr>
<tr>
<td>Accidental</td>
<td>1.20</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

- γk = 0.850 (for the Compressive strength)
- γk = 1.000 (for the Tensile strength)

2. Ultimate Moment Resistance

2.1 Positive Moment

- Design Load
  - Load Combination Name: CL1B1
  - Design Combinations: Persistent & Transient
  - Load Combination Type: FX-MAX
  - MDL = 0.000 kN \cdot m

- Design strength of concrete
  - f'c = f'c lim = 22.67 MPa
- Design strength of reinforcement
  - f'p max = f'p max = 434.73 MPa

- Calculate Neutral Axis
  1. Assume neutral axis depth
  2. Calculate the strain of steel and tendon
  3. Calculate the stress of steel and tendon
  4. Calculate the axial force in concrete, steel, and tendon
  5. Check if the resultant force of cross-section is zero
  6. Repeat step 1 through 5 until the resultant force becomes zero

<table>
<thead>
<tr>
<th>Num.</th>
<th>Neutral depth (mm)</th>
<th>Compression Force (C) (kN)</th>
<th>Tension Force (T) (kN)</th>
<th>Ratio (C/T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>450.00</td>
<td>353.58</td>
<td>181.62</td>
<td>0.1793</td>
</tr>
<tr>
<td>2</td>
<td>575.00</td>
<td>5421.54</td>
<td>170.39</td>
<td>341.47</td>
</tr>
<tr>
<td>3</td>
<td>654.785</td>
<td>5258.73</td>
<td>170.73</td>
<td>385.264</td>
</tr>
<tr>
<td>4</td>
<td>654.346</td>
<td>5258.73</td>
<td>170.73</td>
<td>385.264</td>
</tr>
<tr>
<td>5</td>
<td>654.346</td>
<td>5258.73</td>
<td>170.73</td>
<td>385.264</td>
</tr>
</tbody>
</table>
Composite Girder Design as per EN1994-2

Enter the Partial Factors

Select the desired Ultimate Limit Stress
Composite Plate Girder Design as per EN1994-2

- Bending Resistance
- Resistance to Vertical Shear
- Resistance to Lateral-Torsional Buckling
- Resistance to Transverse Force
- Resistance to Longitudinal Shear
- Resistance to Fatigue

Flexural Resistance

Design Parameter
Composite Girder Design as per AASHTO LRFD 12

**Composite Steel Girder Design Parameters**

- **Code:** AASHTO-LRFD12
- **Update by Code:**

  - **Strength Resistance Factor**
    - Resistance factor for yielding (\(\Phi_v\)) = 0.95
    - Resistance factor for fracture (\(\Phi_u\)) = 0.8
    - Resistance factor for axial comp. (\(\Phi_c\)) = 0.9
    - Resistance factor for flexure (\(\Phi_f\)) = 1
    - Resistance factor for shear (\(\Phi_v\)) = 1
    - Resistance factor for shear connector (\(\Phi_{se}\)) = 0.85
    - Resistance factor for bearing (\(\Phi_b\)) = 1

- **Girder Type for Box/Tub Section**
  - Single Box Sections
  - Multiple Box Sections
  - Consider St. Venant Torsion and Distortion Stresses

- **Option For Strength Limit State**
  - Appendix A6 for Negative Flexure Resistance in Web Compact / NonCompact Sections
  - \(M_n<1.3\Phi My\) in Positive Flexure and Compact Sections (6.10.7.1; 2.3)
  - Post-buckling Tension-field Action for Shear Resistance (6.10.9.3.2)

- **Design Parameters**
  - Strength Limit State Flexure
  - Strength Limit State-Shear
  - Service Limit State
  - Constructability
  - Fatigue Limit State
  - Shear Connectors, Longitudinal Stiffeners

**Options**
- Enter Strength Reduction Factor
- Option for Strength Limit State Calculation
- Select the desired Limit Stress
Composite Girder Design as per AASHTO LRFD 12: Materials, Rebar, Stiffener and Shear Connector
Composite Girder Design as per AASHTO LRFD 12 Design Force/Moment

Composite Plate Girder Design

Part 3. Design
Composite Girder Design as per AASHTO LRFD 12—Design Result Table
Composite Girder Design as per AASHTO LRFD 12 – Excel Report and Result Diagram
Composite Girder Design as per AASHTO LRFD 12 - Excel Report and Result Diagram

Design Parameters...
Design Material...
Load Combination Type...
Longitudinal Reinforcement...
Transverse Stiffener...
Unbraced Length...
Design Position...
Position for Design Output...
Shear Connector...
Fatigue Parameters...
Curved Bridge Info...

Design Tables

Design

Print Result

Design Result Tables

Design Result Diagram
Reinforced Concrete Design as per Eurocode 2-2:05 – Design Report
20 Bridge Project Applications selected worldwide

- 6 Bridges from Europe
- 8 Bridges from Asia
- 6 Bridges from Americas
Ironton-Russell Bridge

- Overall bridge length: 1,900 ft
- Main span: 950 ft
- Tower height: 519 ft
- Location: Crossing the Ohio River between Ironton and Russell
- Function/usage: Roadway Bridge
- Designer: Michael Baker, Jr., Inc.
- Cost of construction: $110 Million
- Number of elements and element types used:
  - Truss (Cable): 70
  - Beam: 2088
  - Shell: 2730
- Type of analysis:
  - Construction Stage Analysis with Time-Dependent Effects
  - Unknown Load Factor Analysis
  - Eigenvalue Analysis
  - Thermal Analysis
  - Vehicle Load Optimization
### Weirton-Steubenville Bridge

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall bridge length</td>
<td>1,965 ft</td>
</tr>
<tr>
<td>Main span</td>
<td>820 ft</td>
</tr>
<tr>
<td>Tower height</td>
<td>365 ft</td>
</tr>
<tr>
<td>Location</td>
<td>Crossing the Ohio River between Weirton (West Virginia) and Steubenville (Ohio)</td>
</tr>
<tr>
<td>Function/usage</td>
<td>Roadway Bridge</td>
</tr>
<tr>
<td>Contractor</td>
<td>S.J. Groves &amp; Sons Co.</td>
</tr>
<tr>
<td>Designer</td>
<td>Michael Baker, Jr., Inc.</td>
</tr>
<tr>
<td>Consultant</td>
<td>T.Y. Lin International</td>
</tr>
<tr>
<td>Year of completion</td>
<td>1989 (Health Monitoring, 2005)</td>
</tr>
<tr>
<td>Cost of construction</td>
<td>$30 Million</td>
</tr>
</tbody>
</table>
| Number of elements and element types used | Truss (Cable): 52  
Beam: 484  
Shell: 13312 |
| Type of analysis              | Construction Stage Analysis  
Cable Tension Optimization |
La Jabalina Bridge

- Overall bridge length: 191 m
- Location: Durango
- Function/usage: Roadway Bridge
- Designer: TRIADA SA de CV
- Number of elements and element types used:
  - Beam: 63
  - Tendon Profile: 64
- Type of analysis:
  - Construction Stage Analysis with Time-Dependent Effects
  - Response Spectrum Analysis
  - Eigen Value Analysis
  - Vehicle Load Optimization
El Marquéz Bridge

Overall bridge length: 102 m
Location: Michoacán
Function/usage: Roadway Bridge
Designer: COPECSA de CV
Number of elements and element types used: Beam: 2224
Type of analysis: Response Spectrum Analysis, Eigen Value Analysis, Vehicle Load Optimization
Tarango Bridge

Overall bridge length: 206 m
Location: Mexico City
Function/usage: Roadway Bridge
Designer: Carlos Fernandez Casado S de RL
Number of elements and element types used:
- Truss (Cable): 176
- Beam: 1653

Types of analysis:
- Construction Stage Analysis with Time-Dependent Effects
- Response Spectrum Analysis
- Eigen Value Analysis
- Vehicle Load Optimization
**Avenida Suba - Avenida Boyacá Bridge**

- Overall bridge length: 370 m
- Location: Cali
- Function/usage: Roadway Bridge
- Designer: Gregorio Renteria
- Number of elements and element types used:
  - Beam: 153
  - Tendon Profile: 140
- Type of analysis:
  - Construction Stage Analysis with Time-Dependent Effects
  - Response Spectrum Analysis
  - Eigen Value Analysis
  - Vehicle Load Optimization
**Lange Wapper Bridge**

<table>
<thead>
<tr>
<th><strong>Overall bridge length</strong></th>
<th>1,520 m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main span</strong></td>
<td>600 m</td>
</tr>
<tr>
<td><strong>Tower height</strong></td>
<td>150 m</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Antwerp</td>
</tr>
<tr>
<td><strong>Function/usage</strong></td>
<td>Roadway Bridge</td>
</tr>
<tr>
<td><strong>Consultant</strong></td>
<td>IC+E, TUDelft</td>
</tr>
</tbody>
</table>
| **Number of elements and element types used** | Solid: 7930 (concrete deck)  
Shell: 7733 (crossbeam’s web)  
Beam: 20151 (crossbeam’s flange, truss’s top and bottom chord and diagonal)  
Truss: 128 (Stay cables) |
| **Type of analysis**     | Construction Stage Analysis  
Cable Tension Optimization  
Vehicle Load Optimization |
| **FE model by**          | N. Löfgren |
TU Delft / Movares Research Project on Train-Structure Interaction

<table>
<thead>
<tr>
<th>Overall bridge length</th>
<th>400 m</th>
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</thead>
<tbody>
<tr>
<td>Main span</td>
<td>200 m</td>
</tr>
<tr>
<td>Tower height</td>
<td>75 m (60 m above the deck)</td>
</tr>
<tr>
<td>Function/usage</td>
<td>Railway Bridge</td>
</tr>
<tr>
<td>Consultant</td>
<td>Movares Nederland BV</td>
</tr>
<tr>
<td>Number of elements and element types used</td>
<td>Truss: 56 (Stay cables) Beam: 582 (Deck and Tower)</td>
</tr>
<tr>
<td>type of analysis</td>
<td>Static Analysis Vehicle Load Optimization Time History Analysis</td>
</tr>
<tr>
<td>FE model by</td>
<td>A. Steenbrink</td>
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### Korabelny Farvater Bridge

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<th>Value</th>
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<tbody>
<tr>
<td>Overall bridge length</td>
<td>620 m</td>
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<tr>
<td>Main span</td>
<td>310 m</td>
</tr>
<tr>
<td>Tower height</td>
<td>128 m</td>
</tr>
<tr>
<td>Location</td>
<td>Saint-Petersburg</td>
</tr>
<tr>
<td>Function/usage</td>
<td>Roadway Bridge</td>
</tr>
<tr>
<td>Designer</td>
<td>Institute Strojproject</td>
</tr>
<tr>
<td>Consultant</td>
<td>Freyssinet International</td>
</tr>
<tr>
<td>Year of completion</td>
<td>Under design</td>
</tr>
<tr>
<td>Cost of construction</td>
<td>$20 Million</td>
</tr>
<tr>
<td>Number of elements and element types used</td>
<td>Truss (Cable): 104, Beam: 4063, Shell: 2288</td>
</tr>
<tr>
<td>Type of analysis</td>
<td>Static Analysis, Vehicle Load Optimization, Eigenvalue Analysis</td>
</tr>
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</table>
### Lazarevsky Bridge

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<th>Category</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Overall bridge length</td>
<td>120 m</td>
</tr>
<tr>
<td>Main span</td>
<td>120 m</td>
</tr>
<tr>
<td>Tower height</td>
<td>26 m</td>
</tr>
<tr>
<td>Location</td>
<td>Saint-Petersburg</td>
</tr>
<tr>
<td>Function/usage</td>
<td>Roadway Bridge</td>
</tr>
<tr>
<td>Contractor</td>
<td>Mostostroj 6</td>
</tr>
<tr>
<td>Designer</td>
<td>Institute Strojproject</td>
</tr>
<tr>
<td>Year of completion</td>
<td>2009</td>
</tr>
<tr>
<td>Cost of construction</td>
<td>$30 Million</td>
</tr>
</tbody>
</table>
| Number of elements and element types used | Truss: 10  
Beam: 903  
Shell: 637 |  

### Type of analysis
- Static Analysis
- Vehicle Load Optimization
- Eigenvalue Analysis
- Construction Stage Analysis
**Basarab viaduct Bridge**

- **Overall bridge length**: 1478.5 m
- **Main span**: 125 m
- **Location**: Bucharest
- **Function/usage**: Roadway / Tramway Bridge
- **Designer**: C&T Engineering Srl
- **Number of elements and element types used**:
  - Beam: 3073
  - Plate: 549
- **Type of analysis**: Nonlinear dynamic time history analysis with Lead Rubber Bearing Isolators (LRB) and Viscous Dampers
### Sernyi Bridge

- **Overall bridge length**: 248 m
- **Main span**: 144 m
- **Tower height**: 66 m and 48 m
- **Location**: Saint-Petersburg
- **Function/usage**: Roadway Bridge
- **Designer**: Institute Strojproject
- **Year of completion**: Under design
- **Cost of construction**: $50 Million
- **Number of elements and element types used**:
  - Truss (Cable): 40
  - Beam: 1633
  - Shell: 926
- **Type of analysis**:
  - Static Analysis
  - Vehicle Load Optimization
Nga Tu So Overfly Bridge

Overall bridge length: 189 m
Location: HaNoi
Function/usage: Roadway Bridge
Designer: VINACONEX, CIPHanoi
Number of elements and element types used:
- Truss (Cable): 16
- Beam: 308
Type of analysis:
- Construction Stage Analysis with Time-Dependent Effects
- Response Spectrum Analysis
- Eigen Value Analysis
- Vehicle Load Optimization
### Thuan Phuoc Bridge

<table>
<thead>
<tr>
<th>Overall bridge length</th>
<th>654 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Da Nang</td>
</tr>
<tr>
<td>Function/usage</td>
<td>Roadway Bridge</td>
</tr>
<tr>
<td>Designer</td>
<td>Tecco533, CIPHanoi</td>
</tr>
<tr>
<td>Number of elements and element types used</td>
<td>Truss (Cable): 266 Beam: 82</td>
</tr>
<tr>
<td>Type of analysis</td>
<td>Response Spectrum Analysis Eigen Value Analysis Large Displacement Analysis Vehicle Load Optimization</td>
</tr>
</tbody>
</table>
Bang Hwa Bridge

- **Overall bridge length**: 2559 m
- **Location**: Seoul
- **Function/usage**: Roadway Bridge
- **Designer**: Sam An Engineering
- **Year of completion**: 2000
- **Cost of construction**: $0.2 Billion
- **Number of elements and element types used**: Beam: 2603
- **Type of analysis**: Eigen Value Analysis, Response Spectrum Analysis, Vehicle Load Optimization
Kum Ga Bridge – **7 Spans of Extradosed bridge**

- **Overall bridge length**: 795 m
- **Location**: Chung Ju
- **Function/usage**: Roadway Bridge
- **Designer**: Chung Suk Engineering
- **Number of elements and element types used**
  - Truss (Cable): 144
  - Beam: 644
- **Type of analysis**
  - Construction Stage Analysis with Time-Dependent Effects
  - Cable Tension Optimization
  - Geometric Nonlinear Analysis
  - Vehicle Load Optimization
### Young Jong Bridge – *World’s 1st 3D self-anchored suspension bridge*

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall bridge length</td>
<td>4420 m</td>
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<tr>
<td>Tower height</td>
<td>107 m</td>
</tr>
<tr>
<td>Location</td>
<td>Incheon</td>
</tr>
<tr>
<td>Function/usage</td>
<td>Roadway / Railway Bridge</td>
</tr>
<tr>
<td>Designer</td>
<td>U Sin Corporation</td>
</tr>
<tr>
<td>Year of completion</td>
<td>2000</td>
</tr>
<tr>
<td>Cost of construction</td>
<td>$ 0.9 Billion</td>
</tr>
</tbody>
</table>
| Number of elements and element types used | Truss (Cable): 162  
Beam: 1930 |
| Type of analysis              | Response Spectrum Analysis  
Eigen Value Analysis  
Large Displacement Analysis  
Vehicle Load Optimization |
Incheon 2\textsuperscript{nd} Bridge – 5\textsuperscript{th} Longest Cable Stayed Bridge

- Overall bridge length: 1480 m
- Main span: 800 m
- Tower height: 230 m
- Location: Incheon
- Function/usage: Roadway Bridge
- Designer: Seoyeong Engineering and Chodai Co., Ltd
- Year of completion: 2009
- Cost of construction: $2.4 Billion
- Number of elements and element types used:
  - Truss (Cable): 176
  - Beam: 1653
- Type of analysis:
  - Construction Stage Analysis with Time-Dependent Effects
  - Cable Tension Optimization
  - Geometric Nonlinear Analysis
  - Vehicle Load Optimization
Stonecutters Bridge – 2nd Longest Cable Stayed Bridge

<table>
<thead>
<tr>
<th>Overall bridge length</th>
<th>1600 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main span</td>
<td>1018 m</td>
</tr>
<tr>
<td>Tower height</td>
<td>295 m</td>
</tr>
<tr>
<td>Location</td>
<td>Between Tsing Yi and Kowloon City, Hong Kong, China</td>
</tr>
<tr>
<td>Function/usage</td>
<td>Roadway Bridge</td>
</tr>
<tr>
<td>Designer</td>
<td>Ove Arup &amp; Partners</td>
</tr>
<tr>
<td>Cost of construction</td>
<td>$355 Million</td>
</tr>
<tr>
<td>Number of elements and element types used</td>
<td>Truss (Cable): 224, Beam: 1638</td>
</tr>
</tbody>
</table>

Type of analysis:
- Construction Stage Analysis with Time-Dependent Effects
- Cable Tension Optimization
- Geometric Nonlinear Analysis
- Eigenvalue Analysis
- Thermal Analysis
- buckling analysis
### Sutong Bridge – *Longest Cable Stayed Bridge*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall bridge length</td>
<td>8206 m</td>
</tr>
<tr>
<td>Main span</td>
<td>1088 m</td>
</tr>
<tr>
<td>Tower height</td>
<td>306 m</td>
</tr>
<tr>
<td>Location</td>
<td>Crossing Yangtze River in China between Nantong and Changshu</td>
</tr>
<tr>
<td>Function/usage</td>
<td>Roadway Bridge</td>
</tr>
<tr>
<td>Designer</td>
<td>Jiangsu Province Communications Planning and Design Institute</td>
</tr>
<tr>
<td>Cost of construction</td>
<td>$750 Million</td>
</tr>
<tr>
<td>Number of elements and element types used</td>
<td>Truss (Cable): 272 Beam: 760</td>
</tr>
<tr>
<td>Type of analysis</td>
<td>Construction Stage Analysis with Time-Dependent Effects Cable Tension Optimization Geometric Nonlinear Analysis Eigenvalue Analysis Thermal Analysis Buckling Analysis</td>
</tr>
</tbody>
</table>
Russky Island Bridge – Longest Cable Stayed Bridge

Russky Island Bridge (Russia)

World’s Longest Cable Stayed Bridge

Main Span = 1,104 m
Sunda Strait Bridge – *Longest Suspension Bridge*

**Sunda Strait Bridge (Indonesia)**

**World’s Longest Suspension Bridge**

Main Span = 3,500 m
“Thank you”

Bridging Your Innovations to Realities - midas Civil