3D Tunnel Modeling and Excavation

Angel Francisco Martinez
Application Engineer
MIDAS NY
Content

01 Introduction
02 Benefits of GTS NX for Tunneling
03 Demo
Introduction
About MIDAS

No. 1 in software for civil engineering

650 Developers and Engineers

120 Distribute in 120 countries

10,000 Clients

30,000 Licenses
Products

Buildings and General Structures

**midas Gen**  
Integrated Design System for Building and General Structures

**midas Design+**  
Structural Component Design & Detailing

Bridges

**midas Civil**  
Integrated Solution System for Bridge and Civil Structures

**midas FEA**  
Advanced Nonlinear and Detail Analysis System

Geotechnical

**midas GTS NX**  
2D / 3D Geotechnical and Tunnel analysis System

**SoilWorks**  
Geotechnical Solutions for Practical Design

Mechanical

**midas NFX**  
Total Solutions for True Analysis-driven Design

**midas FX+**  
General Pre & Post Processor for Finite Element Analysis

northamerica.midasuser.com

www.midasgtnsnx.com
Network Global

Export to over 120 countries
Retains the largest CAE market share

Headquarters & Branches

Korea
USA
Japan
China
India
UK
Russia
Argentina
Bolivia
Brazil
Chile
Colombia
Czech
Ecuador
Egypt
Ethiopia
Greece
Indonesia
Italy
Lithuania
Malaysia
Mexico
Nigeria
Spain
Taiwan
Thailand
Turkey
United Kingdom
Venezuela
Vietnam
UAE

Russia
Singapore
Slovenia
Vietnam
UAE
Benefits of GTS NX for Tunneling
Why GTS NX for Tunnels

- Friendly Interface
- Complete
- Innovating
Friendly Interface
Friendly User Interface

Commands based on AutoCAD

Work tree

Message window
Friendly Interface

Simplified Modeling
AutoCAD geometries Import
Verification of connection before and after meshing
Friendly Interface

**Advanced Meshing**
Mesh size control
Integrations of embedded structural elements and connected with mesh
Complete
Any type of tunnel
Parametric Analysis

• Compare results in same model by varying specific parameters.

K0 = 0.5 @ 4.3mm

K0 = 1.0 @ 5.5mm

K0 = 1.5 @ 8.3mm

K0 = 2.0 @ 14.5mm
Complete

Semi Coupled Analysis

- Pore Pressure
- Flow Path
- Nodal Head

Flow Paths

Flow Quantity
Jointed Rock Mass and Faults

GTS NX also allows you to model rock faults using an interface.

A plane of the surface is used to model the discontinuity.
Wizard for easy construction stages set up

Define multiple construction stages

- Construction stage analysis settings (≥ 2 stages)
  - Parametric multiple analyses in a single file for material / property / excavation method / construction method
  - No need to create multiple models for different conditions
  - Optimal construction method and construction sequence extracted

Ring cut excavation
Bench cut excavation

Comparison of results between different excavation methods in the same model file
Comparison of bending compressive stresses in shotcrete between different excavation methods
Complete

**Structural data base**

- Extraction of 2D and 1D elements to model reinforcement as a shotcrete and rock bolts

- Tunnel walls
- Rock Bolts
- Shotcrete
## Constitutive Models

<table>
<thead>
<tr>
<th>Model type</th>
<th>Ground material</th>
<th>Structure material</th>
<th>Material behavior properties</th>
<th>Model type</th>
<th>Ground material</th>
<th>Structure material</th>
<th>Material behavior properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasto</td>
<td>O</td>
<td>O</td>
<td>Linear elastic</td>
<td>Modified UBCSAND</td>
<td>O</td>
<td>X</td>
<td>Elasto-plastic</td>
</tr>
<tr>
<td>Tresca</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
<td>Sekiguchi-Ohta (Inviscid)</td>
<td>O</td>
<td>X</td>
<td>Elasto-plastic</td>
</tr>
<tr>
<td>von Mises (Nonlinear)</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
<td>Sekiguchi-Ohta (Viscid)</td>
<td>O</td>
<td>X</td>
<td>Elasto-plastic</td>
</tr>
<tr>
<td>Mohr-Coulomb</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
<td>Modified Ramberg-Osgood</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
</tr>
<tr>
<td>Drucker Prager</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
<td>Modified Hardin-Demeich</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
</tr>
<tr>
<td>Hoek Brown</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
<td>Hardening Soil (small strain stiffness)</td>
<td>O</td>
<td>X</td>
<td>Elasto-plastic</td>
</tr>
<tr>
<td>Generalized Hoek Brown</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
<td>Generalized SCLAY/1S</td>
<td>O</td>
<td>X</td>
<td>Elasto-plastic</td>
</tr>
<tr>
<td>Hyperbolic(Duncan-Chang)</td>
<td>O</td>
<td>X</td>
<td>Elasto-plastic</td>
<td>CWFS</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
</tr>
<tr>
<td>Strain Softening</td>
<td>O</td>
<td>X</td>
<td>Elasto-plastic</td>
<td>Transversely isotropic</td>
<td>O</td>
<td>O</td>
<td>Linear elastic</td>
</tr>
<tr>
<td>Modified Cam Clay</td>
<td>O</td>
<td>X</td>
<td>Elasto-plastic</td>
<td>Jointed Rock Mass</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
</tr>
<tr>
<td>Jardine</td>
<td>O</td>
<td>X</td>
<td>Nonlinear elastic</td>
<td>2D Orthotropic</td>
<td>X</td>
<td>O</td>
<td>Linear elastic</td>
</tr>
<tr>
<td>D-min</td>
<td>O</td>
<td>X</td>
<td>Nonlinear elastic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified Mohr-Coulomb</td>
<td>O</td>
<td>O</td>
<td>Elasto-plastic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft Soil</td>
<td>O</td>
<td>X</td>
<td>Elasto-plastic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft Soil Creep</td>
<td>O</td>
<td>X</td>
<td>Elasto-plastic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Safety Factor

Cohesion, Friction Angle and tensile strength (optional) can be defined as the failure criteria. Users can find out, potential failure and plastic failure zone directly.
TBM

Contraction (Shield)

- Name: Shell Contraction-1
- Object: Selected 480 Object(s)
- Contraction: 10 %
- Contraction Inc.: -12 %
- Ref. Depth: -2400 cm

Shield TBM
Grout
Excavation soil
Soil
Segments
Complete

Loads

3D Model Analysis

Schematic View

Model View

Sum of the reactions from 3D model (including the resistance force of the inner part of the shield): 23.4534 tonm²

The resistance force of inside Shield TBM:
Sum of the reactions from 3D model: 23.4534 tonm² - Theoretical result: 22.5556 tonm²

Total Face Pressure = 21.56 tonm²
Complete

Result Extraction
Innovative
Wizard Túnel

- Standardized ground / structures modeling automation wizard
- 3D tunnel modeling wizard
Wizard - General

Input tunnel size and cut type
Wizard – Reinforcement

Input support distribution and material
Wizard – Excavation

Input Excavation stages and direction.
Wizard – Mesh

Input Mesh Size and soil properties.
Innovative

Wizard – Results
Demo
Modeling 3D Tunnel

Weathered Soil
Soft Rock
Bed Rock

Steel Pipe
Reinforced Area
Geometry Modeling

1. IMPORT Soil CAD Files (units m)
2. Generate Strata: Extrude -200m
3. Divide layers by the 7 surfaces
Geometry Modeling

1. Delete 4 left over geometries on borders
2. IMPORT Tunnel CAD Files (units m)
3. Translate tunnel geometry with 2 point vector
Connect CAD

1. Imprint 160 points on last face
   Shortest path option
2. Auto Connect all solids >
   Boolean
3. Check Duplicates before and after
Material Import

1. IMPORT MATERIAL Properties
2. Open: Final tunnel with umbrella reinforcement file
3. Import All
Mesh Generation

- Generate Mesh and Create Elements

  Tunnel elements: Size 2m
  - Varying Soil Properties
  - 1st segments: Weathered Soil
  - 2nd segments: Soft Rock
  - 3rd segments: Bed Rock
Mesh Generation

- Generate Mesh and Create Elements
  - Reinforce Zones with Pipe Beams: 2m
Mesh Generation

- Generate Mesh and Create Elements
  1. Layer 1: Size 6m / Property Weathered rock
  2. Layer 2: Size 12m / Property Soft rock
  3. Layer 3: Size 18m / Property Bed rock
- Check Mesh
Mesh Generation

Create Shell Elements

1. Extract Tunnel Lining

2. Delete ends and bottom
Mesh Generation

- Generate Mesh and Create Elements
  1. Mesh Structural 1D elements
     - Top and bottom sets
  2. Translate Mesh sets in X direction
     - Copy and move top rock bolts sets 4m 35 times
     - Repeat for bottom rock bolt set
1. **Load Conditions**
   - *Self weight load*

2. **Boundary Conditions**
   - *Auto Ground Support*
   - *Beam rotation restriction*
## Construction Stages

- **Renumber Tunnels mesh sets**
  1. Top sets
  2. Bottom sets
Construction Stages

- **Renumber mesh sets**
  1. Walls - Top sets
  2. Walls - bottom sets
Loads & Boundary Conditions

- **Boundary Conditions**
  - Change properties
    1. 3D umbrella sets
    2. 2D tunnel wall sets top and bottom
Construction Stages

1. Create Stage Set
2. Stage Definition Wizard
   - I.S. all soil
   - Fill in rules as shown
   - Apply Rules
Construction Stages

- CS
  1. Add Null stage #2: Click ON Clear Displacements and SRM (slope stability)
  2. Add Excavation stage #3: Deactivate Cut Excavation set
Construction Stages

- Add 6 Umbrella mesh sets to stages S3, S9, S15, S21, S27, S33
Analysis Case

1. Set CS Analysis Case
   Analysis Control
   • Stress Initiation
   • k0 condition
   Output Control
   • Check on strains

2. Run analysis
Post-Processing

Results

1. Null Stage SRM: FOS 2.2  
   Strains > Max Shear Strains
2. Stage 43 > Displacements > Total
3. Make cut on Y plane and Probe (3D - 2D Wizard)
Post-Processing

1. Extract Results for construction stages
2. Settlement Profile Tz max
3. On Table Right Click > Show Graph
Post-Processing

- Extract Results for construction stages
- Max displacements of tunnel crown
Post-Processing

- Forces and moments in structural members
  1. Truss
  2. Beam
  3. Shell
Thanks!

http://globalsupport.midasuser.com/helpdesk/