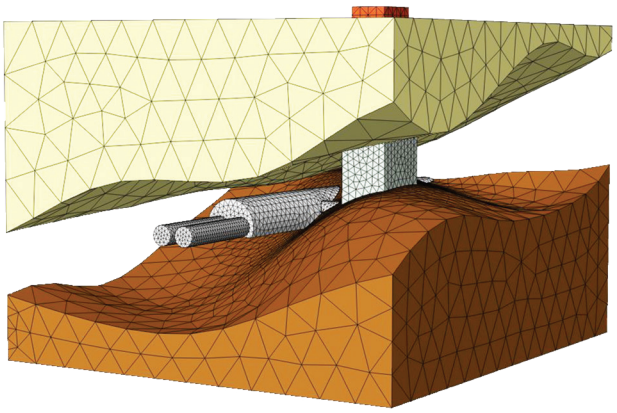
DIANA

SOLUTIONS FOR TUNNELLING & UNDERGROUND STRUCTURES



DIANA FEA
a TNO Company

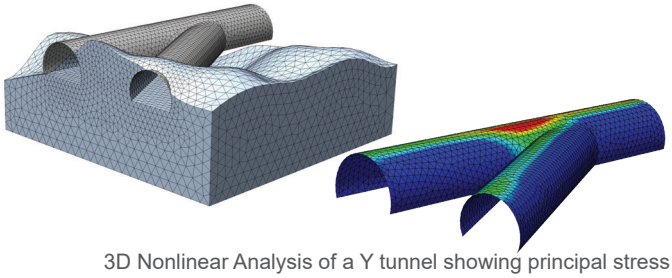
DIANA

SOLUTIONS FOR TUNNELLING & UNDERGROUND STRUCTURES

DIANA can be utilised in a number of ways in tunnel projects. The focus for analysis is normally tunnel induced settlement or lining stress analysis, but DIANA can also be used to research how a tunnel may react in the event of a fire, explosion or even a seismic event.

Now, with increasing congestion in modern cities, we are turning even more to underground transportation systems. The consequence is not only tunnelling under existing structures but, often, tunnelling under existing tunnels. Ground movement is an inevitable risk to nearby structures which must be carefully assessed, both at the planning stage and as the project unfolds. This, in addition to the potential negative effect on the safety of construction and the project cost, means that the ability to make these predictions accurately is key. Surface settlement caused by shallow tunnel construction in Greenfield sites can be predicted with some confidence. Surface settlement in urban areas, however, presents a much more complex interaction between the tunnel and its shafts, the ground and the building.

Using the DIANA software, it is possible to create detailed 2D and 3D analyses of the interaction between the building, the ground, the tunnel and its shafts. The analysis of existing and new build tunnel linings under the effect of events causing structural damage, freezing, fire, flood, or earthquake are critical to the safety and longevity of the tunnel. With DIANA, a model of the tunnel segments and joints, along with the soil and grout pressures upon it, and potential factors listed above, can be analysed to show intrinsic possible deformations.



3D Nonlinear Analysis of a Y tunnel showing principal stress

Dedicated Features

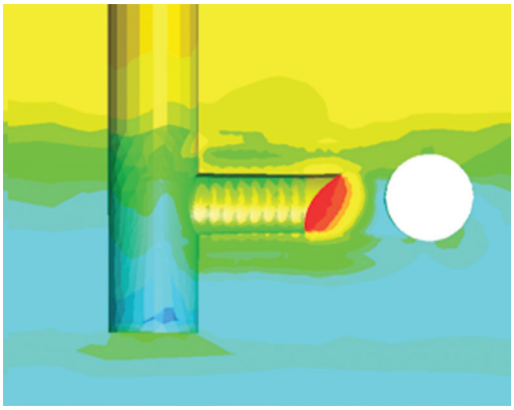
- In-situ Stress (Ko procedure/gravity loading/pre-stress) and Pore-pressure Initialisation
- Drained / undrained analysis
- Construction-staged analysis
- Seepage analysis (steady state / transient)
- Saturated or partially saturated flow
- Consolidation analysis (full coupled stress-flow analysis)
- Pressure dependent degree of saturation
- Porosity or saturation dependent permeability
- Deformation dependent density and porosity
- Large displacement and large strain nonlinear analysis
- Special elements for nonlinear modelling of joints between the TBM lining segments
- Ground freezing analysis including latent heat consumption, thermal expansion and temperature dependent elasto-plasticity
- Generalised plane strain elements for 2D modelling of inclined tunnels or shafts in strongly anisotropic in-situ stresses
- Mesh-independent embedded bars and grids that allow easy modelling of rock bolts, nails or geotextiles in solid soil elements, and reinforcement in beam or shell structural elements
- Soil-structure interaction with nonlinear behaviour for both soil and structure
- Wide range of material models for the analysis of nonlinear concrete material behaviour
- Transient nonlinear analysis for viscous behaviour such as creep, shrinkage or swelling, ambient influence such as temperature or chemical concentration
- Young concrete analysis including hydration heat, shrinkage, hardening, visco-elasticity and cracking
- Higher order solid elements up to cubic interpolation

Material models

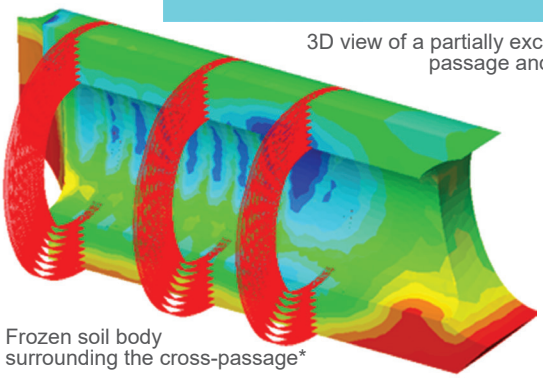
- Mohr-Coulomb, Tresca
- Drucker-Prager, Von Mises
- Transversely isotropic
- Duncan-Chang
- Hoek-Brown
- Jointed Rock
- Modified Cam-Clay
- Jardine (London clay)
- Modified Mohr-Coulomb (Cap model)
- Special interface models
- User supplied subroutine
- Discrete cracking with interface elements
- Multi-directional fixed crack model
- Total-strain crack models with fixed and rotating cracks
- Fiber reinforced material models
- Creep and shrinkage models

Dynamic Analysis & Liquefaction

- Eigenvalue analysis (eigenfrequencies, eigenmodes, participation factors, effective masses)
- Direct frequency response analysis
- Modal frequency response analysis
- Spectral response analysis (ABS, SRSS, and CQC modal combinations)
- Linear and nonlinear time domain analysis (total, transient and steady state, solution)
- Various time integration methods, e.g. Newmark, Wilson-theta, Runge-Kutta
- Hybrid frequency-time domain analysis
- Fluid-structure interaction
- Multi-directional base acceleration loads
- Prescribed nodal acceleration loads
- Distributed mass elements (2D line elements + 3D surface elements)
- Bounding/boundary elements for far field behaviour (2D line elements + 3D surface elements)
- Viscous, structural, and continuous damping
- 2D/3D liquefaction models including user-supplied models



3D view of a partially excavated cross-passage and tunnel tube*



Frozen soil body surrounding the cross-passage*

* Images supplied courtesy of J.T. Lukkikholt, Witteveen+Bos

General Product Functionality

Element types

- Truss
- Timoshenko, Bernoulli, and Mindlin beam
- Plane stress and plane strain
- Complete/general plane strain
- Axisymmetric
- Plate bending
- Flat, curved and layered shells
- Solid
- Composed (line/surface)
- Interface
- Contact
- Discrete spring/dashpot
- Base spring
- Bounding
- Point mass/damping
- Embedded reinforcements
- Flow
- Embedded pile
- Boundary surface
- Perfectly Matched Layers (PML)

Preprocessing

- CAD like geometry modelling functionality
- Parasolid built-in tools
- Import CAD/Revit file formats
- Python scripting
- Advanced selection methods
- Advanced geometry modelling
- Boolean operation for solid modelling
- Auto clash detection
- Geometry check and repair tools
- Practical mouse snapping
- Auto-, map- and protrude-mesh methods
- Hybrid mesher
- Mesh manipulation and check functionality
- Loads and boundary conditions applicable both on geometry or mesh
- Function based definition of loads and boundary conditions
- MS-Excel compatible tables

Postprocessing

- Contour and vector plots
- Iso-surface, slice, clipping and partition plot
- Diagram and vector plot
- Results extraction to MS-Excel compatible table
- Screen-shots in different picture formats
- Result animation
- Automatic report generation

Solution procedures

- Automatic solver selection
- Out-of-core direct equation solvers
- Nonlinear equation solvers
- Automatic substructuring
- Eigenvalue analysis
- Newton-Raphson, Quasi-Newton, Linear and Constant stiffness iterative procedures
- Load and displacement control incremental procedures
- Arc length control incremental procedure
- Adaptive load and time increments
- Automatic incremental loading
- Direct, iterative and eigen solvers with parallel processing
- Updated and total Lagrange geometrical nonlinear formulation

Services

Support & training

Successful finite element modelling requires a sound understanding of the background theory with good engineering judgment. We at DIANA FEA BV, together with our partners, are dedicated to provide the highest level of service for DIANA:

- Personalised hotline and email support by highly qualified staff
- Customised training solutions
- Regular training courses
- Extensive technical and theoretical manuals
- Online training sessions

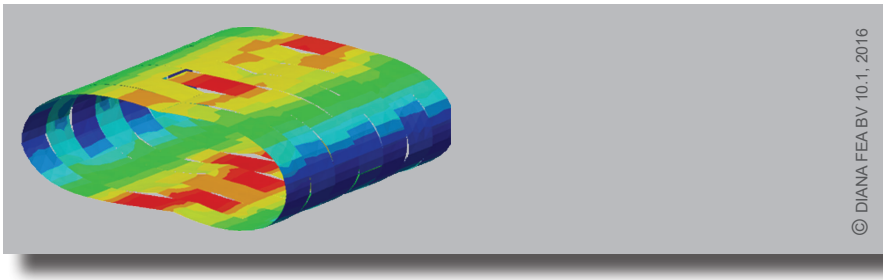
Analysis consultancy

DIANA FEA BV provides a service for analysis consultancy projects on behalf of their clients which includes analysis with DIANA and the interpretation of associated results

Software services

DIANA FEA BV Consultants and software development team can provide customised solutions for your engineering problems:

- Specialised software with dedicated GUI
- New modelling capabilities development and implementation
- Integration with customer software



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