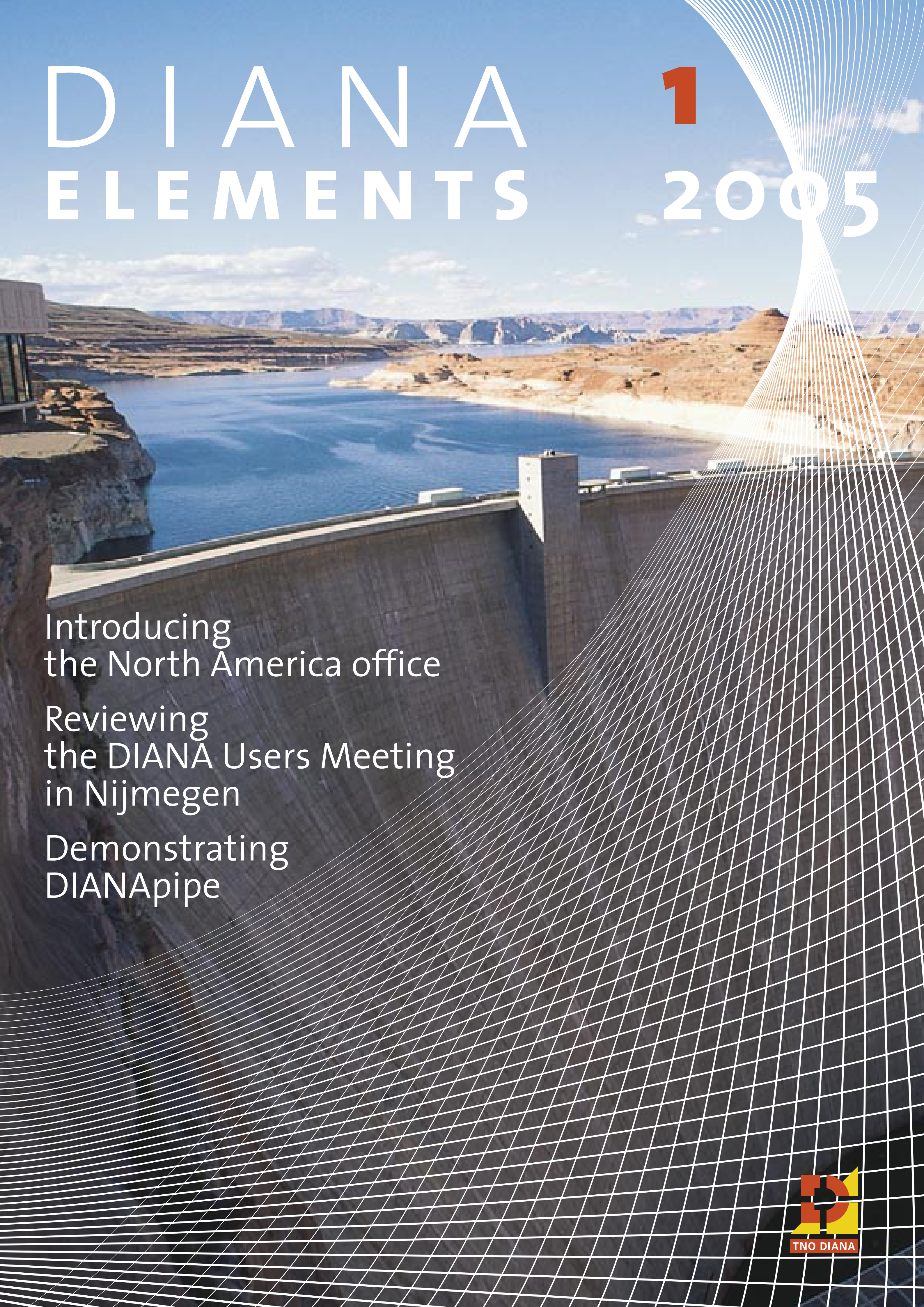
FE Model for concrete half-slab floor shear failure

DIANA ELEMENTS

1 2005



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TNO DIANA

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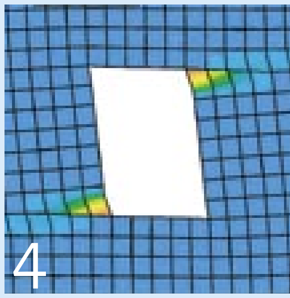

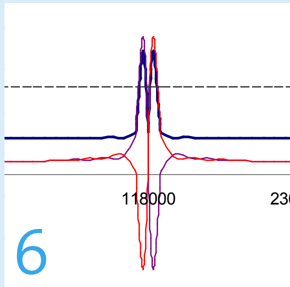

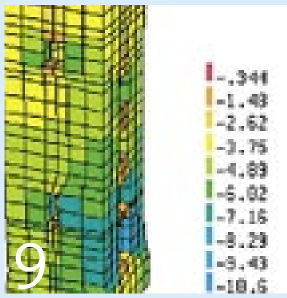

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Cover photo
Dam at Grand Canyon, USA
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COLOPHON

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DIANA ELEMENTS is distributed to all DIANA users and other interested persons.

The editors welcome letters, technical articles, news of forthcoming events, publications of topical interest and new project descriptions.

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Editorial

Reinder van der Meer
CEO TNO DIANA BV

It is with proud and with enthusiasm that we catch up with the DIANA tradition to publish a DIANA magazine. Its name is DIANA ELEMENTS.

DIANA ELEMENTS is meant for DIANA users worldwide and all other interested persons.

We welcome letters, technical articles and news of forthcoming events. In the next issue we will also start with DIANA NEWSROUND as a standard element of the magazine.

We wish you lots of reading pleasure and we are looking forward to hearing your reactions!

New staff TNO DIANA BV

To strengthen its product development and user-support teams TNO DIANA BV has recently recruited the following engineers:

Ton van Overbeek

Ton van Overbeek (25) has graduated as a civil engineer at Delft University on the subject 'a system approach in fire safety engineering'. During his study he gathered experience with DIANA and investigated different approaches for numerical analysis of fires in buildings. Ton strengthens the TNO DIANA user-support team.

Ahmed Elkadi

Ahmed Elkadi (36), originally from Egypt, holds a B.Sc. degree from Ain Shams University, Cairo on the subject of 'Soil Mechanics and Foundations'. Afterwards, He worked for 6 years as a Geotechnical and Structural engineer at NECB in Cairo before he moved to the Netherlands for his M.Sc. study in Engineering Geology at the International Institute for Geo-Information Science and Earth Observation (ITC) in Delft. He obtained his Master's degree in 2000 and afterwards became a research assistant at Delft University of Technology from which he expects to receive the Doctorate degree later this year on his thesis with the title: 'Fracture scaling of concrete under multiaxial compression'. Ahmed works on Geomechanics applications at TNO DIANA.

Berent Wolters

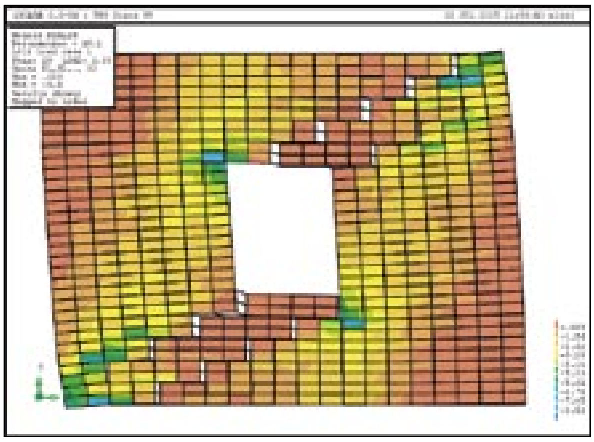
Berent Wolters (29) has a Master's degree in Mechanical Engineering from Eindhoven University of Technology. After his studies, he continued as a research assistant at the department of Biomedical Engineering of that same university. In his research project, he studied fluid-structure interaction in abdominal aortic aneurysms by means of patient-specific computational models. He will defend his thesis on the subject later this year. Berent joined TNO DIANA as a developer of the computational mechanics functionality of DIANA.

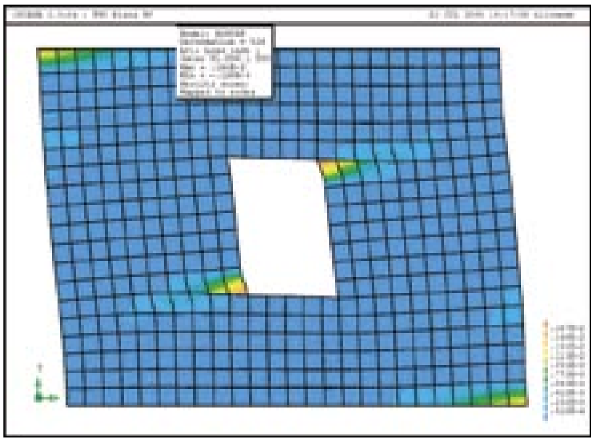
DIANA 9 for Modeling Masonry

↑ **A shear wall with opening, subjected to an initial vertical load. Diagonal zigzag cracks arise initially from two corners.**

↓ **A typical analysis result using interface elements for mortar and joints and continuum elements for the units. The plot shows compressive principal stresses.**

↓↓ **A typical analysis result using continuum elements only and "smearing" and homogenizing the masonry behavior. The plot shows total vertical strains.**





DIANA is an extensive multi-purpose finite element software package that is used to analyze a variety of technically challenging problems that arise in a wide range of civil engineering disciplines. Developed since the early 1970's, DIANA has established a reputation for providing the very highest standard of analysis capability and is used regularly by world's leading Universities, Research organizations and Engineering companies.

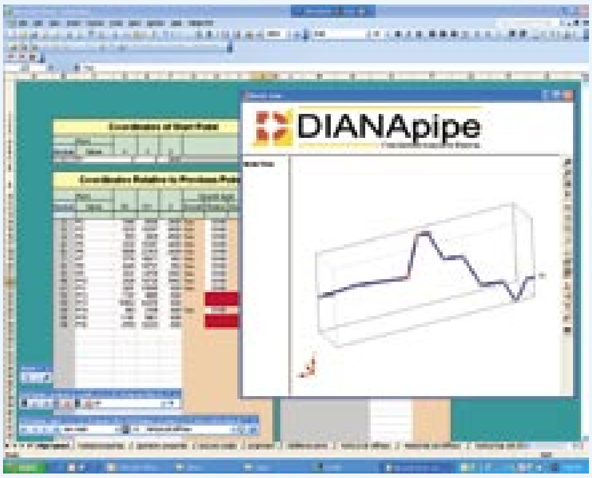
A wide range of new functionality is added in the latest release of DIANA, DIANA9. Amongst others:

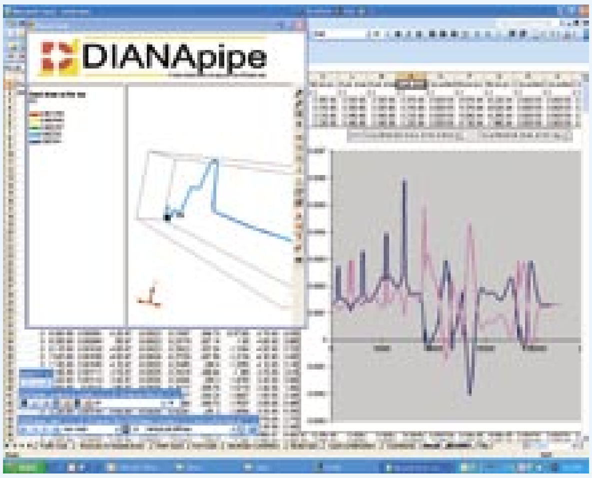
- A new graphical user interface, with a new command-tree structure
- A new property manager forms for assigning material and physical properties of the model.
- New possibilities to add a wide range of CAD formats.
- New numerical solution procedures for linear and non-linear analysis.

Masonry is the oldest building material that still finds wide use in today's building industries. However, innovative applications of structural masonry are hindered by the fact that the development of the design rules has not kept pace with the developments for concrete and steel. The underlying reason is the lack of insight and models for the complex behavior of units, mortar, joints and masonry as a composite material.

Partnering with the Technical Universities of Delft and Eindhoven in the Netherlands, the University of Stellenbosch in South Africa and the University of Minho in Portugal boosted the development of masonry models in DIANA.
The pictures illustrate typical applications of DIANA for masonry structures. In this case for masonry shear walls with opening.

DIANApipe





↑ DIANApipe screenshot: Input of the path of the pipeline and a 3D model viewer to check the model.

↑↑ DIANApipe screenshot: Output of circumferential strains along the pipeline as a Microsoft Excel graph or via a 3D Result Viewer.

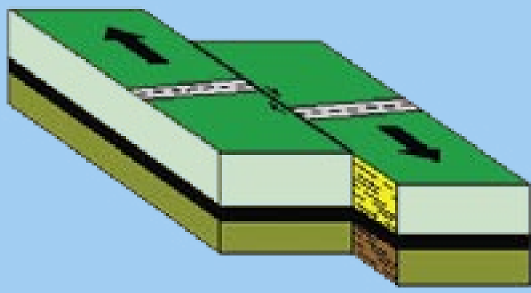
The protection of pipelines from ground movements and external loading is a typical challenge for which engineers turn to DIANApipe. Enclosing the powerful DIANA finite element system, DIANApipe offers a tailored, MS Excel based, user-interface for the structural design of new pipelines and for the integrity assessment of existing pipelines.

Gerd-Jan Schreppers (TNO DIANA BV)

Modified Maekawa Concrete Model

In the DIANA 9.1 version the Modified Maekawa concrete model has been made available. This model combines a multi-axial damage plasticity model for the effect of crushing in the compressive regime with a crack model based on total strain for the tensile regime.
The damage plasticity model has been developed by the research group of professor Maekawa of Tokyo University. The crack model is directly related to the Total Strain crack models in DIANA. The model also describes hysteresis in tensile and compressive unloading-reloading loops according to the experiences of professor Maekawa. The implementation in DIANA of these effects into what we call the `Modified Maekawa' concrete model, is the result of the efforts of a working group, consisting of a number of Japanese universities and companies in the period 2001-2002.
The attractive points of the Modified Maekawa concrete model are that it is defined by engineering parameters such as the tensile and compressive strength and the fracture energy, and that it covers all loading situations. Other models, focused on a specific loading situation, might provide better results in this specific situation. However, these models generally perform not so well under conditions for which they are not intended.

Strike slip fault: horizontal fault offset



Max Hendriks (TNO DIANA bv, The Netherlands)
Waseem Dekelbab (TNO DIANA NA, USA)

Modeling the pipeline response for a pipeline crossing an active fault during a large earthquake

This paper presents an assessment of a carbon steel pipeline crossing an active fault during a large earthquake. Active faults might lead to significant levels of focused horizontal fault deformations. The pipeline should be able to withstand these permanent ground deformations.

DIANApipe
DIANApipe is a DIANA based analysis tool embedded in MS Excel. The Finite Element tool is based on 'beam and spring' modeling. That is, the buried pipeline is modeled as a beam on a nonlinear Winkler foundation. This method is a commonly used finite element approach for buried pipelines. It takes into account 3D effects in a pipeline subjected to differential soil settlements, temperature variations, internal pressures, topsoil loads and traffic loads. The technique has been introduced in design codes and guidelines like the Japanese JSCE, the Dutch NEN and the American Lifelines Alliance (ASCE and FEMA). For earthquake analysis a pseudo-static analysis is performed.

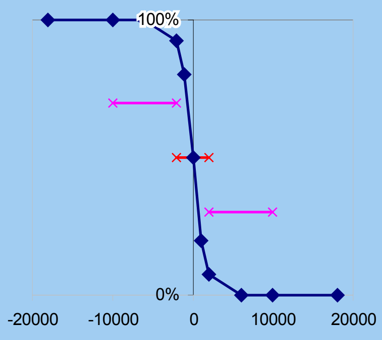
Pipeline
A carbon steel pipe for refined products, 20 inch (508 mm) outer diameter, 0.375 inch (9.5 mm) wall thickness, operates at an internal pressure of 1130 psig (7.8 N/mm²). The Specified Minimum Yield Strength (SMYS) of the pipeline material is 60,000 psi (413.7 N/mm²).

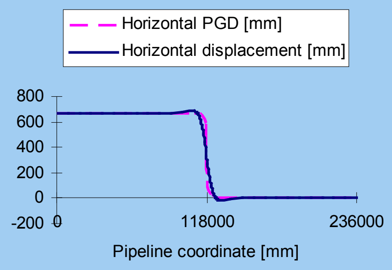
Soil
The buried pipeline has a soil cover of 3 feet (914 mm). The soil with assumed sandy/silt conditions has a unit weight of 115 pounds per cubic feet (18,000 N/m³). The internal friction angle is 35°. There are no traffic loads.

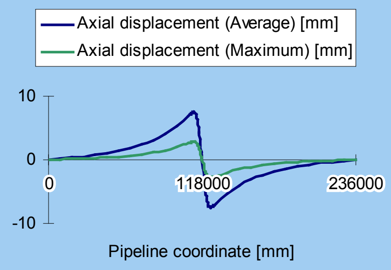
Fault crossing
A straight long section of the pipeline is crossing the fault at an approximate angle of 53°. The average displacement, "slip-per-event", is estimated as 500 mm. The maximum displacement is estimated as 840 mm.

Distribution of surface slip
Rather than using a "guillotine" type of horizontal fault offset, we apply a distributed horizontal displacement across the fault zone. Historical earthquakes show that a large percentage of the total surface displacement may occur as distributed deformation away from the primary fault rupture. Following the approach in [1] we assume a near-surface faulting and fracturing area, designated as the "A-zone". It is estimated that 85% of the total surface displacement will occur in this zone. The median width of the A-zone for the current fault is 13 feet (4000 mm). The remaining 15% of displacement will occur equally in two zones, the "B zones". The width of each B-zone is 26 feet (8000 mm). Figure 1 shows the postulated distribution of fault offset across the fault zone. The A-zone and B-zones are indicated in red respectively in purple.

Soil and soil-pipe interface representation.
Soil loading on the pipeline is represented by discrete nonlinear springs. We follow the recommendations in [2] to compute the maximum soil spring forces and associated relative displacements necessary to develop these forces. The table 1 summarizes the main soil spring characteristics:







↑ **Figure 1: Percentage of the total displacement versus the distance (mm) perpendicular to fault**

↑ **Figure 2: Lateral displacement of the pipeline versus the permanent ground displacement**

↑ **Figure 3: Axial displacement of the pipeline for a postulated average and postulated maximum earth quake**

Table 1: Soil spring characteristics based on the guidelines of the American Lifelines Alliance (ALA)

Axial soil springs		
Ult. soil friction displacement	4.0	mm
Ultimate soil friction	0.007	N/mm²
Lateral soil springs		
Horizontal soil stiffness	0.004	N/mm³
Ult. horizontal bearing cap.	0.228	N/mm²
Vertical uplift soil springs		
Vertical top soil stiffness	0.0022	N/mm³
Ult. vert. top soil bearing cap.	0.39	N/mm²
Vertical bearing soil springs		
Vertical soil stiffness	0.0179	N/mm³
Ultimate vert. bearing capacity	0.908	N/mm²

DIANApipe model

The pipeline is modeled as a straight pipe of 236,000 mm. The center of the fault is at 118,000 mm. At the two outer ends of the pipe the pipeline is constrained in longitudinal direction.

Main results

Figure 2 below show the horizontal (or lateral) displacements of the pipeline and the Permanent Ground Displacements (PGD), both as a function of the pipeline coordinate. The plots show the results for the postulated maximum fault displacements: 840 mm at an angle of 53°. Plots like these show to which extend the pipeline follows the ground deformations and thus gives a first indication of the soil-pipe interaction.

Figure 3 shows the axial displacements (along the pipeline) as a function of the pipeline coordinate for two scenarios: a postulated average fault displacement of 500 mm at an angle of 53° and a postulated maximum displacement of 840 mm. The plot shows that the pipeline is moving towards the fault.

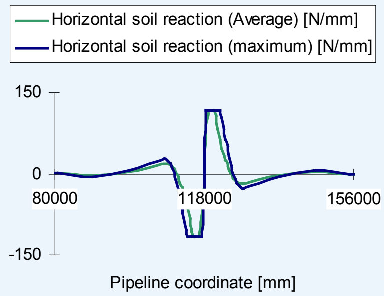
Figure 4 shows the lateral soil reaction as a function of the pipeline coordinate. Especially for the postulated maximum earthquake the plot indicates that the lateral ultimate bearing capacity is reached.

Figure 5 shows the axial stresses at the two sides of the pipeline and the maximum Von Mises stress. The Von Mises stress also includes the effect of hoop stresses. For comparison the SMYS has been indicated. The plot shows the results for the maximum fault displacements (840 mm at an angle of 53°).

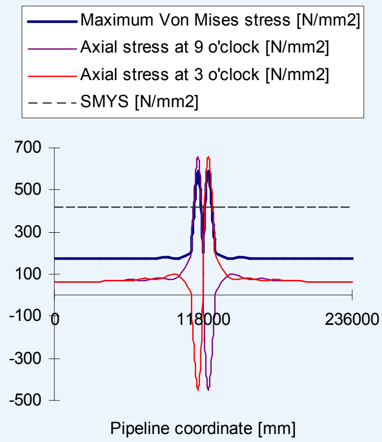
References

[1] Kelson, K.I., Hitchcock, C.S. and others, “Fault Rupture Assessments for High-Pressure Pipelines in the Southern San Francisco Bay Area, California”, Proceedings of IPC 2004, International Pipeline Conference, October 4-8, 2004, Calgary, Canada, Paper IPC04-0212, ASME.

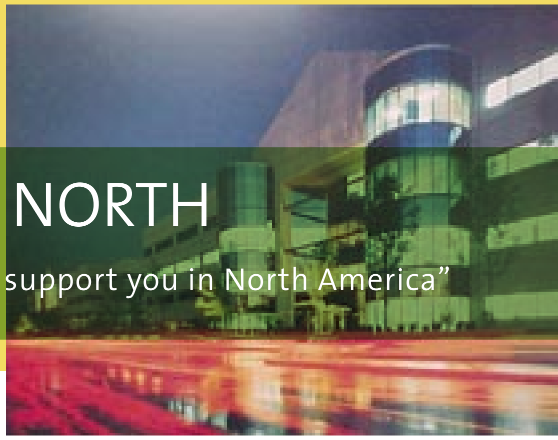
[2] Guidelines for the Design of Buried Steel Pipe, American Lifelines Alliance (FEMA and ASCE), July 2001.



↑ **Figure 4: Horizontal soils reaction along the pipeline**



↑ **Figure 5: Stresses along the pipeline**



Welcome to TNO DIANA NORTH AMERICA _ "We crossed the ocean to support you in North America"

As a result of growing demand and marketplace on DIANA software products and consulting services in North America, TNO DIANA BV established TNO DIANA NORTH AMERICA, Inc., in December 2003 in Detroit, Michigan.

Today our office proudly works and supports top Canadian and USA universities from coast to coast, from Stanford University to Rutgers University. Moreover, TNO DIANA N.A. works closely with American Concrete Institute Committees to enhance Finite Element Analysis (FEA) usage by scientists, designers, and construction industries. Recently, our research team presented FEA / DIANA as a powerful tool to predict early-age bridge deck cracking at the Seventh International Symposium of Utilization of High Strength / High Performance Concrete Symposium, June 20–24, 2005, VA, USA.

Our team of professional engineers works with designers and private consulting groups to utilize FEA and DIANA software to optimize the structural/geotechnical analyses and to reduce the manpower per project. URS Corporation, NTH Consulting, Ltd., and The STEBBINS Engineering and Manufacturing Company utilize our 3D modeling capabilities to enhance structural and geotechnical analyses in their projects.

DIANA training classes are offered around the year in house, clients' site, and universities. The latest workshop is in cooperation with University of Illinois Urbana Champaign from August 15 to 17, 2005. Live software demo and presentation are available around the year at ACI conventions, ASCE Structures congress, ASCE Pipelines, and etc. Please visit our booth at the following conferences.

- SPE, Society of Petroleum Engineering, ATCE 2005 from October 9 to 12 in Dallas, Texas
- ACI 2005 Fall Convention November 6 to 10 in New Orleans, LA

You can also arrange an appointment at our booth by contacting Dr. Waseem Dekelbab via email at waseem@usdiana.com or call (734)-779-4850.

↑ TNO DIANA North America, Inc.

Ane de Boer - Ministry of Public Works and Water Management, DIANA Users Association, The Netherlands

Reviewing the International DIANA Users Meeting in Nijmegen

On 14 and 15 April 2005 an International Users Meeting was organized in Nijmegen, The Netherlands. This review includes abstracts of the presentations.

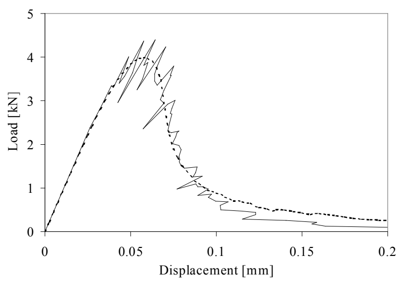
The arrangement of this meeting was similar as for the previous International Users Meeting on 18-19 March 2004 in London, UK. Users were giving the change to meet other DIANA users and exchange ideas. The bulk of the event consisted of lectures by DIANA users. Halfway a social event was organized. Questionnaires confirmed that this setup is highly appreciated by the participants.

Apart from International DIANA Users Meetings also various national or local DIANA Users Meetings are organized.

Next to the meetings, every 4-5 year an international DIANA conference is organized. Opposed to the user meetings the conferences are based on presenting papers. These papers are reviewed and are published. The next international DIANA conferences will be organized in San Francisco, USA.

Repeated linear analyses as an alternative to nonlinear analysis

J.G. Rots, S. Invernizzi,
Delft University of Technology, The Netherlands



Example of outcome sequentially linear saw-tooth softening analysis

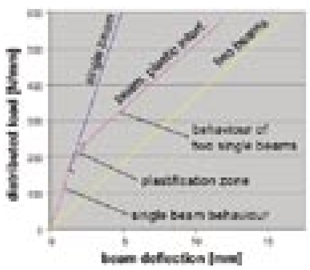
Over the past years techniques for the nonlinear analysis of structures have been enhanced significantly via improved solution procedures, extended finite element techniques and increased robustness of constitutive models. Nevertheless, problems still remain, especially for real world structures of softening materials like concrete, masonry or glass. The softening gives negative stiffness and risk of bifurcations due to multiple cracks that compete to survive. In this contribution, a new method is proposed. The softening diagram of negative slope is replaced by a saw-tooth diagram of positive slopes. The incremental-iterative Newton method is replaced by a series of linear steps using a smart scaling technique with subsequent stiffness/strength reduction per element.

This event-by-event strategy is robust and reliable. The stiffness is always positive definite – life becomes easy, divergence or ill-conditioning cannot occur. The procedure fits in with RC engineering practice, where the use of reduced stiffness at areas of anticipated cracking is common. Practical examples are masonry facades subjected to North-South line tunneling in Amsterdam and reinforced concrete structures.

FE model for concrete half-slab floor shear failure

H. Hofmeyer, M. Verbaten, H. Monster
ABT consulting engineers, The Netherlands

In 2002, a car park was constructed in Roermond, The Netherlands, using half-slab concrete floors. Half-slab floors consist of (1) pre-cast concrete planks with reinforcing lattice girders as bottom layer, (2) lightweight foam positioned between the girders and (3) in-situ poured concrete as top layer. Once constructed, some parts of the concrete floor showed very serious deflections of up to 150 mm, although all design calculations seemed to be correct. ABT engineers were consulted about this problem.



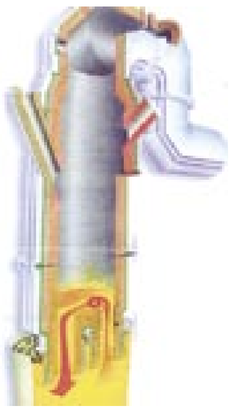
The hypothesis was that the half-slab floor failed even before the Serviceability Limit State (SLS) was reached by shear failure between the middle and top layer, which was not taken into account during the design. A 3D FE Diana model was built to check this hypothesis. The floor was modeled by volume-elements, and between the three layers, shear surfaces were modeled with interface elements.

The model showed that the floor indeed fails by shear failure before the SLS is reached. The FE model was also used to test the repair strategy. As a further result, full-scale experiments are planned to further investigate the problem.

Modeling the thermal expansion of the refractory lining of a RH-degasser taking into consideration the influence of joints

D. Gruber,
Universitat Leoben, Austria

The RH-degasser is a secondary metallurgical aggregate and allows to decarburize liquid steel to a level of 30 ppm carbon for the production of ultra-low-carbon-grade steels. Expansion allowances of the refractory lining of the degasser have the function of reducing stresses in axial direction and of avoiding compressive failure.

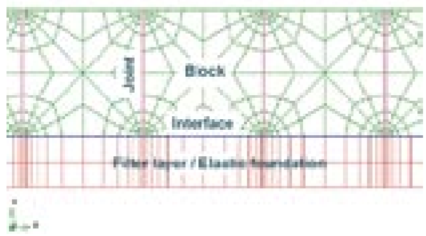


Nevertheless, compressive stresses at the hot face of the refractory lining are desirable in order to avoid penetration of the hot metal. The influence of the opening of joints at the cold end on the expansion behavior of the lining is discussed in this work. The joints between the bricks were modeled with interface elements. The behavior of interface elements was described by the Coulomb Friction model and in the case of vertical interfaces by anisotropic elasticity. For reducing the calculation time an axisymmetric model was built instead of a three dimensional model. This model considers all (approximately 100) horizontal joints between the bricks and two vertical joints. The findings indicate that the calculations have to allow for an opening of joints between the bricks to get realistic results. Investigations show further that numerical methods to predict the thermo mechanical expansion of the refractory linings are a feasible tool for the design of expansion allowances.

Finite element calculations of brittle joint behavior in clamped block revetments in the Netherlands

D.J. Peters,
Royal Haskoning, The Netherlands

Clamping forces contribute to the strength of placed revetments. On this phenomena model testing has been performed in the laboratory of Delft University. The model consisted of a full scale 1.5 x 5 m block revetment specimen and was loaded with a normal force and with pull-out forces. The blocks act jointly as a beam due to the compressive normal force. Bending moments and shear forces in the beam can be taken into account by eccentricity of the normal force and by friction between the elements.



The laboratory test results were analyzed with both analytical model calculations and with finite element simulations.

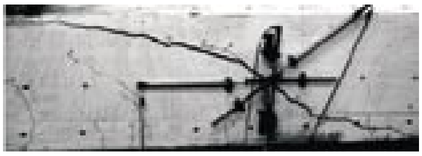
In the response analysis the revetment is considered as a non-linear elastic beam on an elastic foundation. The FE model consists of plain strain elements. The failure mode of buckling of the internal arch appears to be susceptible to the initial gaps and joint stiffness. The failure mode shows three zones of concentrated curvature, similar to a three-point bending problem in structural mechanics. At the stage of excessive deformation, buckling occurs.

Three-dimensional finite element calculations of biaxial hollow slabs

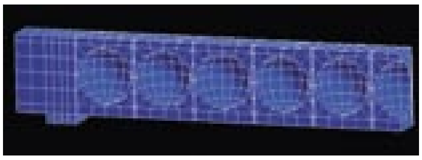
M. Schnellenbach-Held, M. Aldejohann,
University of Duisburg-Essen, Germany

In biaxial hollow slabs rotation symmetrical hollow bodies (balls) are used to achieve a uniform load bearing behavior with equal efficiency in two directions. Due to a dead-load reduction of up to 35 % larger spans or smaller columns and foundations can be used.

The special construction of these slabs causes a three-dimensional load bearing behavior especially in the area of the hollow bodies.



To investigate this load bearing behavior shear tests have been carried out at the institute.



To analyze the test results and the three-dimensional load bearing behavior three-dimensional nonlinear Finite-Element calculations have been performed.
For these calculations 20 node CHX 60 brick-elements with quadratic interpolation were used. The failure in tension was described by the Hordijk theory. For failure in compression the Thorenfeldt theory in combination with the total strain fixed crack model was used.
The effect of aggregate interlock was described by a constant shear retention factor.
To reduce the calculation time the finite element system was split in the symmetrical axis and additional constraints were applied.
The results of these calculations and some problems which occurred during the calculations are the subject of the study.

3D Advance Modeling to Support Design of Concrete Treatment Shaft in the United States

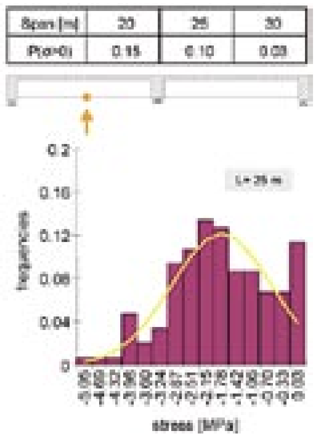
W. Dekelbab, M. Hendriks, O. Ramadan
TNO DIANA North America, TNO DIANA BV, NTH Consultants, Ltd.

As a part of the East Dearborn Combines Sewer Overflow (CSO) control project, a treatment shaft will be constructed in the vacant parcel of land between Prospect St. and Irving Ave in Dearborn, Michigan. The purpose of this treatment shaft is to provide disinfection for the flows from the Irving and Prospect Avenue sewers. The treatment shaft will be constructed offline and have an inside diameter of 95 feet and will extend to a depth of approximately 165 feet below ground surface. The caisson dimensions will be parametrically modeled in full 3D finite element model using DIANA software so it can be used for any similar structure with different dimensions. The finite element model will address a number of design and construction questions related to this new treatment shaft such as the effect of retaining wall above the caisson on caisson strength and stability, investigate the effect of the caisson casting imperfection and define the allowable initial deviation, analyze the bottom cone shell, and finally investigate the uplifting of the caisson.

Probabilistic analysis of structures sensible to creep, shrinkage and cracking of concrete

C. Sousa and A. Serra Neves
University of Oporto, Portugal

An additional DIANA application for probabilistic analysis of continuous bridge decks constructed with pre-cast beams is studied. In these structures, stress and strain change significantly with time, being dependent on creep and shrinkage deformations, in virtue of the sequence involved in its construction. Creep and shrinkage are uncertain properties. As a result, the structural response of this type of structures will have a significant variability.



In order to obtain a rigorous characterization of the structural behavior, a probabilistic analysis was made, through a Monte Carlo simulation, with non–linear analysis carried out with DIANA. The following parameters were

considered as statistical variables: relative humidity, temperature, concrete compressive strength, pre-stress, creep and shrinkage.
Some DIANA features were employed:
- user supplied subroutine, to include Eurocode2 (2002) creep model, and its variability;
- neutral file to obtain the results, statistically assessed later;
- analysis of pre-stressed phased structures considering, simultaneously, concrete creep, shrinkage and cracking, and steel yielding.

An EXCEL macro inter-acting with DIANA automated the probabilistic analysis procedure. Beam elements were employed but other types of finite elements may be used.
The procedure developed allows the rigorous characterization of service behavior of structures sensible to creep, shrinkage and concrete cracking.

Reassessment of concrete platforms

K.V. Hoiseth
NTNU-Trondheim, Norway

Model tests of offshore-platforms have revealed excessive wave-in-deck forces caused by platform subsidence. Analyses indicate that design sea-states will generate stress conditions in the non-linear range, which in turn may have significant influence with respect to prediction of the dynamic response. Use of non-linear analyses and a realistic modeling of the material are therefore important for integrity assessment of the structures, and for verification of previous design analyses. The FEM package DIANA is an appropriate tool for such kinds of investigations due to extensive and well-documented mechanical material models for reinforced concrete applications. The current study took the case of an existing platform and comprised the following issues: linear-elastic analysis, a non-linear static analysis to illustrate the response of one load (wave) cycle, a transient dynamic analysis, with non-linear modeling of the concrete and reinforcement, including cracking. A non-linear model of the platform was established to demonstrate the material behavior during wave loading. The study showed that, taking dynamic response into account as well as the non-linear mechanical behavior, the load carrying capacity in the ultimate limit state condition can be increased. The study demonstrated that the available material models in Diana are able to capture the main physical behavior of pre-stressed reinforced concrete members subjected to dynamic loadings.

Strengthening of concrete structures with Externally Bonded CFRP

D.A. Hordijk, Adviesbureau ir. J.G. Hageman B.V. and Eindhoven University of Technology, The Netherlands

Strengthening of concrete structures with Fiber Reinforced Polymers (FRP), mainly based on Carbon Fibers: CFRP) is a young innovative technique that is increasingly being applied. It not only offers solutions for cases where something went wrong in design or execution of a concrete structure, but it supplies good opportunities for cases of a change of function or use of an existing building or bridge. With our ever more rapidly changing functional demands and e.g. increasing traffic loads, the latter is very often the case.

The technique of strengthening by means of externally bonded steel plates has been known for more than 30 years, while strengthening with externally bonded CFRP has been applied for less than a decade. The reason that the first (steel plates) is only incidentally applied, while the latter (CFRP) is booming, is mainly to do with the ease of application (very light, no supports required, no restrictions in length).

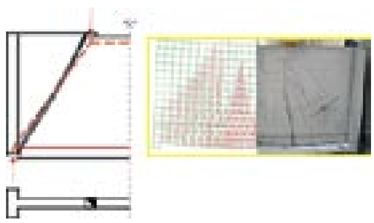
In the presentation the state of the art will be presented, addressing the various applied techniques (prefabricated and in-situ application, strengthening for bending, shear or wrapping columns), available design guides (fib-Bulletin 14, Dutch Recommendation) and new developments (bolted strips, pre-stressed strips). Also insight will be given in experimental and numerical investigations performed at Eindhoven University of Technology.

Nonlinear analysis of concrete structures with DIANA: examples and possibilities.

M. Pimentel, P. Cachim and
J. Figueiras, University of Porto, Portugal

Even today, in engineering practice, structural behavior is not properly analyzed. Virtual sates of equilibrium are usually considered using linear elastic analyses. For frame structures this design procedure gives safe and economic results since it is strongly based on structural concrete design codes recommendations. Simultaneously there is a great amount of experience among the technical community in detailing this kind of structural elements. However this is not the case for plate and shell structures exhibiting more complex structural behavior.

The work illustrates some applications of concrete models currently available in DIANA. In the first part, the main features of concrete non-linear behavior that must be considered in a material model are briefly discussed. In order to calibrate and evaluate the available numerical models some applications are analyzed and the obtained numerical results are compared with experimental ones.



The practical case is the applicability of non-linear finite element analysis, which can be demonstrated in the design process and safety evaluation of a complex pre-stressed concrete structure. Both 2D and 3D analysis are the subject of the study. The structural elements analyzed are the shear beams that support the upper level of a water treatment plant reservoir.

Structural Fire Safety engineering solutions using computer modeling techniques

A. Allam, Halcrow Group Ltd and University of Ulster, United Kingdom

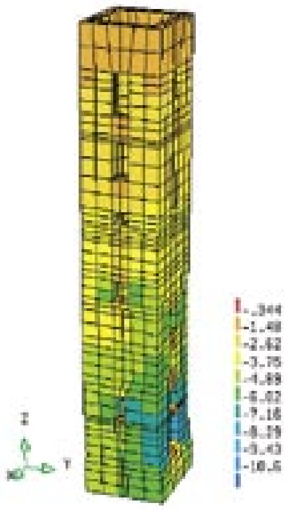
Fire is recognized as a significant hazard in the service life of a structure. Therefore, there is a clear need to provide an improved understanding of the performance of materials and structures in fire and to provide clear design guidance in order to progress cost effective designs. Indeed, recent work has cast doubt on the notion of a standard time-temperature response, pointing to discrepancies in the construction and geometry of individual furnaces which have a significant impact on the temperature obtained by the element under test. These, together with observations from real building fires, have contributed to the general observation that whole structures exhibit very different performance in fire than single elements.

Progress in structural fire safety can be integrated into the overall fire safety engineering approach pursued in the most recent generation of codes of practice. These new approaches should consider fire safety engineering as an integrated package of measures designed to achieve the maximum benefit from the available methods for preventing and controlling the consequences of fire. This new framework should be of benefit to the architect looking for better solutions; controlling authorities wishing to ask the right questions and engineers developing new avenues and skills in fire safety engineering.

DIANA nonlinear simulation and damage assessment of an historical masonry tower

A.Carpinteri, S. Invernizzi,
G. Lacidogna, Politecnico di Torino, Italy

A case study of a masonry building, called "Torre Sineo", dated XIII century, which is the tallest of the many medieval towers preserved in the town of Alba (Italy). The damage assessment of historical masonry buildings is often a complex task. It is crucial to distinguish between stable damage patterns and damage evolution leading to a catastrophic structural collapse. Some damage patterns can be subsequently activated by unforeseen events like earthquakes or improper functional extensions or restorations. Moreover, the limited ductility of the masonry, combined with the large scale of the tower, provides a quite brittle structural behavior.



The first part of the study is a fully three-dimensional finite element model of the tower. The geometry of the structure is carefully taken into account, and it is shown how the many openings influence the stress flow in the structure.

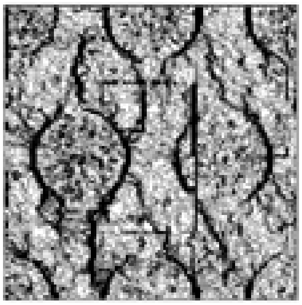
Not only the dead load is considered, but also the effect of the wind, the eccentricity of the tower, as well as the effect of small magnitude earthquakes recorded in the area during the last few years. The structural response has been obtained under different constitutive assumptions for the masonry. Plasticity with composite yield surface as well as smeared crack models have been investigated in depth, emphasizing the differences in the structural behavior. The rheological behavior of the masonry is taken into account to assess the influence of delayed deformations under persistent load action. The finite element analysis has been carried out with the DIANA code.

The second part is to compare the numerical results with in situ acquisitions obtained by non-destructive techniques. This comparison is an essential requirement for the reliability assessment of the tower. Finally, an engineering judgment is proposed for the nonlinear models, based on their capability to reproduce the experimental acquisitions in the present case.

Experimental investigations and numerical simulations using DIANA of concrete on the mesoscale

C. Rieger and T.Wilhelm, Darmstadt University of Technology, Germany

For the simulation of concrete on the mesoscale the hardened cement paste as well as the portion of aggregates up to a defined maximum particle size diameter is defined as a homogeneous matrix, since the larger aggregate size fraction is taken into account explicitly. Furthermore the Interfacial Transition Zone between matrix and aggregate is considered separately. With suitable laws describing the mechanical behavior of the materials the bearing and deforming behavior of concrete can be modeled with the help of numerical simulations. Their effects can be computed by systematic variation of individual material parameters on the mechanical behavior respectively damage evolution of concrete. Such numerical studies are a powerful tool for optimizing the material regarding specific demands. They lead thereby in principle to a better understanding of the material. It is however essential to prove such numerical simulations by means of experimental investigations.

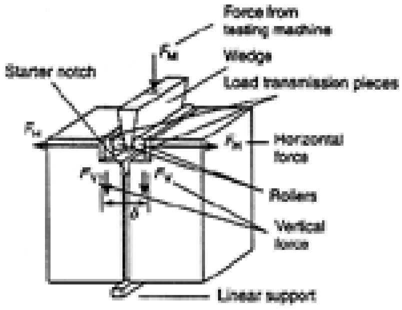


Results of numerical simulations using DIANA of the bearing and deformation behavior of concrete on the mesoscale are given.

The basis for the geometry and material properties of the numerical model is provided by experimental investigations on a two-dimensional model concrete consisting of spherical aggregates embedded in a mortar matrix. From these experimental investigations full field displacements of the specimens' surface on the micro range are provided for different loading stages with the help of a novel digital image correlation technique, which enables high-precision optimization and quality control of the numerical simulation. With the help of the simulations, a mechanical model could be derived which describes the damage evolution and growth in concrete depending of its constituents.

Numerical simulation of a fracture test for refractories

T. Auer, Universitat Leoben, Austria



To succeed in developing new refractories, knowledge of fracture mechanical parameters, especially the specific fracture energy, is of great importance. For this purpose a wedge splitting test according to Tschegg, which delivers this material data, became a feasible and established test method.

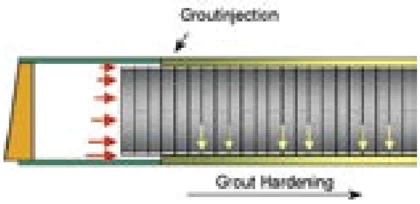
Simulating the test procedure with the FEM package DIANA, influence of the material parameters e.g. young's modulus, specific fracture energy and tensile strength are investigated. In a first step the material behavior was described by the multi directional fixed crack model. Application of this smeared crack model shows inadequate localization of the crack and results in an incorrect solution. Therefore the discrete cracking model with tension softening behavior according to Hordijk has been chosen for the further procedures. Simple equilibrium conditions have been applied to check the consistency of the results. The effect of the convergence limit was also analyzed and the results helped to find an optimum between required accuracy and computing time. The calculations show that the displacement of the load/displacement curve at a defined fraction of the maximal load depends only on the characteristic length, which is a parameter for brittleness and the ratio of the specific fracture energy to the tensile strength. This study includes the calculation of tensile strength and specific fracture energy from load/displacement curves which are measured until an arbitrary threshold value of the force. In addition, having the material data, it is possible to predict the result by a simple spreadsheet calculation.

A compilation CD with the presentations could be send to you on request. Please mail to info@dianausers.nl

4D analysis of a shield driven tunnel

N. van Empel, Witteveen & Bos, The Netherlands

A phased 3D (4D) DIANA model has been developed in order to simulate the boring process of a shield driven tunnel. During the construction of the Sophia Rail tunnel in the Netherlands deformation measurements of the soil and tunnel lining have been performed and also the TBM process parameters have been monitored. These measurements have not only provided the necessary input for the model but have also made it possible to assess the predictive strength of the model.



The developed DIANA model combines a state of the art model of the soil (3D continuum) and a realistic model of the segmented tunnel (curved shells with explicitly modeled joints). Also the development in time and space of pressures in the grout, injected around the tunnel, has been accurately modeled.

Therefore the model cannot only be used to predict 4D settlements in the soil but also the 4D developments of forces and deformations in the tunnel structure. The results of the model have been compared with the measurement data, which has provided a clear picture of the behavior of the model in comparison with the mechanisms observed in reality.

Social Event: Burgers' Ocean

Hans van Vliet,
ABT consulting, The Netherlands

As an introduction to the social event and the technical excursions highlights of the constructions projects for Burgers Zoo are presented. The presentation emphasis on design details of Burger's Ocean.

DIANA Newsround

Starting from the next issue, DIANA ELEMENTS will include a new section named DIANA Newsround. DIANA Newsround will include DIANA related news from DIANA users worldwide. It might e.g. include information on new projects and other activities, job opportunities, finished research projects, etc.. Items in DIANA Newsround should be concise and preferably include a website or e-mail address for further information. Please send items for subsequent editions of DIANA ELEMENTS to info@tnodiana.com

Calendar

2005

5-7 September	COMPLAS 2005, Barcelona, Spain
12 September	National DIANA Users Meeting, Munich, Germany
13-14 September	Training course: Analysis of Concrete Structures, Leicester, UK
13-14 September	Training course: Analysis of Concrete Structures, Munich, Germany
15-16 September	Training course: Analysis of Masonry Structures, Munich, Germany
15-16 September	Training course, New Jersey, USA
20-23 September	Training course: Introduction to DIANA and Analysis for Concrete Structures, Delft, the Netherlands
9-11 October	DIANA demonstration at ATCE 2005, Dallas, TX, USA
November	DIANA Week in Japan with Japanese Users Meetings and DIANA 9 courses
9 November	DIANA Users Association: Annual Meeting & Technical Symposium, Nieuwegein, the Netherlands
10 November	DIANApipe training course, Delft, the Netherlands
22-23 November	Training course: Introduction to DIANA, Watford, UK
24-25 November	Training course: Fire safety engineering, Watford, UK
6 December	Training course: Introduction to DIANA, Delft, the Netherlands
7-8 December	Training course: Geotechnical applications, Delft, the Netherlands
9 December	Training course: Working with User Supplied Subroutines, Delft, the Netherlands

2006

25-26 January	Training course: Analysis of Concrete Structures, Delft, the Netherlands
27 January	Training course: Young Hardening Concrete, Delft, the Netherlands
16-17 March	International DIANA Users Meeting, Essen, Germany
27-30 March	Euro-C, Mayrhofen, Austria

For actual information on training courses, conferences and other events visit www.tnodiana.com and see the sections training and events.

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