FINAL PROGRAM

10th International

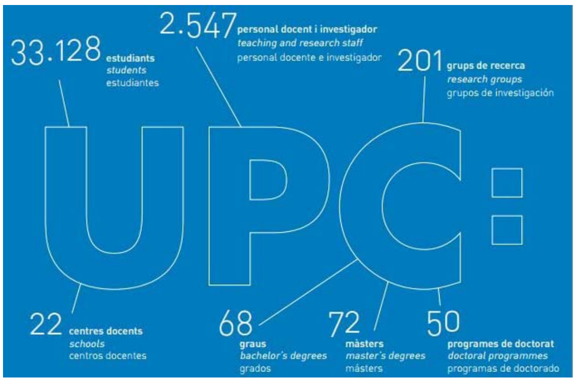
DIANA Users Meeting

29-30 October 2015

Hosted by

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Department of Construction Engineering



Accessibility to Barcelona

Barcelona airport is 14km from Barcelona city centre.
There is shuttle http://www.aerobusbcn.com every 5mins from both terminals and a train, from terminal 2, every 30mins.

Venue

The meeting will take place at Campus Nord, Higher Technical School of Engineers of Roads, Canals and Ports of Barcelona (ETSECCPB), Assembly Room (Sala de Actes). Calle Jordi Girona1-3, **Building C2**, first floorBarcelona.

Directions to arrive to Campus Nord

There is a shuttle (Aerobus) every 5 minutes from both terminals at the airport and that takes around 30 minutes to Plaza Catalunya and then you can take the metro (green line L3) until Zona Universitaria (which will be around 20 minutes). Then there is a 10 minute walk until the venue.
From terminal 2 there is a train every 30 minutes to Plaza Catalunya.
From the airport the shuttle + metro is the best option.


Ciutat Universitària
Zona Universitària
Palau Reial

Program International DIANA Users Meeting

Thursday 29 October

8:30 Registration

9:00 Opening

9:10 Welcome by Prof. Antonio Mari, Director of the Department of Construction Engineering, UPC, Barcelona, Spain

9:30 *Prof.Jesús Miguel Bairán, Department of Construction Engineering, UPC, Barcelona, Spain*
Capturing 3D effects and non-linear response in concrete frame elements by means of high order cross-section models

10:15 *BogdanOrlic, B.B.T. Wassing, Netherlands*
Field-scale three-dimensional geomechanical modelling of gas reservoirs: workflow and case studies

10:45 Break

11:15 *Morten Engen, Max A. N. Hendriks, Jan ArveØverli, Erik Åldstedt, Norway*
A Material Model Suitable for NLFEA of Large Reinforced Concrete Structures
Ignasi Fernandez Perez, Jesús M. Bairán, Antonio R. Marí, Sweden
Modelling of corroded steel reinforcement bars based on 3D scan geometry
Cor van der Veen, Netherlands
Shear Behaviour of prestressed dapped end beams

12:45 Lunch

14:00 *Prof.RuiFaria, University of Porto, Faculty of Engineering, Portugal*
Assessment of structural concrete behaviour with advanced numerical modelling

14:45 *Michele Simoni, Andrea Chiozzi, A. Tralli, Italy*
On nonlinear analysis of historical masonry monuments damaged by Emilia 2012 earthquake
Marcel 't Hart, Dirk Jan Peters, Netherlands
Local buckling of large diameter steel tubes (partly) filled with sand
Noemi Duarte, Ulric Celada, Jesús M. Bairan, Antonio R. Mari, Spain
Numerical and analytical simulation of partially prestressed beams
Coen van der Vliet, Ronald W.M.G. Heijmans, Netherlands
Feasibility immersed tunnel in seismic region

16:45 Closure first day

16:50 Refreshment

17:00 **Social Event**
17:00 Bus to SagradaFamilia
18:00 Visit SagradaFamilia
19:30 Bus to restaurant
20:30 Aperitivo
21:00 Dinner
23:00 Bus back to Plaza Catalunya

Friday 30 October

9:00 Opening

9:05 *Sebastian W.H. Ensink, Cor van der Veen, Ane de Boer, Netherlands*
Shear tests on large T-shaped Prestressed Concrete Beams
Elena V. Sarmiento, Max A.N. Hendriks, Terje Kanstad, Norway
Accounting for the fibre orientation on the structural performance of flowable fibre reinforced concrete
Richard Roggeveld, Frank J. Kaalberg, Netherlands
Assessment of Loading Capacity Fire-Fighting-Platform

10:35 Break

11:00 *Jiangpeng Shu, Mario Plos, Kamyab Zandi, Karin Lundgren, Sweden*
Numerical prediction of punching behaviour for RC bridge deck slabs using 3D continuum non-linear FE analysis
Yuguang Yang, Netherlands
Calculation and modelling of a shear test on a 4 meter concrete slab strip without shear reinforcement
Ab van den Bos, TNO DIANA BV, Netherlands
DIANA SUPPORT issues

12:30 Visit UPC lab Structural Technology Laboratory (LTE)

13:15 Lunch

14:15 *Beatrice Belletti, Cecilia Damoni, Max Hendriks, Ane de Boer, Italy*
Validating the Guidelines for Nonlinear Finite Element Analysis
Gerd-Jan Schreppers, TNO DIANA BV, Netherlands
New DIANA Release 10

15:15 User Wishes

15:55 Closure event

16:00 Refreshment and Farewell

Capturing 3D effects and non-linear response in concrete frame elements by means of high order cross-section models

Jesus Miguel Bairan
Associate professor
Universitat Politècncia de Catalunya
School of Civil Engineering

Abstract

Frame elements are useful in practical assessment of large structures, as they allow for fast model building and result interpretation, compared to more complex solid models. In these elements, non-linear response is possible by means of uniaxial fibre discretization of the cross-section in smeared inelastic models or by lumped inelastic models through localized plastic-hinges. Nevertheless, as the hypothesis of plane-sections is inherited from basic beam theories, only some strain fields are considered, i.e. longitudinal axial strains in Navier-Bernoulli theory and also in-plain shear strains in Timoshenko theory, while the other strain components are neglected. For elastic and isotropic materials, this assumption is satisfactory; however, this is not the case in many common situations. Cracked reinforced concrete elements exhibit induced anisotropy, nonlinear relationship between longitudinal and transversal strains. Particularly, crack-induced anisotropic response of concrete is essential in activating some resisting mechanisms in reinforced concrete, like shear and torsion, which cannot be captured with traditional frame elements.

In this lecture, a theory is presented in which cross-section based on Navier-Bernoulli formulations are enriched by means of warping and distortion fields, internally computed in the cross-section model. The warping-distortion field allows for considering multiaxial strain tensor and thus multiaxial constitutive models in sectional analysis or frame models. This theory allows for the correct estimation of strains and stress distribution under combined loading of cracked concrete elements and other materials showing anisotropic behaviour, like CFRP, under combined loading. The effects of different confining materials is naturally considered through out-of-plane compatibility of the cross section. After the 3D formulation, two simplified models are presented, for accounting for dynamic loading and the assessment of existing and repaired infrastructures. Case studies will be discussed showing the advantages and possible improvements of the formulations and possible future applications.

ASSESSMENT OF STRUCTURAL CONCRETE BEHAVIOUR WITH ADVANCED NUMERICAL MODELLING

RUI FARIA

University of Porto, Faculty of Engineering, Portugal

ABSTRACT

Presently available numerical models for the analysis of concrete structures, usually based on the Finite Element Method, allow that complex problems can be realistically addressed at a macro-scale level, to help solving real civil engineering problems. Such models are quite useful for better designing structures with cutting edge architectural solutions, interpretation of structural malfunctions, or for supporting selection of the best solutions for retrofitting and strengthening interventions. In some of these complex problems nonlinear analyses are required, to address the complete structural behaviour at ultimate limit states.

This lecture will present the experience of the research group LABEST – Laboratory for the Concrete Technology and Structural Behaviour, hosted at the Faculty of Engineering of the University of Porto (Portugal), on the numerical simulation of real scale concrete structures. The presentation includes several examples where usefulness of advanced numerical analyses is to be demonstrated. Mostly performed with software DIANA, and including situations where user supplied subroutines needed to be developed and implemented, such analyses cope participations in international benchmarks, as well as the simulation of large scale concrete structures, from which it is worth remarking:

- Simulation of the performance of shear critical reinforced concrete elements;
- Assessment of the performance of reinforced concrete slabs undergoing restrained drying shrinkage deformations and loaded with service loads, to quantify the minimum reinforcement needed for cracking width control;
- Analyses of the precast concrete viaducts that provide access to a recent Portuguese bridge, on a ~10km long crossing over the Tagus river, in support of the extensive *in situ* monitoring campaign performed during construction;
- Nonlinear analysis of a prestressed concrete bridge located in the north of Portugal, presenting several pathologies;
- Thermo-mechanical analysis of the concrete embodying the Turbine Spiral Case of the Power Station of Batalha dam, located in Brazil.

Relevant conclusions are presented at the end.

Field-scale three-dimensional geomechanical modelling of gas reservoirs: workflow and case studies

Bogdan Orlic, B.B.T. Wassing
TNO Geo-energy, P.O. Box 80015, 3508 TA Utrecht, The Netherlands

Gas production and fluid injection into the subsurface will induce the poro-mechanical and thermal effects that can mechanically damage rock formations, re-activate pre-existing fractures and geological faults, create new fractures and cause subsidence at the ground surface. The geomechanical effects can play an important role in the production of hydrocarbons or the use of depleted fields as natural gas storage sites or CO_2 disposal sites. Assessment of depletion- and injection-related geomechanical effects can in many cases be done by using analytical and semi-analytical approaches, and 2D numerical models. The use of large-scale, 3D numerical geomechanical models is however required in cases of complex reservoir structures and the spatial variability of material properties that have significant bearings on the geomechanical response of reservoir.

We will present a workflow for construction of 3D finite element meshes from geometrically complex structural geological surface-based models. Several examples will be presented to illustrate the use of field-scale finite element models of real gas reservoirs for different purposes: (i) prediction of subsidence due to gas extraction from gas fields in the Northern Adriatic, Italy; (ii) assessment of the potential for fault reactivation and induced seismicity during underground gas storage operations in the Netherlands; and (iii) evaluation of the geomechanical effects of CO_2 injection and storage in a depleted gas reservoir in Poland.

A Material Model Suitable for NLFEA of Large Reinforced Concrete Structures

Morten Engen[1,2], Max A. N. Hendriks[1,3], Jan Arve Øverli[1], Erik Åldstedt[2]
[1]Department of Structural Engineering, Norwegian University of Science and Technology, Trondheim, Norway
[2]Multiconsult ASA, Oslo, Norway
[3]Delft University of Technology, Delft, The Netherlands

ABSTRACT

In order to utilize non-linear finite element analyses during design of large concrete structures, there is need for a suitable material model for concrete. A fully triaxial empirically based material model has been implemented in a commercial finite element code. For simplicity, full brittleness was assumed, and a fixed, non-orthogonal crack formation algorithm was developed with a maximum of three cracks per integration point. The material model also allows for crack closure. In the accompanying presentation, results from a selection of benchmark analyses will be presented, and the inherent modelling uncertainty will be discussed. Despite the simplicity of the material model, a low modelling uncertainty was achieved. The material model is currently being tested in DIANA.

Key words: Reinforced Concrete, Large Concrete Structures, Modelling Uncertainty, Non-linear Finite Element Analysis, Structural Design.

MODELLING OF CORRODED STEEL REINFORCEMENT BARS BASED ON 3D SCANN GEOMETRY

Ignasi Fernandez Perez*, Jesús M. Bairán, Antonio R. Marí

* Chalmers University of Technology
Department of Civil and Environmental Engineering, Division of Structural Engineering,
412 96, Gothenburg, Sweden

ABSTRACT

Pitting on the steel surface due to steel corrosion produce different local effects in the bar, which take into non-uniform stress distribution throughout the cross-section, due to stress localization at the pit tip and centre of gravity displacement, for instance. Hence, what in first instance may be a uniaxial load, may turn into a multiaxial stress states in the surrounding of the pits. The study of corrosion in such a local ways could be interesting to go in depth in the corrosion phenomenon and its effects on the steel bar. Hence, the use of 3D scan technique open a broad range of possibilities; a statistical analysis of the pitting distribution, a 3D FEM model of the whole bar studying effects like stress concentration, multiaxial stress behaviour or non-homogeneous material distribution, or the analysis of the critical cross-section and the pitting geometry, for instance.

3D model development of scanned corroded specimens tested under tensile and cyclic loads were performed. The presented models describe the test conditions. A comparison between the experimental and the numerical data was performed. To pursue this goal, DIANA finite element software combined with the pre and post processor GiD were used. The direct tensile and cyclic load test were both reproduced with DIANA. Since DIANA only allows fatigue calculations in elastic analisys, a fatigue model to identify the damage level of each element after every cycle has been developed by means of an external subroutine. This subroutine made possible removing the elements from the model for the next steps whether they were broken and consider no-linear behaviour.

The presented model allows reproducing the fatigue life and tensile behaviour with a good agreement with respect to the experimental data. Fatigue life estimation require a high computational cost since in each load step the non-linear stress state has to be obtained. On the other hand, tensile test is low computational cost despite are needed many intermediate steps to describe the σ-ε behaviour until ultimate stress.

A multi-axial behaviour is described in the critical pitted cross-section. Simplest uniaxial models require an overestimation of the critical steel cross-section area to include these effects and get a good estimation of the yielding and ultimate stresses. The higher corrosion was the larger difference between the 3D model and the uniaxial calculation. As it was expected, since the multi-axial state in high-corroded cross-section is amplified.

Shear Behaviour of prestressed dapped end beams

Cor van der Veen, Delft University of Technology, Netherlands

Abstract

This (Master)study specifically investigates the shear resistance of vertically prestressed dapped end beams. An analytical study is performed in order to evaluate the influence of vertically prestressing on the failure mechanism and the shear resistance of vertically prestressed dapped end beams. Next, an analytical calculation procedure based on the equilibrium of the "torn-off" section is used to determine the bearing reaction of several prestressed dapped end beams. Additionally, a Case Study is performed to verify if the results of a finite element analysis (FEA) using a highly simplified model are in accordance with the experimental results described in CUR-report 40 of a full size test on a prestressed dapped end beam.

Determining the design shear resistance of vertically prestressed dapped end beams using the equilibrium calculation procedure will give very conservative results.

The finite element model (FEM) used is highly simplified. Only the prestressing cables and Dywidag bars are included in the model and loads are not distributed over multiple nodes. Overall it can be concluded that initiation as well as the direction of crack propagation are simulated quite well. However it is not possible to make realistic statements about crack propagation, crack width and realistic crack strains at different load steps. More important, the calculated bearing reaction is a safe lower limit of the shear resistance.

It is expected that modelling of all reinforcement bars will result in a less conservative shear resistance. Further research is required to verify the statement above.

On nonlinear analysis of historical masonry monuments damaged by Emilia 2012 earthquake

Michele Simoni, Andrea Chiozzi, A. Tralli
Department of Engineering, University of Ferrara, Italy

Abstract

The finite element analysis program DIANA has been used since 10 years at the Engineering Department of the University of Ferrara for evaluating the load-bearing capacity of masonry historical buildings. Some of these studies have been published in international technical journals [1-7] and conference proceedings. [9-11]
The purpose of this presentation is to illustrate some of the more recent studies concerning historical buildings damaged by the recent 2012 Emilia(Italy) earthquake. In particular, such studies addressed the structural analysis of two medieval towers.
The first one is the Fornasini tower, a XIII century watching tower located in Poggio Renatico, near Ferrara [9-11] which was severely damaged. Of particular interest are the nonlinear static analyses of the first floor vaults and a comparison between the push-over analysis of the whole structure, performed according to the Italian Building Code, and a full nonlinear dynamic analysis.
The second one is the tower of the fortress of San Felice sul Panaro [6], one of the most significant monument which was strongly damaged by 2012 seismic events. These studies, not yet published, involve the large cross vault of the "room of Julius II"; here a modal push-over analysis was performed instead of a regular push-over analysis, since the participation mass corresponding to the first vibration mode was found to be less then 60% of the total mass. This type of analysis was already been successfully applied to the masonry Chimney of the Faculty of Engineering of Ferrara [5].
Finally, the present contribution covers the studies done on the "Prospettiva di Corso della Giovecca" in Ferrara, where static, pushover and dynamic analyses were carried out in order to design an innovative seismic isolation system for the protection of heavy ancient marble pinnacle [7].

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Local buckling of large diameter steel tubes (partly) filled with sand

Marcel ‘t Hart, Dirk Jan Peters, RoyalHaskoningDHV, Netherlands

In the Rotterdam harbour a series of large diameter steel monopoles need to be installed. Also existing piles need to be re-evaluated because of changed conditions.

Laterally loaded piles and dolphin piles have been subject of many investigations in the past. Nevertheless a number of knowledge gaps and potential issues for optimisation can be identified. Amongst them are: the effect of sand-fill on the pile stiffness and on the local buckling risk, the risk of local buckling at the transition of sand-filled and empty and at the transition of wall thickness.

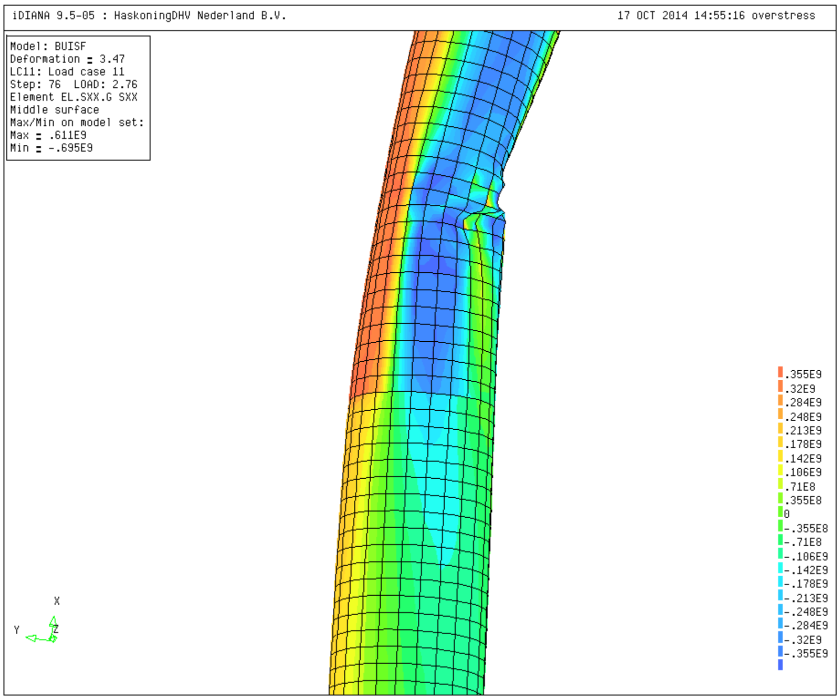
Due to the increased ship sizes and corresponding harbour depths, the piles tend to have larger diameters and lengths, which requires the advanced knowledge of the local buckling risks under pile bending.

Port of Rotterdam has decided to carry out a research program into the safety and economy of laterally loaded steel piles. In November 2014 a full scale test has been carried out on eight 914 mm diameter piles.

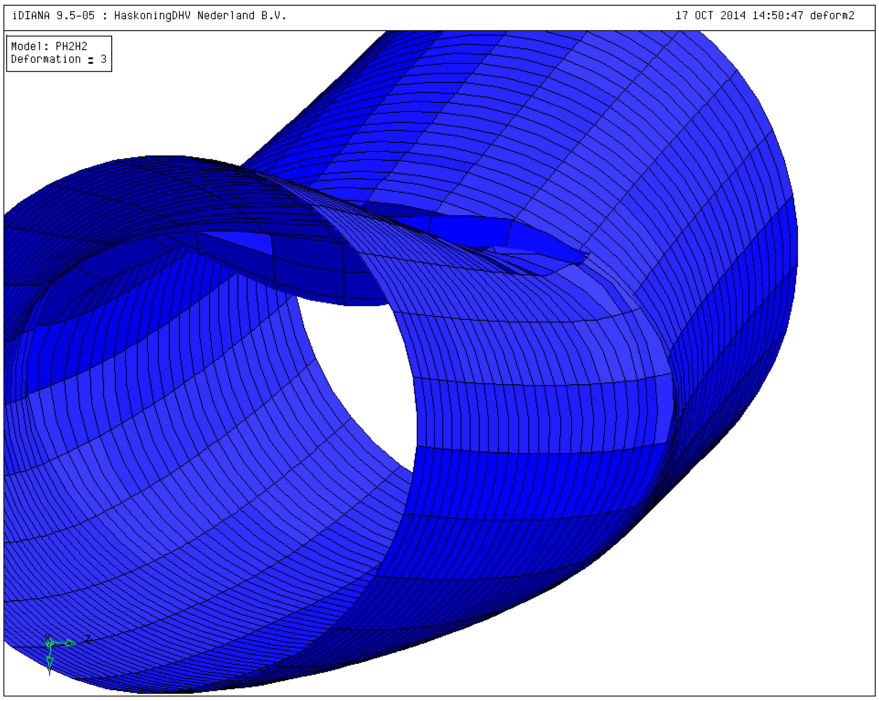
The available design methods and prediction methods for local buckling can be found in the applicable codes and in literature. The available methods are valid for uniform loaded, prismatic empty tube sections. Therefore the predictions were supplemented with DIANA modelling for sand-filled tubes and for wall-thickness transitions.

The predicted bending moments at local buckling calculation by DIANA were generally 15 to 20% higher than the codes. In many cases the local buckling occurred beyond the field limit. The measured bending moment in the tests confirmed the DIANA predictions.

Graphical presentation of the FEM bucling prediction calculation results



FEM results picture showing stresses and the deformed shape of a tube with a wall thickness transition



FEM results picture of a deformed shape

Numerical and analytical simulation of partially prestressed beams

Noemi Duarte, Ulric Celada, Jesús M. Bairán, Antonio R. Mari
Universitat Politècnica de Catalunya, Department of Construction Eng., Jordi Girona, 1-3, Campus Nord, C-1, 08034 Barcelona, Spain

Abstract
An experimental shear test campaign of eight partially pretested isostatic I shaped beams is being carried out in the UPC Barcelona Tech Lab to analyze shear behavior of that type of prestressed elements under serviceably and ultimate state loads. The experimental campaign objectives are to study the influence of compression chord and prestress level in the ultimate shear load capacity and to analyze the influence of different stirrup spacing, different amount of reinforcement and levels of web compression due to prestressed in crack pattern and crack width.

Fig 1: Experimental campaign

In this work one of the tested beams is analyzed using different numerical and analytical methods in order to compare different models accuracy with those obtained from the test considering both load capacity and crack patterns.
Two numerical models developed in the UPC, a 1D layered frame model with axial-shear bending interaction (Ferreira et al. 2014) and a nonlinear fibre sectional model capable of simulating total interaction between all six beam internal forces (Bairán & Marí 2007), and commercial nonlinear finite element analysis program DIANA are used to predict results. Definition of the models, main variables affecting these models, as well as constitutive parameters needed and discussion of results are discussed.
Finally test results are compared with a new shear-flexural capacity model recently developed in the UPC (Marí et al. 2014); the model is mechanical-based relying on the assumption that ultimate state shear is resisted mainly by stirrups if provided and by the un-cracked concrete chord.

Acknowledgements
The present research has been carried out with the support of the project 'Performance-based design of partially prestressed concrete structures. Proposal of new design methodology, experimental verification and design criteria' [grant number BIA2012-36848].

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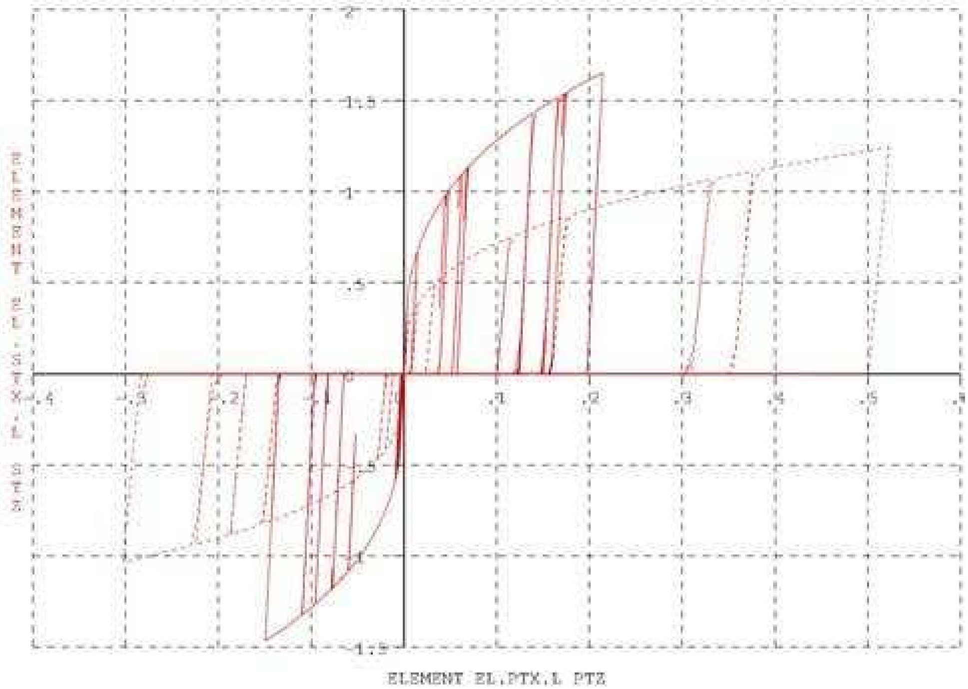
Feasibility immersed tunnel in seismic region

Coen van der Vliet and Ronald W.M.G. Heijmans, Arcadis, Netherlands

The municipality of Istanbul investigates the possibility of a tunnel crossing the Golden Horn, the major inlet to the Bosphorus. Apart from the geometrical challenges to design a tunnel with traffic interchanges at the densely built banks, one of the major conditions relates to the seismic activity of the region. Due to the relatively deep and narrow cross section of the Golden Horn, the tunnel has to be immersed on piers somewhere in between the river bed and the water surface. The resulting dynamic behaviour of the entire system (bedrock, piers, tunnel sections and transition structures) differs significantly from the usual behaviour of a tunnel immersed in a backfilled trench.
In order to evaluate the feasibility, a preliminary design had to be performed in which special attention was paid to the behaviour under seismic loading. Several structural calculation models have been used to investigate the dynamic characteristics of the structure: a n-block-spring-damper model for the sensitivity study, and DIANA FE-models to integrate the soil behaviour, the soil-structure-interaction (user-supplied) and the (nonlinear) structural behaviour.
The analyses resulted in a more-or-less optimised design, with particular solutions for flexible joints between tunnel sections and transition structures.
Apart from a general introduction to the project and the specific structural challenges, the presentation covers the way we dealt with soil-structure-interaction and the associated material models.

Figure: Tractions in the (user supplied) P-Y-springs for soil-structure interaction



Shear tests on large T-shaped Prestressed Concrete Beams

Sebastiaan W.H. Ensink[1], Cor van der Veen[1], Ane de Boer[2]
[1] Delft University of Technology, the Netherlands
[2]Rijkswaterstaat, the Netherlands

Abstract

The experimental results of four shear tests on two large T-shaped prestressed concrete beams are presented. These beams have been part of previous experiments at the Stevin II lab at Delft University after which they have remained undamaged. The beams are a 1:2 scale model of the approach bridge of the Van Brienenoord bridge in Rotterdam in the Netherlands. However the reinforcement and prestressing is not an exact scale of the real bridge beams and was designed with requirements of the aforementioned previous experiments.

The beams have a length of 12 m and a depth of 1.3 m. The shear reinforcement consist of stirrups Ø10 at an average distance of 114 mm. The beams are prefabricated in a factory and each beam is pre-tensioned using 24 strands Ø15.7 mm. Empty ducts in the top flange, used in previous experiments for transverse prestressing, are filled with high strength concrete to prevent a premature failure of the compression zone.

The four shear tests consist of a single point load at a distance of 2.1d from the support. The results of the shear tests are compared to NLFEA and design formula.

Accounting for the fibre orientation on the structural performance of flowable fibre reinforced concrete

Elena V. Sarmiento*, Max A.N. Hendriks*† Terje Kanstad*

* Norwegian University of science and technology (NTNU)
Rich. Birkelandsvei 1A, 7491 Trondheim, Norway

† Delft University of Technology
Faculty of Civil Engineering and Geosciences
Stevinweg 1, 2628CN, Delft, The Netherlands

Synergies between fibre reinforcement and self-compacting concrete (SCC) have been demonstrated in terms of residual strength, see e.g. [1], and in terms of production aspects. Often large scatters are found in test results for fibre reinforced structural elements. A non-homogenous distribution of the fibres in the elements is probably the main explanation of the scatter.

This work focuses on a finite element based sensitivity analysis in order to explain the effect of non-homogenous and non-isotropic fibre distributions on the structural performance. The fibre structure can be characterised by a field of fibre orientation tensors and a maps of local fibre content. They can be assessed with Computed Tomography scanning or simulated with fluid dynamics modelling [2]. In the present study the fibre structure is considered as known.

Finite element modelling thus requires an accurate description of the fibres, especially where it comes to the non-uniform fibre dispersion. Moreover it requires an adequate constitutive model which takes into account the local fibre orientation and which describes the multi-axial behaviour and fracture of fibre reinforced concrete. Beghini et al [3], propose such a model based on a microplane formulation. In the present work a constitutive model is used based on an (local) orthogonal smeared crack formulation, assuming rotating crack orientations. Whereas the tensile strength is assumed to depend only marginally on the fibre orientation, the softening behaviour is defined based on the local fibre content, the local fibre orientation tensor and the principal stress direction.

As a case study, test series of beams are used. The beams were cut from a square fibre reinforced self-compacting concrete slab. The finite element modelling of the beams is validated and sensitivity studies with respect to the local fibre directions are performed. This work concludes with notes on the adequacy of the modelling in general and specifically discusses the modelling of strain hardening and softening of fibre reinforced concrete within standard smeared cracking models.

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Assessment of Loading Capacity Fire-Fighting-Platform

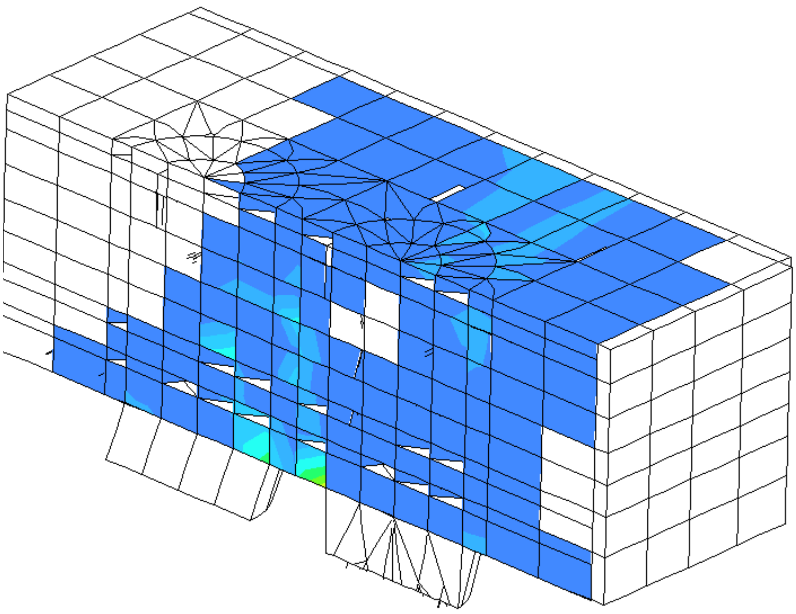
Richard P. Roggeveld, Frank J. Kaalberg, Witteveen+Bos, The Netherlands

During construction of a Fire-Fighting-Platform, before final concrete casting phase, the incomplete installation of the reinforcement near the pile heads was discovered. As a result, the stirrups would have too little welding length to be fully functional. The loading capacity of the platform would be insufficient to comply with building codes, therefore the platform would either have to be dismantled and rebuilt, or it would have to be strengthened. Dismantling would most likely result in a delayed project completion, financial consequences and legal procedures. Strengthening the platform would be the least disadvantageous option, but only if an underpinned decision could be made rapidly.

The platform is situated off shore in the Mediterranean Sea near Cyprus. It is founded on 38 meter long steel piles which are loaded horizontally by waves and berthed vessels. These horizontal loads generate large pile reactions in opposite directions at their joint. This joint is formed by a small portion of the slab, where large shear and punching forces are introduced into the platform. Due to the incompleteness of the stirrups, a secure connection could not be established. A detailed analysis of the joint was performed to assess the feasibility of repair measures, aiming at preserving the nearly completed platform and avoiding dismantling and project delay.

Using Diana, the effect of the redesign on the ultimate loading capacity of the platform was evaluated, by applying the normative loading schemes from the design calculations. The redesign, consisting of a grid of steel members and adjustments to the upper reinforcement cage, showed to be an effective strengthening measure. The measures have been implemented, preserving the platform and preventing costly delays.

Figure 1: cross-section of platform corner, showing crack development



Numerical prediction of punching behaviour for RC bridge deck slabs using 3D continuum non-linear FE analysis

Jiangpeng Shu[1], Mario Plos[1], Kamyab Zandi[1,2], Karin Lundgren[1]

[1]*Department of Civil and Environmental Engineering,*
Chalmers University of Technology,
412 96 Gothenburg, Sweden
[2]*CBI Swedish Cement and Concrete Research Institute,*
501 15 Borås, Sweden

Existing infrastructure represents a substantial part of the societal assets and existing bridges represent a huge capital that need to be well administrated. Bridge deck slabs are among the most exposed bridge parts and are often critical for punching failure. Consequently, it is important to examine if the current assessment and analysis methods are appropriate.

Nonlinear finite element analysis (FEA) has been proved to be an enhanced method to evaluate the punching capacity of Reinforced Concrete (RC) slabs with high level of accuracy. However, even though nonlinear FEA has been used increasingly for the assessment of existing structures, building codes do not provide specific guidance on how to perform these analyses. Therefore, the overall aim of this study is to investigate how accurate the response of slabs can be predicted with nonlinear finite element (FE) analysis, and how the modelling choices might influence the analysis results.

The study was conducted by carrying out nonlinear FE analysis for RC slabs subjected to punching failure, using three-dimensional (3D) continuum elements. The load-carrying capacity, load-deflection response, crack pattern and reaction-force distribution of the slabs were compared to experimental data available. The influence of several modelling parameters was investigated, including geometric nonlinearity, element properties, material model of concrete, the model of reinforcement and boundary condition.

The analyses of the tested slabs show possibility to accurately predict the load-carrying capacity and realistically simulate the behaviour of slabs. In the future, existing methodologies for the design and evaluation of RC slabs are to be further developed, especially for structural assessment of existing bridge deck slabs using enhanced evaluation with nonlinear FE analysis. Recommendations for such analyses will be established and parameters for evaluation of safety will be developed.

Calculation and modelling of a shear test on a 4 meter concrete slab strip without shear reinforcement

Yuguang Yang, Delft University of Technology, Netherlands

The size effect of reinforced concrete members without shear reinforcement under shear has been considered a riddle for years. The shear failure process involves several physical mechanisms. Starting from different mechanism(s), different researchers have proposed several theoretical models on this phenomenon. Although most of the models compare well with the currently available test results, they can be extrapolated towards quite different directions when the depth of the specimen becomes even larger. On the other hand, in the engineering practice, the dimensions of the structural elements are getting larger, they are often beyond the largest available test specimens. These large elements are usually of great importance. Therefore an accurate size effect model is rather important for structural safety. In order to check the extrapolation of the current size effect models on shear, in May 2015, a shear test was carried out by Prof. Collins and Bentz in the University of Toronto. The depth of the specimen reaches 4 meters. It is the largest recorded shear test up to now. Before the test, they proposed a competition to predict the test results, which is open for all types of theoretical models or Non linear FEM programs. Although the competition has finished, it can still be considered as a valuable case study to evaluate the Non-linear FEM simulations. In this presentation, this competition and the related shear theories on the size effect of reinforced concrete members without shear reinforcement are introduced. Further study with TNO-Diana on the test are called for within the group of Diana users.

DIANA SUPPORT (support@tnodiana.com)

Ab van den Bos, TNO DIANA

DIANA support is the first line helpdesk for questions from our users all over the globe. The questions come from different type of countries, cultures and users. Our staff is trained to receive, note down and prioritise the questions in our ticket system. The feedback is arranged by a first line and second line principle.
An in depth look into the world of support is given in the presentation. A technically topics ranking will be outlined. Other aspects that will be presented will be e.g. how the quality control is arranged. At last the coming differences for the future with the new version will be outlined.

Validating the Guidelines for Nonlinear Finite Element Analysis

Beatrice Belletti*, Cecilia Damoni*, Max Hendriks#, Ane de Boer+

* University of Parma, Parco Area delle Scienze 181/A 43124 Parma, Italy
# Delft University of Technology, Stevinweg 1, 2628CN Delft, The Netherlands
+ Rijkswaterstaat, Ministry of Infrastructure and the Environment

The Dutch Ministry of Infrastructure and the Environment run a project to re-evaluate the load carrying capacity of existing bridges and viaducts in the whole country because of the increase of traffic and the reallocation of emercency lanes to traffic lanes. For a certain amount of Dutch bridges and other infrastructures the safety verifications were not satisfied if the usual analytical procedures, proposed by the current norms, were adopted in the calculations. For this reason the Dutch Ministry of Ministry of Infrastructure and the Environment proposed to make a structural assessment of existing structures through the use of nonlinear finite element analyses with the final release of a document containing guidelines for nonlinear finite element (NLFE) analyses of reinforced and prestressed concrete elements [1]. After the publication it became necessary widespreading the procedure for the application of the guidelines; hence to this aim the Dutch Ministry of Transport, Public Works and Water Management proposed to extend the project. In the project, presented in the paper, four reinforced concrete (RC) beams, four prestressed concrete (PC) beams and five RC slabs, characterized by different failure modes, are analyzed by means of nonlinear finite element analyses and analytical calculations. For all case studies analyzed the reporting of results follows a specific scheme, in order to systematize the analysis process and to facilitate users of finite element codes in the reading and validation of the results obtained. In particular for each case study are described: the geometry, the experimental results available from literature, the finite element modeling, the material constitutive model used in NLFE analyses and the convergence criteria. The results obtained are analyzed by means of reporting the significant material limit state, the crack pattern and the convergence trend. In order to control the results obtained from NLFE analyses in terms of bearing capacity and failure mode, analytical calculation are also performed in accordance to the current design codes and guidelines [2], [3]. Furthermore, according to the Model Code 2010 philosophy, the level of approximation approach has been applied to all case studies through the safety format methods. Thanks to the application of safety format methods, used for the evaluation of the design resistance by means of both analytical and numerical calculations, it has been in fact possible to estimate the difference in terms of structural bearing capacity between standard analytical calculations and the results obtained from NLFE analyses, and hence to estimate the advantages of using NLFE analyses.

[1] Guidelines for Non-linear Finite Element Analyses of Concrete Structures. Rijkswaterstaat Technisch Document RTD:1016:2012, Utrecht: Rijkswaterstaat Centre for Infrastructure; 2012.

[2] CEB-FIP Bulletin d'Information 65&66 - Model Code 2010.

[3] UNI EN 1992-1-1:2005: Eurocode 2 - Design of concrete structures - Part 1-1: General rules and rules for buildings.