Graduation Theses
March 2010

Civil Engineering
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5 | Master’s Theses October 2009
For graduates, the Master’s thesis is the crowning touch to their studies. The thesis is an extensive piece of academic research and writing that is carried out independently. By completing a thesis, graduates demonstrate that they are worthy of the title of Master of Science. The time spent studying at our faculty has given them the skills and knowledge needed to complete this comprehensive task. The theses collected in this book reflect the high academic quality of our graduates. They have used their theses not only to address relevant societal problems, but also to present innovative solutions. Their theses reflect their capabilities and the fact that they are truly ready to embark on their careers.

These theses are valuable documents for the faculty of Civil Engineering and Geosciences. They help us to establish and demonstrate the societal relevance and quality of our teaching programmes. The high standards we pursue at our faculty are reflected throughout this book. Our graduates skillfully address relevant issues such as coping with climate change and sustainable design. They also provide workable solutions, reflecting one of our faculty’s primary aims: to contribute to the progress of society.

It gives me great pride to present our graduates in this book. They will now leave their student days behind them and enter the work force. I wish them good luck in continuing their valuable work for society.

Prof. Louis de Quelerij
Dean of the Faculty of Civil Engineering and Geosciences
Explanation of the graduation book

"Graduation Thesis March 2010" contains the summaries of the theses of the students who graduated as Master of Science in "Civil Engineering", "Transport, Infrastructure and Logistics" or "Offshore Engineering" at the Delft University of Technology.

The purpose of this publication is to inform professionals working in these fields about recent developments in teaching and research at the Faculty of Civil Engineering and Geosciences. In many cases, the subject of the Master’s thesis is based on a request from professionals working in the field in question. In other cases, such individuals will collaborate in the realization of a Master’s thesis. Alternatively, the thesis may be part of a wider research project within the department itself. The primary goal of the Master’s thesis is to round-off a student’s course of study at the TU, and to enable them to graduate as a Master of Science. As the regulations stand, this requires an investment of 22 to 26 weeks of study. The summary of every completed thesis is published in "Master’s Theses march 2010", whether they are merely average or truly outstanding.

The book’s layout
The summaries of the various theses are published per Master’s programme and specialization:

The Civil Engineering Master’s programme has five specializations:
- Structural Engineering
- Building Engineering
- Hydraulic and Geo Engineering
- Water Management
- Transport & Planning

Besides the Master’s programme Civil Engineering, the faculty participates in the following interfaculty Master’s programmes:
- The Offshore Engineering Master’s programme
- The Transport, Infrastructure and Logistics Master’s programme

All of the summaries have a similar layout. Call the department in question if you require further details about a specific thesis (the phone number is given at the end of each summary).

Following the new summaries, an overview of all the summaries of last year can be found. These are organized according to the set up of the previous publications.

Within every Master Programme, there are different departments. These correspond to the different specializations within each programme. To make this more clear, an overview of all the specializations is provided in the last pages of this book. Here you can also find the professors who are involved in each specialty.

The aim of the book
The main purpose of publishing these Master’s theses is to ensure that the outside world is better informed about the research that is carried out at the Faculty of Civil Engineering and Geosciences. It is also hoped that this book will enhance communication with professionals working in this field, and help them to become better informed about the capacities of current graduates.

Further details
Contact the department in question if you require further details about one or more of the published summaries (the phone number is given at the end of each summary). A small charge is sometimes levied to cover the costs of printing and posting a thesis. It is not always possible for us to send complete theses. If you so wish, you can also make an appointment to view a particular thesis.

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Theses Civil Engineering

*Structural Engineering*
Self-healing in ECC materials with high content of different micro-fibres and micro-particles

Although Fiber Reinforced Concrete has been accepted in practice since the 1980’s, most of its applications are limited to non structural use which can be at least partially attributed to the limited performance, economic constraint, lack of design guidelines and inconvenient processing. Meanwhile in constructed facilities the need for improvement in ductility and durability has received increasing attention. This attention has led to the development of strain hardening cementitious composites, termed as Engineering Cementitious Composites (ECC) which are continuously evolved over the last 15 years. Fibre reinforced ECC have been deliberately engineered using micromechanics theory to possess self controlled crack width that does not depend on steel reinforcement or structural dimensions. Instead, the fibres used in ECC are tailored to work with a mortar matrix in order to suppress localized brittle fracture in favour of distributed microcrack damage, even when the composite is tensioned to several percent strain. This ability of ECC to achieve controlled tight crack width can be used so as to promote the self-healing process since, as suggested by previous studies, the crack width of the cementitious material was found to play an important role for self-healing to take place. Within self-healing we actually can distinguish two mechanisms: a) the crack is blocked with small particles from the crack faces or small parts present in fluids that flow through the crack and b) a chemical reaction takes place connecting the two crack surfaces. The reaction can be continuing hydration of the cement or a chemical reaction that occurs after hydration (like the formation of calcium carbonate).

In the present experimental research, which is a part of a wider research, the crack tightening and self healing behaviour of strain hardening cementitious composites are investigated. What is interesting about these composites is that they contain different types of additives such as steel fibres, rockwool fibres and polymers. Their common characteristic is that they all contain Polyvinyl Alcohol (PVA) fibres.

In the exploring phase of this study, the main hypothesis that was established was that the addition of extra fibres (steel and rockwool) or extra particles such as polymers, will not only improve the self healing behaviour of the mix containing only PVA fibres but also lead to the formation of tighter cracks in it.

In order to verify or reject the above mentioned hypothesis several mixes were prepared. Moreover, four point bending tests were used to precrack the specimens of the different mixes. Some of the precracked samples where then cured in water and others in air for 28 days. After curing, they were tested until final strength using again the four point bending test and then they were compared to the virgin specimens focusing on the strength and stiffness recovery that they presented. As it was observed, the water cured specimens showed considerably higher percentage of strength as well as stiffness recovery compared with the air cured samples.

To continue with, before the phase of final failure the cured samples were put under the light microscope in order to measure the width of the cracks that were formed as well as attain a good idea about the rate of healing performed. As it was expected the water cured specimens showed considerably better healing results compared to the air cured samples.

Finally, Environmental Scanning Electronic Microscopy (ESEM) was used in order to help us find the chemical identity of the healing products formed inside the cracks. Upon further analysis, a comparison with the results derived from the other half of the project is made, concerning mixes with lower conciseness of additives. The aforesaid comparison aims towards presenting a more complete outline of the ECC self-healing behaviour.

Student: S. Antonopoulou
Committee: Prof.dr.ir. K. van Breugel, Dr.ir. E. Schlangen, Ir. W.J.M. Peperkamp, Ir. L.J.M. Houben

For further information please contact the section Structural Engineering, +31 (0)15 278 45 78
The main objective of this Master thesis is the design of a building method for the realisation of underpasses underneath highways making use of immersion techniques. By means of two main requirements, minimising the traffic nuisance and leaving the groundwater level unaltered, research is done to derive the technical and financial feasibility of a building method in which the closed part of an underpass is situated underneath a standard highway.

The current building methods for realizing tunnels and underpasses in The Netherlands are discussed and evaluated according to the method of the multi criteria evaluation. With the help of the method of Systems Engineering, six concepts are designed. The strong points of the current building methods are combined and the weak points are improved. After an extended evaluation a concept, which combines the current roof-wall method with the immersed tunnel, is chosen.

This concept design of the building method is developed in detail. From a multidisciplinary point of view, attention is paid to the concrete structure, hydraulic engineering and geotechnical aspects, building processes, risks and costs. With respect to other building methods, the building time in which traffic experiences nuisance, is minimized to two weekends of 50 hours.

Eventually the designed building method is very time-consuming. Creating a building dock and building an immersion element is unnecessary if one, after excavating the immersion groove, applies a weight floor of underwater concrete. By executing many calculations, the constructional feasibility of this alternative method without immersion techniques, is proved.

For both designed building methods a risk management plan is drawn. With the risks that are present after mastering measures are taken, a Monte Carlo simulation is executed. The costs for risk are estimated at approximately € 500.000,-. The risks of both methods are by definition not larger than the risk of other building methods.

The developed building method with immersion techniques costs € 3.872.000,- and the costs for the alternative method without immersion are € 2.383.000,-. The traffic nuisance of both methods are identical and the groundwater level stays unaltered in both methods. The alternative method without immersion is 38% cost-effective and for that reason, it is much more attractive. For comparison, the costs for more traditional building methods are derived. A building dock with a total re-route of the highway has little traffic nuisance as a consequence, but the costs are 45% more than for the alternative method without immersion. A building dock with application of a permanent 4-0 system costs just 8% less, but consequently leads to long-term traffic congestion.

Further research to building methods for the realisation of underpasses underneath highways, which makes use of immersion techniques, is not recommended. To Strukton Civiel it is recommended to consider the designed alternative building method seriously, when infrastructural plans for the realisation building underpasses are made.

Immersion of underpasses underneath highways

Student: Jordi van Groesen
Committee: Prof.dr.ir. J.C. Walraven, Prof.drs.ir. J.C. Vrijling (both University of Technology Delft), Dr.ir.drs. C.R. Braam (University of Technology Delft / Adviesbureau ir. J.G. Hageman BV), Ing. A.A.N van den Berg (Strukton Civiel), Ing. Th.J. Collignon (Strukton Engineering)

For further information please contact the section Structural Engineering, +31 (0)15 278 45 78
Dry High Performance Fiber Cables for Civil Engineering Structures

Influence of abrasion at the anchorage on the lifespan

SmartRigging and FibreMax are Dutch companies that have developed a technique for producing dry fiber cables. Unlike fiber-reinforced plastics no resin is used to facilitate cooperation of the fibers, hence the name dry fiber cable. The fibers used are high performance types such as aramid, PBO, Dyneema and carbon.

Due to the extremely high strength and low weight, the dry synthetic fiber cables show major advantages for engineering. An extensive literature study into the possibilities of the cables and the specific characteristics of different types of fibers has been performed. Because there is virtually no knowledge of wear of the cables under repetitive loads, an experimental study of this phenomenon forms the core of the thesis.

The fibers used in the study don’t suffer classical fatigue of the material. However in each load cycle the fibers move back and forth against the metal end fitting, causing wear of the fiber surface and finally fracture. To gain insight into how the wear occurs, the mechanical behavior of the end fitting is studied. To determine the stresses and displacements a mathematical model, based on test measurement, is built. This model shows that axial tension, lateral pressure and relative displacement are all greatest at the point where the fiber and end fitting just let go. Therefore the entire abrasion is concentrated in this section.

The experimental research focuses on cables of aramid. In addition to various load schemes also the fiber type and dimensions of cables and end fittings are varied. In addition, a limited series of tests have been done on PBO, Dyneema and carbon fiber. Since carbon fiber is not suitable as dry fiber cable, some prototype cables of carbon fiber composite have been tested.

With the extensive series of tests on Twaron 2200 (an aramid type with high strength and modulus) a connection is found to predict the lifespan of the cable, based on the tension and contact pressure at the anchorage. A specific type Technora (a different kind of aramid, specially designed for dynamic applications) has a much longer life.

The nature and type of aramid that is used has a major influence on the wear behavior. The limited series of tests on PBO produce a perfect line in the single-logarithmic SN curve. For both materials, the experimental results show a remarkably low scatter, therefore it is concluded that the lifetime of dry fiber cables is fairly predictable.

The tests on prototype carbon composite cables show very long lifespan. If further developed, cables of this material could lend itself perfectly for Civil Engineering applications.

Student: Detlev Keijdener
Committee: Prof.dr.ir. J.C. Walraven, Dr. A. Romeijn, Dr.ir. C. van der Veen, Dr.ir.ing. S. Koussios, Ir. L.J.M. Houben

For further information please contact the section Structural Engineering, +31 (0)15 278 45 78
Recalculation of a post-tensioned solid concrete slab bridge (1963)

Introduction
Recently Rijkswaterstaat started a large maintenance project of the Dutch infrastructure. On one side, aging of the existing infrastructure takes place, therefore a need to know if the existing (concrete) structures still meet the criteria. On the other side changes have taken place in standard setting of the actions on bridges for road traffic as well as in the actual intensity of road traffic. Because of this the question rises if the existing bridges still can resist the heavier loads. In this research special attention goes out to exceptional transport and how to deal with it. The bridge considered lies in the A16 in Rotterdam.

Research objectives
1. Does the bridge steel meet the current standards?
2. What is the maximum bearing load capacity concerning exceptional transport? The research is aimed at fail safety and durability.

Research strategy
The bridge is modeled with the FEM package TNO DIANA. With this computer program the ultimate load bearing capacity is determined on a 1D and 2D level. From this the maximum transport weights are deduced. To maximize the admissible transport weight different aspects and possibilities for allowing a transport are investigated.
1. Occupation of multiple lanes by exceptional transport.
2. Increase of the compressive strength of concrete.
3. Should the effect of an exceptional transport be limited by the effect of loadmodel 1?
4. Dimensions of the exceptional transport.
5. Theoretical or actual lane configuration.

Conclusions
1. The bridge meets the current standards
2. Residual capacity:
In the parameter study a vehicle of limited dimensions and theoretical lane configuration seems to be the safe approach. With this the maximum load is determined for the passage of an exceptional transport. The residual capacity is determined for the different aspects of fail safety and durability.

Bending moment
There is more than enough residual capacity in the bridge to support vehicle loads up to 3600 kN (B45) and 4156 kN (B65).

Shear force
is the most critical aspect of the fail safety. Shear force is, because of the width reduction in the intermediate supports, very sensitive to concentrated loads. For a short vehicle (tandem configuration) a maximum load is found of 1558 kN, a load of 2073 kN is reached by limiting the axle force to 300 kN with distances 1,2 meter.

Fatigue
An unlimited life expectancy is reached with loadmodel 1. Together with loadmodel 4: “standard vehicles”, a fictive vehicle is added for which a daily passage is possible. The maximum load of the truck is 2096 kN.

Crack width
A maximum vehicle load of 2970 kN is possible.

Student: J. Kooiman
Committee: Prof. dr. ir. J.C. Walraven, Dr. ir. C. van der Veen, Ir. A. de Boer (RWS), Dr. ing. A. Romeijn, Ir. L.J.M. Houben.
Effect of cope holes in the crossbeam of orthotropic steel bridge decks

The orthotropic steel bridge deck is commonly used as bridge deck structure. However, it is sensitive to fatigue. Fatigue cracks arise at different locations. The crack in the steel bridge deck plate, at the trough-to-crossbeam-to-deck plate weld is investigated in this thesis.

Objective of this research is to find out if a round cope hole reduces the peak stress at the trough-to-crossbeam-to-deck plate weld. If so, by how much is reduction and to what degree compared to a normal cope hole. The investigation consists of two parts: first some FE models are made and next an experiment is carried out.

A lot of FE models are made to investigate the influence of the normal and round cope holes.

It turns out that the larger the radius of the normal cope hole, the smaller the peak stress at the trough-to-crossbeam-to-deck plate weld. However, this effect decreases when the radius is enlarged more and more. At a radius of approximately 35mm an optimum is reached: the cope hole reduces the peak stress with about 39% compared to the situation without a cope hole.

The influence of the round cope hole is also investigated by FE models. According to these FE models made, the round cope hole should be as large as possible and as close as possible to the trough-to-crossbeam-to-deck plate weld. Such a cope hole with a radius of 30mm reduces the peak stress at the trough-to-crossbeam-to-deck plate weld with about 30%.

The two main principles that affect the peak stress reduction are: the larger the cope hole and the closer it is to the trough-to-deck plate weld, the more it reduces the peak stress. However, with a round cope hole the two cannot be realized together: the larger the cope hole, the further away it is located from the trough-to-deck plate weld. Using an oval cope hole solves this problem if the small radius of the oval is directed towards the weld (as close as possible to the weld) and the large radius is in the direction of the crossbeam (larger cope hole). It turns out that the oval cope hole, with a small radius of 15mm and a large radius of 30mm, reduces the peak stress at the trough-to-crossbeam-to-deck plate weld with 39%.

Some full scale experiments have been performed as well. The most promising cope holes, resulting from the FE analysis have been cut in the crossbeam of a test panel: the normal and oval cope hole. The strains are measured at the top side of the deck plate. The stress reduction at the top side of the deck plate is calculated for both cope holes and via a coupling factor the stress reduction is calculated at the bottom side. The results of the tests are in comparison with the FE results.

From the research as described in the MSc thesis it becomes clear that the cope holes at the deck plate reduce the peak stress at the trough-to-crossbeam-to-deck plate weld a lot. Further research is recommended to study the effect of different loading conditions and to obtain information about the fatigue strength of this detail.

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The orthotropic steel deck bridges, built in the 60’s and 70’s in the national highway system in The Netherlands, are showing problems. Cracking occurs in different parts of the superstructure of the bridge. The crack formation is mainly due to heavy traffic. The substantial increase in freight traffic has caused a high frequency loading of the bridges. This results in a significant decrease of the lifetime. A lot of research has been done to obtain a permanent solution to the fatigue problems of the steel bridges mentioned. At this moment, the ministry of infrastructure considers only one solution to the problem: an in situ casted and full shear connected overlay with high strength concrete. This solution presents many practical difficulties. Many of these problems can be solved by the use of prefabricated elements with a non shear connection to the steel deck. The main problem is the long execution time of the current solution. The execution time, and especially traffic congestion, can be drastically reduced by making use of prefabricated concrete slabs.

The purpose of this research is to prevent the fatigue problems during the period of using the existing non movable bridges with orthotropic steel decks, by reducing the stress peaks by making use of prefabricated concrete elements with a non shear connection.

For the two main directions, the transverse and longitudinal, various models were developed. On these models different load models were put, listed in NEN 6706. To simulate the situation, the program Maple was used based on differential equations. From this program, the results followed for the current situation, the situation with a full shear connection and a non shear connection.

The results show that for thin steel deck plates, little difference exists between a full shear connection and a non shear connection. The concrete stress in the non shear connection is twice as much as the full shear connection. However, the levels of these stresses are not such that this can be considered a problem to the concrete. In both solutions, the connection between the lower flanges of the trough profile shows inadequate stress relief for both solutions to prevent long term fatigue problems. Additional research is needed on this particular point.

It is therefore possible to use prefabricated concrete elements with a non shear connection to the steel deck.

Overlay of orthotropic steel deck bridges with prefabricated concrete elements

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Lateral-torsional buckling of coped beams with single sided angles as end connections

The lateral-torsional buckling resistance of beams depends on the support conditions. The current design provisions in Eurocode 3 are based upon full torsional restraint of standard fork support conditions. In practice coped beams are often used for beam-to-beam connections. The copes and the stiffness of the connection often do not provide full torsional restraint. This research presents recommendations for design rules for (coped) beams with single sided angles as end connection.

A numerical model is developed to investigate the influence of the support conditions on the lateral-torsional buckling resistance of beams. The model was verified with laboratory tests. This research describes the background of the numerical model, the test program, the results of the validation and the parametric study.

Based on these results recommendations for design rules are given. As an indication, reduction up to 26.8% in the elastic critical moment and 38.2% in the capacity of the beam occurred during the parametric analysis. The influence of the joints, therefore, cannot be neglected. This research is limited to (coped) beams with single sided angles as end connection.

The recommended design rule is based on the Eurocode design provisions modified by adapting the effective length factors $k_z$ and $k_w$ and the initial imperfection value $a_{LT}$ which influences the reduction factor $\tilde{f}_{LT}$.

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Structural Dynamic Analysis of a VAWT
An integrated approach with the aerodynamic forces

A Vertical Axis Wind Turbine (VAWT) has favorable characteristics as energy converter in the built environment. Contrary to the well-known, mostly large scale, vertical axis wind turbines, the VAWT doesn’t suffer loss of energy due to fluctuations in direction of the wind. For one of the most efficient types, the Turby, a sloped wind flow, which is present at roof tops of higher buildings, does even increase the power output. Although the aerodynamic design is optimized to a completely stable operating machine unexpected vibration problems occur when the wind turbine is put on top of a support structure, mast/tower and foundation.

This thesis tries to find phenomena that cause these vibrations that are observed and understand them. The research is set up from a structural dynamics point of view rather than an aerodynamic approach. Common practice for VAWT design is purely efficiency based related on aerodynamic performance. In a later phase the support structure will be designed then. In this thesis an integrated approach will be used.

A first model is based on the Euler-Bernoulli beam theory where both support structure as wind turbine axis are modeled as flexible elements. Rotation of the wind turbine axis is introduced to see whether a critical rotational speed, known from rotor dynamics, can be distinguished. Besides the investigation on the influence of the rotational speed on the dynamic behavior, the natural frequencies, a practical model is constructed for structural dynamic analysis of the complete structure.

The second model includes the aerodynamic forces and is based on the damped single-mass-spring-system. In addition to the kinematic relations of aerodynamic forces on the blades due to the wind speed and rotational velocity a third influencing parameter is introduced: the shaft vibration. The wind induced shaft vibration model thus includes the influence of the mast/tower/axis velocity into the kinematic relations of a Giromill wind turbine model. Results from the analysis show that at a certain combination of parameters very large vibrations occur.

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Semi-analytical modeling of the earthquake response of an LNG tank using the dynamic sub-structuring technique

Significant interest has been generated in recent years in the development, design and construction of liquefied natural gas (LNG) storage tanks. The growing market attention has increased the need for further improvement of the design procedures in order to reduce the costs and to increase the safety of such large structures. A typical LNG tank consists of a concrete outer cylindrical shell which encloses an inner steel tank where the liquefied gas is stored under very low temperatures.

For this thesis a model is developed, for the prediction of the dynamic response of an LNG tank under seismic loading. In contrast to the most widely used finite element method, the dynamic sub-structuring technique is introduced and the examination of the earthquake induced vibrations of an LNG tank is accomplished in the frequency domain using a semi-analytical approach. Sets of partial differential equations describing the vibrations of the slab, the wall and the dome of the LNG tank are worked out analytically and coupled together to meet displacement compatibility and force equilibrium at the various interfaces. The final solution to the problem is obtained by a developed code in FORTRAN.

Due to the large size of LNG tanks a number of additional factors are also introduced in the calculation procedure. The combined influence that the earthquake wave velocity and the interference between the horizontal and vertical seismic ground motion have on the final response of the structure are examined through a real LNG tank case. Valuable conclusions are consolidated on the above study goals and a number of recommendations concerning the future development of the model are proposed.

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Self healing in ECC materials with low content of different micro-fibres and micro-particles

The crack development in concrete structures leads to large permeability and consequently to durability problems. Controlling crack development and crack width in ordinary concrete has been a great issue for the structural community, while proposed measures seem either insufficient or impractical. For the last fifteen years, the development of Engineered Cementious Composites (ECC) has received serious attention by structural engineers. ECC are a unique type of high performance fibre reinforced cementitious composites (HPFRCC), which feature high tensile ductility with a moderate fibre fraction, typically 2% polyvinyl alcohol (PVA) fibres by volume. Special interest has been given to the capability of ECC materials to deform up to high tensile strains, regularly over 3%, while maintaining very tight crack widths, shown to be in the order of 20 to 60 μm on average.

The design of ECC enables self-healing because the material is capable to bend and crack in narrow hairlines rather than break and split in wide gaps, as the traditional cement behaves. Self-healing is a phenomenon that can repair the cracked material via chemical reactions which take place, connecting the two crack surfaces. Therefore, a point of major concern has been the improvement of the crack width tightness and the self-healing capacity in ECC. This master thesis is a part of a greater project which focuses on the enhancement of the two aforementioned properties of ECC by adding microfibers, such as steelwool and rockwool, and small particles, such as Super Absorbing Polymers (SAP). Hence, the aim of the study is to investigate experimentally the behaviour of ECC material on crack tightening and self-healing. The question that this research intends to answer is whether the addition of these extra microfibers and particles can help the ECC performance, by keeping the average crack width lower and by increasing the degree of self-healing, comparing with the plain ECC material (only with PVA fibres).

In order to study the behaviour of ECC, several mixes with different additives were prepared. A displacement-controlled four-point-bending test was used in order to verify the initial bending strength, and to pre-crack the cement specimens. Then, some of the pre-cracked specimens were cured under water and some of them in air for 28 days. Afterwards, the cured specimens were again tested in four-point-bending, and the results related to strength and stiffness were compared to those of the virgin specimens. In addition, the light-microscope was used for the measurement of crack width, and the detection of the existence, or not, of self-healing at preloaded samples. While the light-microscope proved to be a functional tool, it could not provide information concerning the type of self-healing products that were formed in the cracks. For this purpose the Environmental Scanning Electron Microscopy (ESEM) was used.

Although it is not clear yet what mechanisms are responsible for crack healing, it appeared that self-healing is unbreakably correlated with crack width. Furthermore, significant healing, followed by strength and stiffness recovery, was possible only to the water cured specimens. Upon further analysis, a comparison with the results derived from the associated project is made, concerning mixes with higher conciseness of additives. The aforesaid comparison aims towards presenting a more complete outline of the ECC self-healing behaviour.

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Nonlinear Finite Element Modeling of Cylindrical Diaphragm Wall

Sensitivity in Geometrical Imperfections and Nonsymmetrical Loading Conditions

The increased need of underground structures has lead to a wide variety of retaining structures which keep groundwater outside the area of excavation and provide dry conditions for the construction of the project. One of the technologies strongly related to the construction of large underground structures is the reinforced concrete diaphragm wall.

This thesis focused on the simulation of this type of structure with finite element program DIANA and the investigation of the following research aspects:

- The realistic simulation of the physical nonlinear behaviour of the soil and the diaphragm wall.
- The clarification of the influence that different geometrical deviations have on the behavior of the wall.
- The clarification of the influence that nonsymmetrical loading has on the behavior of the wall.
- The extend to which these considerations have to be taken into account during the design procedure.

Using the developed model linear elastic and nonlinear physical analyses were performed. For the nonlinear analysis, appropriate nonlinear properties were implemented in the model to take account for the soil stiffness and moreover, nonlinear properties were implemented to take account for the type of joints between the panels of the wall and their behavior.

The finite element model was appropriately modified by applying geometrical imperfections and nonlinear physical analyses were performed. These imperfections concerned misalignments in horizontal plane, as well as deviations of single panels from a perfectly vertical configuration. After the clarification of the geometrical imperfections' influence on the behavior of the wall, the model was appropriately modified to take account for nonsymmetrical loading conditions, by firstly assuming sloping soil strata and secondly by assuming differential soil stresses acting on the wall.

According to the outcome, it was concluded that the most critical case is the deviations of panels from a perfectly vertical configuration, while the horizontal misalignments do not have a detrimental influence. Regarding the nonsymmetrical loading conditions, it was concluded that the sloping soil strata do not influence significantly the behavior of the wall, while the differential soil stresses can increase the resulting stresses and it is recommended that it should be taken into account during the design procedure. Finally, after the determination of the most critical factors that have to be taken into account, a number of solutions were proposed in order to optimize the design procedure of these projects.

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2.

Theses Civil Engineering

Building Engineering
Progressive Collapse Indicator

Introduction
Progressive collapse is a collapse where a local failure leads to a disproportionate collapse. Different terms like initial failure, propagation of failures and disproportionate damage are important aspects of such collapses. In current design practice, a method to measure a structures’ progressive collapse sensitivity in its early design phase and taking into account all aspects of a structures collapse resistance does not exist. The objective of this research is to develop a tool that takes into account all aspects of a progressive collapse and can aid the engineer in assessing a design, in its early design stage, on progressive collapse.

The tool
At first, the initial failure is elaborated. Different events can cause the failure of elements. The probability an initiating event occurs at a certain element is different for each element. Mitigating measures can limit the chance of occurring for certain events.

The model is calculated by FEA-software. Only linear and first order calculations are considered. The evaluator of the tool determines whether or not a progressive collapse can be assumed based on four failure criteria. The first criterion is the occurrence of a local mechanism. If this occurs a progressive collapse is counted. The second condition is a strength criterion. For all elements, unity checks are calculated. If a unity check exceeds 1, the element will be removed from the model and the model is reanalysed and evaluated. The third criterion is a deformation condition. If the displacement of an element exceeds a limit it is assumed the element has failed, but will not be removed from the model. Finally, a progressive collapse is based on the amount of total damage. If the damage is disproportionate, the collapse is called a progressive collapse. If none of the above happens, no progressive collapse occurred.

A progressive collapse indicator (PCI) is calculated. One design is analyzed a certain number of iterations, resulting in an amount of progressive collapses. Then, the PCI is the number of progressive collapses, divided by the number of iterations performed. It gives an indication about the sensitivity of a design to progressive collapse.

Conclusions and recommendations
It is concluded that a tool is developed that includes all aspects of a progressive collapse, but that it can not be used in daily practice. Yet, the resulting propagating failure of elements sometimes leads to irregular results and thus needs refinement. Also, since input of a user’s design is not possible, implementations are needed to achieve that.

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Optimization of Solar Energy Usage for Dwellings with a Solar Thermal System

Introduction
Nowadays the tendency of the market for investment in a solar thermal system has improved drastically. Due to depletion of fossil fuels and a growing worldwide awareness about the degradation of our environment, the circumstances for a household to invest in a solar thermal system will improve even more in the future. The main focus of my thesis was how to adjust solar thermal systems to make them more suitable for a specific household.

Problem Definition
In practice, the configuration of a solar thermal system is chosen based upon the type of dwelling. In theory this choice is not completely justifiable because the energy usage of different households living in a same dwelling can be very diverse. The configuration of a solar thermal system should be adjusted in such a way that it is suitable for the specific household that it will be serving.

Research
My research focused on the influence of household-behavior on the configuration of a solar thermal system for dwellings. To describe the relations between household-behavior and the desired optimal configuration of a solar system a special approach was developed. The approach was divided in three phases:

1. Developing a model to determine the thermal energy demands caused by the behavior of a specific household.
1. Creating a model that simulates the performance of a solar thermal system when applied to a specific household. Also, this model had to describe the optimal configuration under the chosen circumstances.
1. Describing relations between the different households, each with their own behavior, and the associated configuration for an optimal solar thermal system.

Results
Both the technical and the financial performance of the solar thermal system are considered when looking at the differences between desired solar systems per household. When considering pure technical performance, the variation in desired configuration for specific households is very significant. These differences between the desired systems for each household are hardly ever influenced by system parameters like the position or orientation of the collector. When considering financial performance, the variation in desired configuration for specific households depends strongly on the financial climate for investment in a solar system. More favorable financial circumstances for investing in a solar thermal system lead to a greater desire to adjust the solar system to the specific household that they will serve. Vice versa in a less favorable financial situation the choice for a standard solar thermal system (based only on the type of dwelling) is made more easily.

Conclusions and Recommendations
When looking at the technical performance it is strongly recommended that in practice the configuration of the solar thermal system is adapted to the household that it will serve. The financial climate for investment is unfortunately not yet sufficient for adjusting solar thermal systems to the specific household. However, looking at the trends for the near future, adjusting the configuration of a solar system to a specific household can soon also be of great financial importance.

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Swimming pool “De Vosse”

Introduction
"De Vosse" is an outdoor swimming pool in Hillegom, The Netherlands. The pool is opened in May, June, July and August; from September until April the pool is closed. In a sunny season “De Vosse” attracts more than 50,000 visitors a year, because it’s one of the few outdoor pools in the region. To attract visitors in an extended opening season, the pool needs upgrading. When the pool will be upgraded to an indoor pool, it will attract less visitors in summer as people like to swim in the open air.

Problem definition
In this graduation project the possibilities for extending the swimming season, without losing the possibility of outdoor swimming in summer, are investigated. The study is restricted to architectural and structural solutions only. Economical feasibility is not taken into account. For the design the existing layout of “De Vosse” is used as a basis. This means the existing pool should be adapted and not replaced by a new complex.

Upgrading to an indoor pool
When the season should be extended, without making any adjustments, four problems arise:
1) visitors will get cold, 2) the energy-loss will increase, 3) the pool will get polluted by falling leaves, 4) the capacity of the dressing rooms will be insufficient. Upgrading to an indoor pool is a solution for all these problems. In order to be able to swim outside, the building needs to be openable.

Openable roof and facade
In the final design the roof can be opened by 15 sliding panels. These panels are moved to the westside of the building by wheels on rails. The eastern facade can be flapped open when rotated around its upper edge. When opened this facade works a canopy.

Structure
At the westside of the building (which has no need to be transparent) high concrete walls are erected. From there, a steel structure spans to the east side (which has a transparent facade). The roof panels are supported by this steel structure. The winches for opening the eastern facade are integrated in a separate steel structure outside the building.

Building physics
To provide thermal comfort, the building needs to be insulated. The junctures between the moving parts of the building are difficult to insulate. Where possible these junctures have rubber profiles, which are pressed together by dead weight.

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Wind-induced sound on buildings and structures

Introduction
As a result of wind flowing around a structure sound may be produced. This sound is especially annoying if it comes in the form of a clearly distinguishable tone. In recent years, an increasing number of such problems have received extended press coverage, among those the "Hoftoren" and "Strijkijzer" highrise projects, both located in the city of The Hague. Obviously, this hasn’t escaped the attention of professionals in the acoustics and building physics field. Given the high level of hindrance and the commercial cost of a project being plagued by wind-induced sounds problems, it would ideally be possible to make accurate prediction beforehand.

Research
Firstly, existing known problems involving wind-induced sound have been studied. An inquiry has been made into the state of affairs with regard to these type of problems among several leading engineering and building physics firms in the Netherlands. This was done in the form of interviews that included their approach to the problem, the possibility of and degree of certainty with such issues can be predicted. As it turned out, commonly used grid were among the more common and least understood causes of—often very loud—noise. Many of the solutions deployed in practice involve either disturbing the (upstream) flow or changing the details (level of rounding, etc.) of the structure. Subsequently, existing literature was studied, followed by wind tunnel testing of a number of one square metre samples of grids with different mesh sizes, thickness, and finishes.

Results
All tested grids could be made to produce loud tones in wind tunnel testing at the Delft University of Technology’s Open Jet Facility. Typically, a grid would only do so under a limited number of specific angles to the main flow, usually two or three different ones. Even minor deviations in the angle could lead to the tone(s) disappearing, sometimes minor differences as a result of tightening the bolds would already suffices for this to happen. In case a specimen was found to produce a tone at a certain angle, sound recording were taken at different wind speed (10, 15, 20, and 25 m/s). Tones were found at speeds as low a 8 m/s, while sound levels up to 114 dB (at 25 m/s) were measured. Analysis of the recordings revealed the existence of two different types of tones (excitation mechanisms):

1. Frequency increased with increasing wind speed. Most common at angles around 30-50 degrees (with 90 degrees defined as the grid surface perpendicular to the main flow), those often consisted of a fundamental frequency along with one or more overtones.

1. Frequency determined by the mesh size. Such tones would have a fixed frequency over a range of wind speeds, with the mesh width or grid height equal to multiples of half its wavelength. This type of tone was first identified in grids by Spruyt (1972).

Conclusions and recommendations
Based on the wind tunnel findings, using the tested grids on roofs or facades is not advisable. Further understanding of the flow in and nearby the mesh is needed to be able to develop a model and opening up the possibility of making accurate predictions. Furthermore, testing countermeasures could be useful: several exist in practice, but it is unclear whether any of those can serve as a more universal solution.

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Precast concrete cores in high-rise buildings

Structural behaviour of precast corner connections

Introduction
Over the last decades one can see a clear increase in the use of precast concrete technology in high-rise buildings. Recent high-rise projects like “Strijkijzer” en “Maastoren” pushed the limits in terms of height and construction speed. The structural stability in these projects is provided by precast elements in the façade, which results in a rather closed façade. To realise a transparent glass façade the stability can be provided by means of a core. This thesis aims at the structural design of a core composed of precast elements.

Objective
In this thesis the structural feasibility of a high-rise core composed of precast elements is studied. Since there is no literature available on the structural behaviour of precast corner connections, the focus of this thesis is on the influence of precast corner connections on the lateral deflections of a core.

Research
With a FE model of the three considered precast corner connections their structural behaviour was studied. It was concluded that the discrete connection stiffness for all three connections was comparable. The stiffness is subsequently imported as a smeared stiffness between perpendicular core walls of a 3D FE model of a high-rise core to study the influence of the corner connections on lateral deflections of the core. Due to the fact that the connection height of the SC is twice as large compared to the IHC and the IACC, the smeared stiffness of the SC is almost half of the remaining connections. So due to the fact that the IHC has twice as many corner connections compared to the SC, the smeared stiffness of the IHC is twice as large.

Conclusions
1 Of the three considered precast corner connections the IHC has the best structural behaviour since it has the highest smeared stiffness and the highest strength.
1 Compared to a monolithic corner connection the IHC shows an increase of lateral deflections of just 3.3 %. The SC results in an increase of 5.9 %.
1 Since the strength of the IACC is lower than the shear stresses in the core of the reference project, the IACC is not suitable to be applied in this high-rise core.

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Theses Civil Engineering

*Hydraulic & Geo Engineering*
Uncertainty analysis of the mud infill prediction of the Olokola LNG approach channel

For a proposed liquefied natural gas export facility, Olokola LNG (OKLNG), located at the western limits of the Niger Delta in Nigeria a 10 km long and 17 m deep approach channel is designed for tankers to reach the terminal at the shoreline. Mud is expected to be deposited in the channel because of the persistent swell climate which mobilizes mud on the seabed. In order to assess operational costs and dredging requirements predictions of the infill rates are required which realistically include possible uncertainties.

An extensive study on the sediment characteristics in the OKLNG area was conducted. Indications were found that the sediment in the water column at OKLNG is unflocculated or poorly flocculated. If confirmed, this would be very unusual and in fact unknown to the best knowledge of the consulted experts for this thesis and in the studied literature. Cohesive sediment in the marine environment is typically flocculated.

In terms of identifying and reducing uncertainties, the sediment state in the water column was found to be the most important uncertainty for the prediction of the mud infill; it has a large influence on the sedimentation mechanism and quantities. Because of this large uncertainty, and in the absence of definitive data, it was decided to investigate the implications of both unflocculated (scenario 1) and flocculated (scenario 2) sediment.

If the sediment is found to be unflocculated, the infill rate is a factor 10 higher than when it is flocculated. Next the sediment concentrations near the bottom are not precisely known, while this information is required to properly predict the mud infill of the channel. All other uncertainties are of minor importance in comparison to the mentioned two.

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Offshore wind parks promise to become an important source of energy in the near future. To make economic use of offshore wind energy possible, foundation structures with minimum costs, but sufficient stiffness have to be designed. The horizontal loads from wind, waves and currents must be in equilibrium with the reaction of the soil. One foundation concept that has often been realized recently is the monopile. The traditional monopile is an open ended large diameter steel cylindrical pile driven into the soil.

In the offshore energy industry the soil in horizontal pile-soil interaction problems is normally modeled by means of multi-linear soil springs, the so called p-y curves developed by the American Petroleum Institute (API). The p-y curves of the API are verified for piles with a diameter of up to 2.0 m.

It was expected that for the design of the large diameter monopile foundations the API method would overestimate the horizontal pile displacements:

• For large diameter piles the shearing resistance in the pile tip may play an important role. This effect is not included in the API method.
• Large diameter piles have more shear stresses around and along the pile shaft due to the larger pile surface. This effect is also not included in the API method.

However, the API does not take the interaction between the soil springs into account for the large diameter monopile foundation. This effect results in larger horizontal pile displacements.

To study on these effects the results of the API method are compared with the results of 3D Finite Element (FE) calculations for both a small diameter foundation pile (D = 1.0 m) and a large diameter monopile foundation (D = 4.3 m). Both piles are embedded 25 m in a homogeneous layer of sand. A representative static horizontal load and bending moment are applied to the pile. For the small diameter foundation pile the results of the 3D FEM should be comparable with the results of the p-y method.

From the calculations it is concluded that the horizontal pile displacements of the 3D FEM are larger than the horizontal pile displacements of the p-y method (API) for both the small and the large diameter foundation pile. From the results it is concluded that the soil modeled with the p-y method overestimates the soil stiffness, it takes the soil stiffness linear with depth instead of with the square root of depth.

The results of the 3D FEM and the results of the p-y method should be comparable for the small diameter foundation pile. Therefore the formulae of the p-y method is modified. The soil stiffness factor k is replaced by the soil stiffness factor $k^*$, which is reduced for the non-linearity of the soil stiffness. Next, the API method is fitted to the FE results.

When the results are comparable for the small diameter pile, the pile diameter is increased. It is concluded that for the large diameter foundation pile the horizontal pile displacements calculated with the 3D FEM are smaller than the horizontal pile displacements calculated with the modified p-y method. It is recommended to do a full-scale pile test for a large diameter monopile foundation to validate the results of the 3D Finite Element Model.

Lateral behavior of large diameter offshore monopile foundations for wind turbines

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Pre-stressed diaphragm walls

Underground construction is one of the ways to optimize use of space in urban areas. Presence of historical buildings in the immediate vicinity introduces the risk of damage. The damage depends on the settlement due the construction of the underground structure and the quality of the buildings. These settlements are related to the deformation of the cofferdam wall. Reduction of deformation of a cofferdam wall is investigated in this study and in particular the feasibility of using pre-stressed diaphragm walls.

The case for this research is project "Spoorzone Delft". This is a tunnel which will be built with the cut & cover construction method using diaphragm walls. The excavation depth of the tunnel is 11m below surface level. The horizontal distance towards the buildings is sometimes limited to 3m. Restrictions on the deformation of the buildings have resulted into a maximum allowed horizontal displacement of 20mm on the cofferdam wall.

Basic design with 1.0 m thick diaphragm wall doesn't meet above mentioned requirements without additional measures. The requirements can be met by increasing the stiffness of the diaphragm wall and / or the use of temporary struts, during excavation.

Stiffness increase of the diaphragm wall is foreseen by means of using eccentric pre-stressing of the diaphragm wall. The pre-tension gives a stiffer diaphragm wall, thus reducing displacements. The eccentricity introduces an bending moment in the diaphragm wall working directly against bending moment forthcoming out of the loads. This reduction is limited to 30% due to the hindered deformation caused by the surrounding soil.

Displacement at the top of the diaphragm wall, which is half of the displacement allowed, is not limited by prestressing. Therefore the use of pre-stressed struts at the top of the diaphragm walls is still needed to limit horizontal displacements.

Design of pre-stressed diaphragm walls has been compared to a design using normal diaphragm walls including the use of pre-stressed struts.

The technical comparison of the designs shows that both application of pre-stressing diaphragm wall and using pre-stressed struts are resulting into reductions of 25% in present displacement. By applying pre-stressed struts, the moments in the diaphragm wall are less compared to pre-stressing diaphragm walls. Both options include risks. Pre-stressing diaphragm walls however has more options for risk reduction compared to the use of struts. Furthermore, damage resulting from strut failure are higher than pre-stressing. The innovative character of pre-stressing d-walls results in relatively many unknown factors which could affect the tension in diaphragm walls. With a further detailing of the design these unknowns could be practically overcome.

The use of an eccentric pre-stressing in diaphragm walls with struts at the top is an effective method to minimize the displacement of a diaphragm wall, in case damage prevention of the buildings required and the available width is restricted.

The use of pre-stressed diaphragm wall is beneficial from a cofferdam width increasing 20m.

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Dune erosion along curved coastlines

The most densely populated and economical most valuable areas in The Netherlands lie below mean sea level. These areas are protected against the sea by a joint coastal dune system. The vital importance of this dune system is reflected in the extensive collection of Dutch legal regulations that ensure the safety level of the dunes.

The assessment methods currently prescribed by these regulations are strictly speaking only valid for infinitely long, uniform and straight coasts. The Dutch coast with its curvatures, islands and estuaries does not meet these prerequisites. The wide application of these assessment methods is mainly justified due to intentional overestimation of the expected dune erosion.

In virtue of the expected climate change and corresponding sea level rise, an effective and reliable coastal management becomes increasingly important. Dutch water management authorities therefore commissioned the development of a renewed probabilistic assessment method for dunes. Such method will provide a more accurate and elegant way of dealing with the large number of uncertainties involved in the dune erosion process.

The original assessment methods for dunes along the Dutch coast are extended with a computational method for additional erosion along convex coastlines. This method is based on a limited data analysis, which resulted in a cautious guideline. It is therefore expected that current regulations underestimate the influence of coastal curvatures on the amount of dune erosion.

In context of the development of a probabilistic assessment method for dunes, little is known about the relevance of coastal curvatures. It is questioned if longshore phenomena in general and coastal curvatures in particular should be incorporated in the newly developed assessment methods.

A probabilistic model set-up is created using the numerical semi-two-dimensional dune erosion model DuroSTA and a Monte Carlo routine. Using this probabilistic model set-up, series of computations with varying coastal curvatures and incident wave angles are made for different types of relevant probabilistic hydraulic conditions. From the results the influence of coastal curvatures on the erosion volumes, and thus the retreat distances and probability of failure, is obtained. The results are compared to current regulations. The model set-up is also used to investigate the physical and probabilistic importance of the model parameters with respect to the model result.

Results show that curvatures found along the Dutch coast can increase the 1/4,000 year retreat distance over 100%. In comparison, the maximum additional retreat distance to account for coastal curvatures is according to current regulations less than 20% in the observed situations. Furthermore the physical importance with respect to the amount of dune erosion of the sediment diameter increases along curved coastlines due to the more efficient transport of suspended sediments. From a probabilistic perspective the storm surge level gains importance due to the common formulation of the correlation between the storm surge level, the significant wave height and peak wave period.

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Spatial distribution of wave overtopping

The goal of this master thesis is to describe the spatial distribution of the wave overtopping discharge over and behind the crest of a coastal defence structure. The influence of the most relevant parameters on this process is explored. This research has been performed by means of a physical model. The following relevant parameters were varied during the experiments to consider their influence on the spatial distribution of the wave overtopping discharge: wave height, wave steepness, water depth, crest height and wave spectrum. Four different types of wave overtopping discharges were measured in this research: total wave overtopping discharge, wave overtopping discharge directly behind the crest, wave overtopping discharge over impermeable backfill and wave overtopping discharge over permeable backfill.

The total overtopping discharge flows over the crest of the breakwater and is divided in two components: the infiltrated discharge into the crest and the overtopping discharge directly behind the crest. A method to describe this distribution is defined. This method includes the influence of the wave height, wave length and crest height. The spatial distribution of the wave overtopping discharge behind the crest depends on the permeability of the backfill. For an impermeable backfill with a slope of 3% towards the breakwater, the overtopping discharge at every point behind the breakwater is divided in two parts: one part flows back over the impermeable backfill under the influence of gravity and the other part passes the point and travels further away from the breakwater.

The final relation between the reduction factor (ratio between the overtopping discharge at a certain distance behind the crest and the overtopping discharge directly behind the crest) and the distance behind the crest was found to depend on a dimensionless presentation of the wave energy flux. For a permeable backfill, the overtopping discharge at every point behind the breakwater is divided in two parts: one part infiltrates into the backfill and the other part passes the point and travels further away from the breakwater. The influence of the wave energy flux on the relation between the reduction factor and the distance behind the crest was found to be smaller than for an impermeable backfill.

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Dit onderzoek voor de gemeente Schiermonnikoog naar de morfologische ontwikkelingen in het Friesche Zeegat en de gevolgen daarvan voor de bevaarbaarheid van de vaarroute Lauwersoog – Schiermonnikoog heeft tot de volgende onderzoeksvragen geleid:

Wat zijn de mogelijkheden tot het doen van een voorspelling naar die ontwikkelingen voor de komende decennia en wat zijn de gevolgen voor de bevaarbaarheid. In hoeverre is het mogelijk een vaarroute te creëren naar een plek dichterbij het dorp.

Door middel van theorie, eerdere onderzoeken en peildata zijn er een hypothesen geformuleerd. Deze hypothesen zijn met een semi-empirische benadering en een Delft3D model (enkel hydrodynamisch met initiële sedimentatie en erosie) getoetst op de juistheid.

Hypothese I is dat de afsluiting van de Lauwerszee tot gevolg heeft gehad dat het bekken uit evenwicht is, maar op dit moment het evenwicht zich aan het herstellen is. Daarmee komt het wantij weer richting het westen met als gevolg dat de verzanding in de vaarroute toeneemt. Dit kan op basis van de semi-empirische vergelijkingen en het scenario in Delft 3D, waarbij de natuur haar gang gaat, niet onomstotelijk bewezen worden. Wat wel duidelijk wordt uit het scenario is dat de verzanding van de Groote Siege doorgaat met beperkte bereikbaarheid van het eiland als mogelijk gevolg.

Hypothese II is dat de effecten van de afsluiting onvoldoende zijn meegenomen bij het bepalen van de huidige locatie. Er bestaan mogelijkheden om een nieuwe route dichterbij het dorp te ontwikkelen. Deze hypothese wordt gestaafd door de uitkomsten van het scenario waarin de natuur haar gang gaat en het scenario waarbij rigoures ingegrepen wordt. Een natuurlijke vaarroute naar een locatie dichterbij het eiland is een utopie. Wel is het mogelijk om een geul te baggeren naar de jachthaven en deze open te houden.

Hypothese III is dat stabilisatie van de huidige vaarroute door middel van een aantal maatregelen mogelijk is. Dit wordt aangetoond met het scenario waarin diverse maatregelen getoetst worden. Deze maatregelen variëren van het weghalen van drempels in de Groote Siege tot het verhogen van de wanden van de geulen met natuurlijke oplossingen (oester/mosselbanken).

De maatregelen hebben allemaal een positieve invloed op de bevaarbaarheid, echter het teruggaan naar het baggerbeleid van voor 2003 levert het meest optimale resultaat.

De conclusie is tweeledig. Op langere termijn verandert de Groote Siege en wordt het eiland beperkt bereikbaar wanneer maatregelen tegen deze verzanding uitblijven. Deze ontwikkelingen vragen om een verder onderzoek naar de gevolgen op langere termijn gecombineerd met de mogelijkheid om een kunstmatige geul aan te leggen naar de jachthaven. Op korte termijn moeten er maatregelen genomen worden waardoor de verdeling van het water in het bekken een positiever effect heeft op de vaarroute en de Groote Siege in het bijzonder. Het is onmogelijk om een vaarroute te vinden waarbij baggerwerkzaamheden niet nodig zijn. Het wad is een dynamische omgeving waarbij de natuur leidend is. De uiteindelijke effecten van ingrepen zijn daardoor altijd met een onzekerheid omgeven. Aanbevolen wordt om een uitgebreider onderzoek met meer factoren voor de lange termijn te starten. Op korte termijn is een nieuwe strategie te bepalen voor het bevaarbaar houden van de vaarroute.

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Piled and reinforced embankments: Comparing scale model tests and theory

The number of piled and reinforced embankment projects in the Netherlands is growing. For this reason a Dutch code, CUR159B, is created in order to improve uniformity in design.

The Dutch design code replicates major parts of the German design code, EBGEO. In particular, the theoretical behaviour of the geosynthetic reinforcement (GR).

An important difference between CUR159B and EBGEO is the criterion for embankment height, which is allowed smaller for the Dutch code.

An important research question is whether this smaller embankment height influences the load distribution and the behaviour of the GR. In addition, differences in embankment material, surcharge load and number of reinforcement layers can influence the load distribution.

For these unknown effects, both theoretical and experimental research can provide the answers.

This research shows an extensive analysis on the design models EBGEO and BS8006. In particular, the design of the GR is studied. Furthermore, some improvements to these design models are suggested to eliminate the found limitations.

A test set-up is designed which allows to measure the complete load distribution as well as the strains and deformations of the GR. This test set-up is very suitable for comparing the measurements with the different tests and with the (improved) design models.

Three tests have been successfully carried out and been compared to both each other and to the design models. It shows some interesting results on arching effects, dilatancy and strains and deformations of the reinforcement. From this research is concluded that the CUR159B is very complete, but still can be improved.

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Connecting Maasvlakte 1 & 2

Research on changes in flow conditions due to the connection of the Maasvlakte 1 & 2 harbor basins and the nautical consequences.

The basins of Maasvlakte 1 and the future Maasvlakte 2 ports will be connected by extending the Yangtzehaven in westward direction. This connection consists of a preliminary stage, the so called temporary connection, during which a canal is dug that serves as a cooling water outlet for the E-on power plant. After the preliminary stage the connection will be completed through which Maasvlakte 2 will be accessible for navigation. The volume of water that enters the port each tidal period is considerably increased by extending the Maasvlakte 1 basins with the Maasvlakte 2 basins. This causes a sudden change in the flow pattern in the waterways towards Maasvlakte 2: the Yangtzehaven and the Papegaaiebek. Pilots and boat masters will have to adapt to this new situation. The main objective of the master thesis is to determine these changes in the flow patterns, to find out whether these changes have adverse consequences for the shipping traffic and to determine what measures might be needed to anticipate to the new situation. Sub objectives should answer the questions whether a temporary connection at a lower cost is possible, whether an alternative solution for the temporary connection improves the flow conditions for the navigation and what the favourable conditions are to realize the connection. Therefor a comparison is made between both stages of the connection and the situation before it. These three situations are modelled with the three dimensional numerical model Delft3D-FLOW.

The temporary connection causes a tidal movement in and out Maasvlakte 2 which results in a zone with increased flow velocities in the Yangtzehaven when the tide is out. The deceleration of the flow causes it to become unstable, resulting in eddy formation in the Yangtzehaven. This will probably influence the accessibility of the Euromax terminal, as it will be harder to control the mooring speed under these conditions. The situation in which Maasvlakte 1 and Maasvlakte 2 are fully connected is indicative for the flow conditions at the beginning of the Yangtzehaven and around the Papegaaiebek because of a further increase of the tidal volume. Vessels make a U-turn at the Papegaaiebek to enter Maasvlakte 2 and due to the complex stratified flow conditions it is possible that the orientation of the forces on the vessels is different for various drafts. Extra attention must be paid to the navigation around the Papegaaiebek in the future and possibly extra tugs will have to be put into service during extreme conditions. By developing and comparing alternative solutions for the temporary connection it is concluded that the temporary connection can most probably not be realized at a lower cost, but it is possible to create more favourable conditions for the navigation by relatively simple adjustments (i.e. widen, deepen or creating a more graduate inflow). By introducing a moored ship to the flow model it is concluded that its presence has a notable influence on the flow pattern in the Yangtzehaven; more eddies are formed but the flow velocities perpendicular to the Euromax quay are reduced. Forces and moments on the ship are within the tolerances of the mooring installations but variations due to the zone with increased flow velocities are an indication that cargo handling might slow down. The activities on the closure of the last gap in the outer contour of Maasvlakte 2 and the realisation of the cooling water canal need to be well prepared and geared to one another to ensure that the connection procedure runs smoothly and to prevent the water in the Maasvlakte 2 basins to rise too high which will hinder the discharge of the cooling water. Ideal conditions for the connection are flood during neap tide because of the low flow velocities directed towards Maasvlakte 2 and winter because of the cooler water in the port basins which is advantageous for the cooling water demands.

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Modelling of Installation Effect of Driven Piles by Hypoplasticity

Driven piles have been selected as a powerful technique to deal with the construction on soft soils. Many case studies have been carried out to capture the soil behaviour during the pile installation, both numerical and experimental methods. However, the results of the numerical method could not completely reproduce the experimental results. The main reason could be due to the constitutive model that can not capture entirely the complicated soil behaviour during the pile installation.

Therefore, this study aims to investigate the soil behaviour under the installation effect of driven piles with respect to the pile jacking and cyclic loading effect, using an advanced soil model - Hypoplasticicty. Here, the installation effect of driven piles is modelled by using a conventional small strain analysis in Plaxis 2D finite element code, in which the prescribed displacements are applied at the pile-soil boundary. A centrifuge pile test is chosen in order to validate the numerical simulations.

The numerical results show that for the pile jacking method the void ratio increases close to the pile shaft while at a further distance the soil body is compacted. Moreover, the horizontal stress decreases by moving far away from the pile. There is also an increase of the horizontal stress leading to an increase of the shear stress along the pile shaft. These results show the very good agreements with the centrifuge test and other experimental as well as numerical results. On the other hand, for the cyclic loading effect it show a promising result in comparison with the soil response found in reality and other numerical simulations. Due to the cyclic loading, a compaction zone appears close to the pile shaft leading to a reduction of stresses around the pile.

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The influence of an Ecobeach PEM on beach development

Since the end of 2006 in the Netherlands a test is going on with a passive beach drainage system called Ecobeach. The system consists of vertical draining tubes with a length of 2.0 m called PEMs (Pressure Equalizing Modules). Under the surface level, every 100 m a row of PEMs is installed between the high and low waterline. Ecobeach is a Danish invention and the inventor claims that at beaches at different places around the world the volume of sand is increased thanks to the PEMs. This “drainage system” differs from other beach drainage systems in the way that normally horizontal drains are being placed under the beach, connected by a pump.

When the Dutch test started very little was known about the functioning of the PEM system. For this reason scientific research to the PEMs was being started in September 2008. First the situation in the test area is examined. The beach, and especially the swash zone, is a complex area, influenced by tides, waves, sediment transport and groundwater flows.

Five hypotheses are formulated of the influence PEMs can have on their environment. If a PEM can influence the groundwater behaviour in its direct vicinity, a process can be initiated which has an effect on the total beach. The initial events, caused directly by the PEMs, have to be studied in the field to make clear if the different hypothesised processes are realistic. Moreover consequences of the possible processes initiated by the PEMs should be recognized if anything happens. For this reason a fieldwork is executed in August-September 2009. Measurement results of the groundwater behaviour in the vicinity of PEMs show that some hypotheses are unlikely, and some are still questionable. An analysis of the sediment in and around the test area makes clear that possibly a process is going on in the Ecobeach test area, which could be a result of the PEMs. Because this study will be continued, this report shows an initial study to a very complex system. It shows the setup of a large study, interesting analysis methods and surprising results. Nevertheless it will lead sometimes to new questions.
In the past (±1980), there have been problems with pile foundations in the area of Almere, because the expected (calculated) bearing capacity was not reached. This was the inducement to adapt the method for calculation of bearing capacity of foundation piles in the municipality of Almere and is hereby the only municipality with a deviated calculation method in the Netherlands. (In this report the calculation method is named NEN-Almere.) The cause of underestimating the bearing capacity is unclear.

Lateral heterogeneous composition of the soil and reduction of bearing capacity of the soil due to installation of displacement piles are two possible causes.

Unclearness about the cause, of underestimating the bearing capacity, has led to review the calculation method that is used nowadays in the municipality of Almere.

The starting point of the review and thesis is to note the underestimating of the bearing capacity when the expected bearing capacity according to NEN 6743-1 and the results from pile load tests on precast concrete piles are compared. The calculation method NEN-Almere will also be investigated to determine if the deviated calculation method leads to better accordance with pile load test results.

If the bearing capacity according to NEN 6743-1 is overestimating the pile load test result, the possible cause has to be found. Besides pile load test results, also CPT results are used to answer this question. Finally, regarding the answers of the previous questions, the last question can be answered if the NEN-Almere should be adapted or not.

Apart the last question the most important conclusions are:

- Both NEN-6743-1 and NEN-Almere (excl. extra reduction of 25%) are overestimating the bearing capacity of a precast concrete pile.
- Reduction of strength of the soil at the top layer of the Pleistocene could occur due to installation of the pile and is caused by horizontal relaxation of overconsolidated soil. Due to relaxation of the soil, cone resistance of the top layer, measured with CPT, were reduced till a value of 10 MPa.
- The composition of soil (lateral) could vary locally in area of Almere and will therefore cause a difference in bearing capacity at the spot of the pile and the location of the CPT, which is usually carried out at a distance from the pile.

Subsequent to the stated conclusions it can be recommended that NEN-Almere should not be used anymore. New calculation methods, which are based on NEN 6743-1, are proposed and evaluated. Two calculation methods where found to be in good accordance with the results of nine pile load test results if compared with the results of NEN-6743-1 and NEN-Almere. The two calculation methods are:

1. Calculation method according to NEN-6743-1 and
   - Reduction of point bearing capacity of 30 % ($\alpha_p = 0,7$).
2. Calculation method according to NEN-6743-1 and
   - Limiting cone resistance to a maximum of 10 MPa in at top of the Pleistocene
   - No reduction of point bearing capacity ($\alpha_p = 1,0$) if the pile tip is less than $8D_{eq}$ in sand.
   - Reduction of point bearing capacity of 30 % ($\alpha_p = 0,7$), if the pile tip is more than $8D_{eq}$ in sand.

A preference for one of the calculation methods is not given.

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Op moment van schrijven is de aanleg van Maasvlakte 2 in volle gang. Het masterplan is echter nog in ontwikkeling, maar steeds meer keuzes worden vastgelegd. Daarom moet onderzocht worden of er op Maasvlakte 2 een ruimteclaim voor een Binnenvaart Service Centrum (BSC) moet blijven staan. Een BSC is een neutrale binnenvaartterminal waar een deel van de binnenvaartcontainers van de verschillende zeeterminals worden afgehandeld. Het BSC heeft een aantal functies. Het BSC vangt de kleine call sizes af voor de terminals. Het BSC vermindert het hoppen voor de binnenvaart. Het BSC biedt een uitwijkmoelijkheid wanneer er calamiteiten op de terminal optreden. En daarnaast kan een BSC een deel van de empty’s (lege containers) afhandelen.

Het Concept BSC is benaderd vanuit de optiek van de terminaloperators. Hierbij is de situatie bekeken waarbij de terminals de maximale overslagcapaciteit bereiken. Vervolgens is gesimuleerd hoe groot de extra overslagcapaciteit is wanneer kleine call sizes naar een BSC worden gestuurd. Hieruit volgt dat wanneer alle calls kleiner dan 25 TEU naar een BSC worden gestuurd, er 5% meer volume overgeslagen kan worden. Voor elke TEU die via het BSC overgeslagen wordt kan 5 TEU extra zeevolume aan de terminal worden overgeslagen. Wanneer alle calls kleiner dan 50 TEU naar het BSC worden gestuurd is deze verhouding lager. Hierbij kan voor elke TEU over het BSC 1,65 TUE extra zeevolume worden overgeslagen. Vervolgens is het BSC voor een stuurcriterium van 25 TEU verder uitgewerkt. Dit BSC moet een capaciteit hebben van 430.000 TEU. Hieruit volgt dat er 6 ligplaatsen nodig zijn, dit is een kadelengte van 554m. 554m is 3% extra ondiepe kadelengte waardoor 5% extra overgeslagen kan worden aan de diepe zeekade.

Voor dit BSC zijn een aantal mogelijke locaties bekeken. Uit de MCA volgt dat de Hartelhaven de meest geschikte locatie is voor het BSC. Voor deze locatie is een ontwerp gemaakt met Wide Span Gantry kranen, en transport per MTS. Daarnaast is een ontwerp gemaakt voor een willekeurige locatie op Maasvlakte 2. Hierbij is geprobeerd het ontwerp zo compact mogelijk te houden, zodat het op verschillende plaatsen ingepast zou kunnen worden. Dit ontwerp is uitgevoerd met insteekhavens en het transport vind plaats per AGV. Voor beide ontwerpen zijn de kosten bepaald. De kosten voor het overslaan van 1 TEU op het conventionele BSC zijn €47,04. Voor het moderne ontwerp liggen de kosten hoger namelijk €47,38 per TEU. De conventionele variant is goedkoper omdat op de locatie in de Hartelhaven al voorzieningen aanwezig zijn. Voor de exploitatie gaat de voorkeur uit naar een coöperatie van de stuwadoors, want wanneer zij meedragen in de investeringskosten zullen zij ook gebruik gaan maken van het BSC.

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Theses Civil Engineering

Watermanagement
Aquifer Thermal Energy Storage (ATES) uses the subsurface to store cold and warm water in order to use this thermal energy for cooling and heating of buildings. In Amsterdam this technique is being used more frequently in the last couple of years, caused by the increased demand for sustainable technologies and the available optimal aquifer conditions below the city. This reports answers questions relating to heterogeneity, salt mixing, thermal pollution, cooperation, and arranging of ATES systems. This is done using a flow and transport groundwater model, which takes into account density and viscosity variations, as a result of temperature and salinity changes. Questions relating to heterogeneity and salinity are answered by means of a case study of the Stopera building, which had an ATES system installed in 2002. The buildings around the Dam Square are used as a case to simulate a hypothetical collective system, which is compared to a hypothetical case with individual systems. Heterogeneity is modeled in two ways: by simulation of a gravel layer, which was found in drillings, and by geostatistically generating heterogeneities in the horizontal plane. When a gravel layer is present, the retrieved energy will be up to 10% lower, compared to the homogeneous situation. This loss in efficiency can be reduced by installing a blind piece of casing opposite this layer. This decreases the maximum efficiency loss to 5%. When heterogeneities are generated in the horizontal plane, the retrieved temperatures and energy amounts seem to be independent of these heterogeneities. Some ranges of heterogeneities were tested, which showed that only for large ranges, in the order of the distance between the warm and cold well, there is a decline of 3% in efficiency. ATES systems not only pump water; along with the water they also pump salt, back and forth between the screens. This will inevitably mix the salt and change the original vertical salt gradient into a horizontal one. It is shown that this effect remains within 100 m from the wells. The overall energy efficiency of a collective system is higher than that of individual systems. Also, less water needs to be pumped to regenerate the aquifer. Fewer wells need to be installed, as each well is used to its maximum capacity. Another benefit of collective ATES systems is that when different connected buildings need cooling and heating at the same time, thermal energy will be exchanged between the buildings without intervention of the subsurface. Monowells are an interesting alternative for collective systems in a thick aquifer, in cases with little space to install the wells, as in historic city centers. Monowells can be placed wherever they are needed, as the horizontal influence of the wells is minimal, while the wells can still have a large capacity because of the thick aquifer in Amsterdam. The efficiency is a little lower than doublets however, and large hydrological effects can take place when many wells pump simultaneously in the top and bottom of an aquifer. The NYSE Euronext building used the subsurface for its cooling from 1989 to 1999, heating the aquifer. In 2000 the system was abandoned, because the extracted cooling water started raising in temperature. The warm bubble, however, is still present in the subsurface, where it will affect future ATES below the Dam Square. Finally, a MATLAB model is developed to assess different arrangements of ATES wells. A situation in which the warm and cold wells are placed in lanes is compared to a situation with no placement restrictions. If the most densely built area of Amsterdam, the Zuidas, was to use ATES for its entire thermal energy need, lane enforcement has its benefits: more buildings can use ATES and the wells will have a higher efficiency, while the distance between buildings and their wells is equal for both simulations. For all less densely built areas, the 'laissez-faire’ situation and lane enforcement both have their specific advantages. In both situations all buildings can install an ATES system. The 'laissez-faire’ situation will reduce installed pipe length, while the performance of the situation with lanes is slightly higher.

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Lake Lauwersmeer is located in the north of the Netherlands between the provinces of Friesland and Groningen. Discharge measurements of the different inflows into the lake and the major outflow into the Waddenzee are continuously performed and used for different studies to the water system. In this MSc research it is attempted to investigate measurement errors by correlating the discharges to the error in the water balance. Revealed error sources are validated by field measurements, amongst which two experimental discharge measurement techniques.

Two water balance periods are studied, chosen on basis of, amongst others, the availability of data:
1. March 31, 2003 – March 30, 2004;

The study of these water balances learned us the following:

a. In the first period discharge measurements at the outflow of the lake into the Waddenzee produced a relatively large systematic error. This error disappeared in between the two periods, probably due to maintenance works;

b. Spurious errors were found in the gauging station of Zoutkamp. It is shown that these errors are mainly caused by wind forcing changing the flow profile and so the depth at which the average flow velocity should be measured. These errors become more important in cases where there is no discharge through the lake.

With respect to the experimental measurement techniques the following can be concluded:

a. Dilution gauging performs badly as measurement technique in situations of laminar or low turbulent flow, even when turbulence is increased artificially by a bubble screen. This method is predominantly of use in small, shallow and highly turbulent rivers where the mixing length of the introduced salt is way smaller;

The integrating rising bubble technique proofed itself a promising technique for discharge measurement in canal reaches with a more or less rectangular cross-section (e.g. sluices, irrigation canals and drainage canals). In this method the displacement of a rising air bubble released at the bottom of the canal is measured. The bubble ‘integrates’ in fact the flow velocity over the depth. The specific discharge at the point where the bubble is released is found by multiplying the displacement by the rising velocity of the air bubble. When releasing air bubbles over the full width of the canal one can integrate these specific discharges to the total discharge of the canal. The displacements at a certain point in time can be measured by photographing the water surface. Improvement of computing and photographing techniques over the last decades make it easier to photogrammetrically correct the pictures to obtain the correct distances. It is shown that the rising velocities can be found best when releasing air bubbles from the tube at the bottom with a pressure just higher than the water pressure at the bottom.
From rainfall to runoff: Hydrological processes resulting in threshold behaviour and low rainwater contribution in rapid subsurface flow.

Rapid subsurface flow at the hillslope scale is a dominant outflow process in many steep, humid watersheds during rain storms. This process is subject to threshold behaviour, where a certain amount of precipitation needs to be added to the hillslope to initiate rapid subsurface flow. Preferential flowpaths as pipes, cracks or fissures where hydraulic conductivities are large, make rapid flow between the hillslope and the stream possible. Interestingly, the subsurface flow is dominated by pre-event or ‘old’ water instead of event or ‘new’ water. In this research, the hydrological processes resulting in the observed threshold behaviour and low new water contribution in subsurface flow are identified and quantified in the Maisbich-catchment in Luxembourg. Along the Maisbich several distinct subsurface flow contributions to the stream have been observed, which are called ‘sources’. Just upstream of one of these sources is the studied plot (150 m²), where eight piezometers are installed. For five days the plot was sprinkled for one hour with 9 mm of artificial rain. Salt and deuterium were added to the sprinkled water as an artificial tracer to distinguish flow pathways and to quantify the new water contribution in the source. Besides the sprinkling, an injection experiment in the most uphill piezometer has been carried out. A combination of hydrometric and hydrochemical measurements and Electrical Resistivity Tomography (ERT) provided the information for the data analysis. Results from the data analysis have been translated into a conceptual lumped model of the significant subsurface hydrological processes, simulating the outflow from the source. The main hydrological processes that were identified and modeled are the unsaturated zone storage, rapid subsurface flow and slow matrix flow. Also a 2D hydrological model of the hillslope has been made to interpret the ERT-data more accurately and give information on the saturation, the salt concentration and heterogeneities in the subsurface of the plot.

The data analysis of the sprinkling experiment and the conceptual model showed that preferential flow is the main process responsible for subsurface flow at the plot-scale during high flow and matrix flow during low flow. However, heterogeneity makes it difficult to predict the direction and amount of subsurface flow at a small scale, but also to identify hydrological processes that are valid on plot-scale. During rain storms, water is stored in both the unsaturated and the saturated zone. Only 24% of the rain water preferentially infiltrates to the saturated zone and mixes with water flowing to the source. As the unsaturated zone becomes more and more saturated, old water is replaced by new water and flows to the saturated zone. It is not until 23 mm of rain has fallen before a rapid subsurface flow of 14 times the baseflow is initiated, for ~90% consisting of old water, because the new water had to replace the stored old water first. This threshold is mainly dependent on the depth of the unsaturated zone, which is in its turn dependent on schist topography, which is the mainly present soil type. The threshold is reached by water that percolated from the unsaturated zone or by rapid subsurface flow from uphill, filling up the saturated zone until the threshold is reached and rapid subsurface flow is continued downhill. In this way a network of connected saturated areas is created, resulting in a large increase in subsurface flow. The more areas become connected, the larger the increase in subsurface flow is. The initial hydrological conditions and the depth of the unsaturated zone influence the extent of the threshold. The wetter the soil and the smaller the unsaturated zone is, the earlier the threshold is reached and rapid subsurface flow is initiated. This means that even small rain events could initiate a large increase in subsurface flow.

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Validation Microsimulation Models for Rail Traffic

The goal of the MSc research is calibration and validation of the Rail Traffic Model OpenTrack. OpenTrack is a microsimulation model for rail traffic. Input for the model are infrastructure characteristics, signalling, rolling stock characteristics, and the timetable. The calibration addresses rolling stock characteristics, like train resistance, traction-speed diagram, and the performance parameter. The correct use of the performance parameter is critical for calibration. The performance parameter makes it possible to simulate the broad range of possible trip times in OpenTrack.

The calibration is based upon real trip times measured on the Dutch railway corridor Rotterdam - Dordrecht. The trip times are based on train detection data provided by the TNV system. The data has been extracted using TNV-Conflict. The distribution of the trip times is investigated; the goal is to implement the same trip time distribution in the output of the OpenTrack model. The advanced possibilities of the performance parameter makes it possible to implement settings for the distribution of train performance and hence trip times. The research showed that a calibration of OpenTrack is possible using this data. However, the required settings of the performance parameter vary considerably, depending on the distance between train stations and the type of rolling stock. Therefore it was not possible to determine a general valid setting for the performance parameter.

In this research, the difference between the simulation results of minimal trip times between stations and the minimal trip times measured on the Dutch tracks for short distances, was a striking outcome. The simulation results are higher than the measured ones. Therefore calibration of OpenTrack for short distances was of poor quality. Further research on this issue is recommended based on a comparison of realized and simulated speed profiles rather than trip times.

Although calibration is possible, the implementation of the performance parameter in the model does not always correspond with the behaviour of the train drivers. Instead of limiting the performance overall, which is the method used in the model, the drivers may also let their trains run on full performance the first half of the trip and switch off the train engine some kilometres before the point where braking action is required. Besides driver behaviour, braking characteristics of the rolling stock can also play a great role if there are differences between the simulation results of the model and the real travelling times.

Train resistance proved to be a parameter of little influence on the simulation results. For other parameters, the effect on the simulation results is not always fully understood. Usage of OpenTrack results is possible, but as always, one must be aware of the limitations of simulation models and possible deviations between the simulation model results and the values one would measure in reality.

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Volgens de Taskforce Mobiliteitsmanagement is nu vaak nog sprake van een hoge mate van abstractie en is er veel behoefte aan praktische tools.

In dit onderzoek is een dergelijke tool (of ‘beslissingsondersteunend systeem’) ontwikkeld. Deze vertelt een organisatie concreet wat de omvang is van haar verkeersemissies (monitoren), wat het hieraan kan doen en wat er potentieel bespaard kan worden (adviseren), zonder dat de bereikbaarheid van de organisatie in het geding komt. Ook krijgt de organisatie met de tool inzicht in kosten en/of baten van de verschillende maatregelen en inzicht krijgen in hoe de emissies zich verhouden tot andere bedrijven (benchmark).

In het advies dat de tool geeft wordt per persoon een ‘optimale’ reiswijze bepaald op basis van de potentie voor twee typen maatregelen op het gebied van mobiliteitsmanagement: modal shift en carpoolen. Hiermee wordt op bedrijfsniveau gekeken naar waar in de vervoerswijzekeuze van werknemers (modal split) winst valt te halen in de emissies. Dit gaat overigens zonder mensen persoonlijk aan te spreken of bijvoorbeeld ‘mensen te verplichten om te gaan fietsen’. Wel kan de organisatie door met reiskostenvergoedingen te schuiven proberen om een bepaald reisgedrag te stimuleren of juist te ontmoedigen.

De uitkomsten van de tool zijn onder andere geëvalueerd aan de hand van een aantal casestudies bij verschillende organisaties. Uit deze casestudies is gebleken dat de tool geloofwaardige resultaten produceert, hoewel op sommige punten de nauwkeurigheid wel iets verbeterd kan worden. Dit laatste kan bereikt worden door gebruik van andere en/ of extra kengetallen en berekeningsmethodes, hoewel deze veranderingen de tool complexer zullen maken en daarmee de uitkomsten wellicht minder betrouwbaar worden. De tool lijkt verder in principe een goed bruikbaar instrument voor CO2-reductieadvies: commentaren van de gebruikers bij organisaties uit de casestudies zijn overwegend positief. Gebruik van de tool heeft daarnaast ook een aantal positieve neveneffecten voor het bedrijf.

De tool bekijkt echter maar een deel van het probleem, namelijk alleen het woon-werkverkeer. Het uitbreiden van de tool voor zakelijke ritten zal de complexiteit van de tool behoorlijk kunnen vergroten, waardoor uitbreiding van de tool niet een eenvoudige taak zal zijn.

De in het onderzoek gegeven aanbevelingen dienen ter verbetering van de nauwkeurigheid en bruikbaarheid van de tool en geven aandachtspunten voor de benaderingswijze van de onderzoeker.

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Allochtonen onderweg

The share of the bike is in the Netherlands in transport 26%, this makes it the second most used transport after the car. But this does not mean that cycling is equally prevalent all over the country. The share of the bike in Amsterdam is 31% and in the Hague 22%. Several models give an explanation of the differences in bike use. From these researches it seems that the share of immigrants has a negative impact on bike use. This research focuses on the topic why immigrants rarely choose the bike and how this behaviour can be influenced in favor of the bike. This research is done in two districts in the Hague. The goal of the research is:

→ To understand the balancing process of immigrant residents in the two districts Transvaalkwartier and Schilderswijk in the Hague of their transport choice within the city. With this information proposals can be made to increase the bicycle use among this group.

Two perspectives to describe transport choice

Economic perspective, the economic perspective assumes that travelers are omniscient and acting rational. The traveler makes a conscious choice for his transport mode and gives weights to factors covered by the elements ‘personal characteristics’ and ‘presence and conditions of the transport systems’. The result is a set of transport modes that could be used to make a trip. The traveler select the transport mode that maximizes his utility.

Psychological perspective, the psychological perspective focuses on attitudes, social norm and custom behavior in the transport choice, taking account of cognitive dissonance and cognitive limitations of the traveler. This perspective take also notice of the ‘personal characteristics’ and the ‘presence and conditions of the transport systems’. Figure 1 shows a schematic representation how these perspectives play a role in the choice. 

The research of the transport mode choice in the Hague shows that more natives have the skills to cycle, more natives owned a bike and also natives used more often the bike than immigrants. The differences in owning a bike is significant compared to natives and Turkish, Moroccans and Surinamese and also the use of the bike differ significantly compared to Turkish and Moroccans. Immigrants significantly used more often the bus/tram. For the car there is a small difference: only natives and Turkish use the car significant more than Surinamese.

Also asked to the inhabitants of the districts why they use the bike or an other transport mode. The two main reasons to go by bike for all inhabitants are: ‘cycling is healthy’; ‘bike is fast’ (little delay). Main reasons to go by the bus/tram are: ‘with this vehicle I feel safe in traffic’; ‘this transport is fast (little delay)’. The auto select residents for the reasons: ‘with the car I can take al lot of luggage’; ‘the vehicle is comfortable’.

To the residents who rarely use a bike, is asked about the main reasons for not using the bike. The two main reasons to not to go by bike are: ‘it is often bad weather (rain/wind/cold)’; ‘on the bike I feel unsafe in the traffic’.

There are two reasons where is a significant difference between natives and immigrants. So Turkish, Moroccans and Surinamese find the reasons convenience (by bus/tram you can get everywhere in the Hague) and in the bus/tram you can meet friends significantly more important to use the bus/tram instead of the bicycle than natives. The reason often put forward that immigrants do not cycle because they seem the bike as a ‘poor man’s vehicle’, hardly appears to play a role. A large majority, find that also successful people could use travel by bike.

Recommendations

Measures to encourage bicycle use among ethnic minorities in the districts in the Hague should focus the cycling facilities in the districts. These are now insufficient so that people feel unsafe on the bike in the traffic. Consistent implementation of an own safe place for bikes in the streets is therefore important. And also a campaign is needed that focus on knowledge, so that inhabitants ‘want’ to cycle, and on the offer of cycling classes, so you ‘can’ cycle.

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Current city planning has great interest to restore water canal systems in urban areas. Main reasons for that are the poor water storage capacities in urban areas due to effects of the climate change such as an increased rainfall and the historic quality of the city that can be enhanced by restoring the old canal system. This survey follows the Waterplan and the program Inner-city (Binnenstad) of the Municipality of Leiden and examines the possibilities to restore a filled canal in the city centre.

For centuries canals adorned the city of Leiden. In the early 20th century the demand for filling up the canals was raising, especially because of hygienic reasons. This demand grew even stronger in the second half of the 20th century because of continuous growth in population, road network and parking facilities. The canal system had become obsolete: the transport function had been lost, ships became larger and industrial warehouses disappeared from the inner city. Thereby it was not necessary to use the canal for draining municipal water, because sewer systems were already built. The discussion about the returning of canals in Leiden is written in the following policy documents of the Municipality of Leiden: the Spatial plan 2025, the Program Inner-city, the Waterplan and the Cultural Heritage Note. The Lange and Stille Mare showed the best properties of all the canals. This choice is based on sufficient width of the street, the arrival of the RijnGouweLijn, a never functional closing and a missing link in the water network. The Lange and Stille Mare are two different streets, these are separated by the Haarlemmerstraat, each with a unique appearance. It has to be examined weather if it is possible to restore the water canal into the street. For the integration of the canal different requirements and conditions are draft concerning:

- Two-way direction for boats and a minimum width of 6.5 meters and a depth of 1.5 meters is necessary.
- Conservation of the current two-way street
- Conservation of the 35 parking spaces
- Space for cafés with pavement
- More shelters for bicycles

Conclusion

The return of a filled up canal provides the development of public space and a quality impulse of the inner city. Additionally the old city pattern is brought back, contributing to the authentic historical appearance of the city. Especially in Leiden this has great potential. The Lange and Stille Mare have the best opportunities to be dug out. This is based on the width of the street, the arrival of the RijnGouweLijn stop at the Langegracht, never functional closing and a missing link in the water network. No problems are foreseen for the traffic network, because the canal is located in the inner city where the traffic volumes are low. None of the current traffic flows and positions are lost with the return of the canal in the street profile.

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6.

Theses Offshore Engineering
Outline design of a semi-submersible wind turbine installation vessel

Wind turbine installation vessels are currently dominated by jack-up barges. These float out to site, lower their legs onto the seabed and ratchet themselves out of the water to counteract the effects of the sea during installation works. This whole operation is costly and time consuming as wind turbines are transported in parts and assembled offshore. For now, jack-ups get the job done, but as wind farms are being pushed into deeper waters they will soon become expendable for this type of work.

In this thesis, an outline design of a dedicated transportation and installation vessel is made to deal with the key complications of the current offshore wind market. The result is a U-shaped semi-submersible with 3 columns, named the SWIV. This configuration offers better motion behaviour than conventional jack-up barges, leading to higher workabilities. This unique vessel is able to transport and install multiple preassembled wind turbines and substructures simultaneously. The SWIV is fitted with three spud legs which can be lowered to the seabed to diminish all motions. A 1200-tonnes capacity crane stacks the preassembled substructures and wind turbines by which the offshore installation time is kept to a minimum.

The proposed design has been subjected to 3D-diffraction analysis using AQWA to investigate the vessel’s hydrodynamics and optimize the column arrangements. To validate the AQWA results and measure viscous damping’s, tank tests of a 1:50 scale model have been conducted at the Hydrodynamic Laboratory of TU Delft. The measured values from tank testing appear to correspond with the AQWA model, which means the computer model can be presumed reliable. The results show that the SWIV has favourable free-floating motions; for harsh Southern North Sea conditions (HS=2m TP=10s) the vertical motions do not exceed 60cm. A preload of 2000 tonnes on each spud leg is sufficient to prevent the SWIV from being elevated by waves.

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Technical feasibility of offshore wind turbine installation with a spudpile vessel

Offshore wind turbines are installed with jack-up vessels. Jack-up installation vessels have several disadvantages compared to floating installation vessels. Floating installation vessels do require alternative systems for stationkeeping and stability. GustoMSC proposed to investigate the technical feasibility of spudpiles for stationkeeping. Since the spudpile vessel remains floating during installation of the offshore wind turbine, the vessel experiences motions due to environmental loads. To determine the motions of the spudpile vessel, a model of the vessel is simulated at a range of environmental conditions. The model is based on calculation and selection of the main parts of the spudpile installation vessel and environmental conditions. The modeling is divided into: vessel, spudpile, spudcarrier, soil mechanics and sea states.

A model of the spudpile installation vessel is made in the hydromechanical simulation software Orcaflex 9.2f. The range of environmental conditions contains a variety of soil and wave parameters resulting in a total of 2880 load cases. Model verification is performed for a static simulation run. Due to limited resources it is not possible to perform verification of a dynamic simulation run. The results of the static simulation run are in agreement with manual calculations.

Limits of both the spudpile and the soil are compared to simulation results. Based on the outcome of the limit check, a number of load cases proved to be unacceptable. The motions of the spudpile vessel in the remaining load cases are used as input for the design of the crane and motion compensation parts. The movement of the spudpile vessel is several meters in x, y and z direction. The rotation of the spudpile vessel is several degrees in pitch, roll and yaw direction. To provide a safe working environment for people near the offshore wind turbine during installation, the suspended load in the crane is not allowed to have more than 0.1m offset from the neutral position. This means that a motion compensated crane is required to perform safe installation.

A mast crane capable to compensate the motions of the main hoist for all 6 degrees of freedom of the vessel with only the hoist rope, luffing rope and slewing ring is designed. With the dimensions of the crane and trigonometric equations, the motions of the vessel are translated into motions of the main hoist suspension point in x, y and z direction. The x, y and z motions are translated into heave, luffing and slewing motions that are required to keep the main hoist hook at a fixed location. Motions of the main hoist hook are compensated using a combination of passive and active hydraulic cylinders for the main hoist and luffing rope. Slewing motion is compensated using rotating hydraulic actuators. The dimensions and power requirements of the motion compensation equipment are determined. The tracking error between the setpoint and the actual location of the main hoist hook is reduced with a feed forward control system. The remaining motions of the main hoist hook result in a swinging motion of the suspended load. The remaining maximum offset of the main hoist hook from the setpoint is 0.8m in sway direction. The swinging offset due to the lag in slewing compensation is 1.8m from the neutral position for a 100m long tower suspended in the crane. Based on the motions of the suspended load it is concluded that it is not possible to perform safe OWT installation with the basic design used in this report. This means that offshore wind turbine installation with the spudpile vessel described in this report is not technically feasible.

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Reducing Seafastening Time for Jacket Removal Projects in the North Sea

At the moment there are around 400 fixed offshore installations in the North Sea. These installations need to be removed sooner or later. At the time of installation no thought has been given to the removal of these structures. As a consequence the structural strength of these structures is insufficient for down-ending. This implies that the jackets have to be transported vertically. Jackets are high and slender structures and therefore have an increased risk at toppling over (uplift). Prevention of uplift will put high demands on the grillage and seafastening. This requires large amounts of steel and welding. The objective of this thesis was to minimize the time required for seafastening by decreasing the design conditions and by improving the conventional grillage and seafastening system. One of the platforms of the Ekofisk field has been taken as base case. This field is located in the North Sea. The jacket of this platform has eight legs and its bottom section weighs 2773 tons.

The design conditions were being decreased by taking into account the beneficial weather conditions at the start of the transport. Removal transports are always preceded by a number of operations which require a very calm seastate. Current guidelines do not take this into account. Transport simulations have been used to reproduce transports after a period of calm weather. The results show that the design conditions can indeed be reduced depending on the tow distance and the starting condition. It appears that the duration of the beneficial weather has no influence on the design conditions.

The design conditions were used to calculate the transport loads by a seakeeping analysis. The transport loads were taken as input for the design of the grillage and seafastening concepts. Six concepts were created with the focus on reducing the seafastening time. The concepts have been worked out in detail and evaluated on a number of different criteria. The partial stages-, brace- and external gripper concepts are potential solutions to reduce the seafastening time of the typical jacket. The external gripper concept has a fast seafastening time but at large investment costs. The brace concept could greatly shorten the seafastening time and increase the cutting tolerance when the typical jacket strength is proven sufficient. The structural strength of the typical jacket is insufficient for the support loads of the wire concept and the sandbox concept. The technical feasibility of the sandbox concept is also insufficient. The epoxy grout concept does not provide a reduction in the seafastening time.

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Integrated Design Methodology for a Monopile Support Structure for Offshore Wind Turbines using Numerical Optimization

In the current support structure design process of an offshore wind turbine, a design split is present. The tower part is designed by the wind turbine manufacturer and the substructure is designed by the foundation designer. Hereby, both design parties use their own design models and programs. However, an offshore wind turbine is a dynamic system. The substructure design influences the design of the tower structure and vice versa. This has resulted in an iterative exchange of design data between the wind turbine manufacturer and foundation designer: the wind turbine manufacturer delivers the tower geometry and time series of responses at interface level to the foundation designer. The foundation designer returns the substructure design, hydrodynamic data and soil data to the wind turbine manufacturer. This design loop is repeated until design convergence has been reached.

The foundation designer returns the substructure design, hydrodynamic data and soil data to the wind turbine manufacturer. This design loop is repeated until design convergence has been reached. In this thesis, an integrated support structure design methodology has been developed. Hereby, the entire support structure is designed according to the same models and programs. The design split has been excluded which enables the application of structural optimization. The integrated design method has been implemented at Siemens Wind Power and Burbo Bank-16 has been used as benchmark to search for steel reduction. Case studies have been performed in which the mass of the support structure is minimized. Hereby, the wall thicknesses along the support structure have been defined as design variables. The constraints that have been considered are the natural frequency, buckling and fatigue damage. In case the natural frequency and buckling constraints have been considered, a mass reduction is found. Here, the integrated support structure design has got a more efficient mass distribution than the current support structure design. Mass optimization subjected to the fatigue constraints has not yet successfully been completed. Though the initial geometry is feasible, the optimizer can not find a feasible solution. It is advised to further investigate the fatigue constraints and to verify whether or not the used algorithm is suitable.

In this thesis, only the wall thicknesses along the support structure have been defined as the design variables. It is interesting to investigate the integrated support structure design methodology in case the diameter and penetration depth are also taken as design variables.

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Feasibility of tripod support structure for Offshore Wind Turbine in deeper waters

The present trend in the offshore wind energy industry is the deployment of wind farms in relatively shallow areas and close to shore locations. A reduction in the amount of steel needed for the support structure and shore cable connection length is achieved.

Monopiles are used as support structures in most of the offshore wind farms up to a water depth range of 20m to 30m. As the drive towards deeper waters grows enormously, a challenge is posed on the use of monopiles because the foundation diameters, wall thicknesses increase with water depth. The need for alternatives to monopiles becomes paramount. Prospective solutions are multi-member structures such as tripods, Jackets, towers and floating structures such as Tension Leg Platform (TLP), Spars etc.

For this study, a tripod structure is chosen from the and the suitability of the structure is assessed between 30m to 70m water depth at 10m intervals. The assessment is based on the requirement for ultimate limit state (ULS), Fatigue limit state (FLS) and allowable natural frequency range due to the rotational speed of the turbine. The structural analysis and design are focused on sizing the members to satisfy the worst load combinations due to wind, waves and current. Checks were performed based on standards such as API–RP2A LRFD and DNV in order to assess the structural integrity of the members. The foundations were designed based on the maximum support reactions and the ultimate bearing capacity of the steel tubular piles.

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An alternative solution for joining and installing tendons of a tension leg platform

The exploration of hydrocarbons has led oil companies into deeper water ever since first offshore oil was produced. Floating structures made it possible to continue the exploration of oil and gas into water depths up to 3000 meters. A particular type of floating platform is the Tension Leg Platform, characterized by its stiff vertical mooring system, balancing the platform's excess of buoyancy with tension. The mooring system exists of steel pipes, called tendons, which are assembled offshore to form large strings. The segments are joined by expensive mechanical connectors. The subject of this thesis will be an investigation of an alternative solution for joining and installing the tendons. Technical, operational and economical feasibility is investigated, including a study of fatigue damage occurring at installation.

An alternative solution for joining tendons is to be explored in proven technologies and installation techniques within Heerema Marine Contractors. The solution is found in offshore pipeline installation, at which pipes are welded in a vertical position in a J-Lay tower. It is standard practice to fabricate tendons of multiple pipe-segments which are welded together onshore. For the investigation of the technical feasibility the focus turns to the offshore reproduction of this onshore circumferential weld. To this end, general welding criteria for tendons are obtained. Conclusion is that there are no reasons to believe that the weld would be unfeasible to be reproduced at the construction vessel, but this can only be proofed with actual (fatigue-)testing after confidential designer's specifications are obtained.

Tendon-segments need to be outfitted with collars to allow the J-Lay process at which the tendon-string is hung-off at a collar-pipe. This collar is welded to the main pipe. These collar-forgings are perfectly round whereas the tendon pipes deviate from roundness and show deviations in diameter and wall thickness. This leads to eccentricity of pipe-faces when pipe-segments are aligned prior to welding. These jumps in geometry lead to stress concentrations and are of great concern to fatigue. Strict fit-up criteria are imposed to the joints to be welded. This leads to the need for matching and sorting of tendon-pipes of the same ovality, diameter and wall thickness. In addition rotation of pipes at the crane vessel's deck is needed for pipe-pipe welding but is needless at the tower for pipe-collar welding since collars are perfectly round.

Installation time is a major contributor to total project costs due to high vessel day rates. In addition to vessel costs, the two methods are compared on transportation costs, material costs and welding qualification costs (which are industry requirements for offshore pipeline installation). It is concluded for two offshore areas of interest (West of Africa and the Gulf of Mexico), that the transportation and installation costs are approximately 30% less for the alternative solution, despite the longer installation time. Major contributor is the elimination of the mechanical connectors.

At West of Africa, installation by Heerema’s crane vessel the Balder, can be accompanied by swell-induced vessel motions. Therefore the fatigue damage at installation is further studied. The two methods differ in the way the tendon-string is suspended at the crane vessel. The load case is selected to be the most occurring sea state at the preferred installation month. The timetraces of the stresses are converted into a histogram of stress ranges and number of cycles using the rainfall cycle-counting technique. Fatigue is calculated based on the Palmgren-Miner theory. It appears that at swell-dominated areas, the fatigue damage encountered by the tendon-string for the current installation method, is 1.3 times higher than for the alternative installation method. This is explained by the way the resonating string is suspended at the crane vessel. At the new method, the clamped string is supported by rollerboxes, which force the string to vibrate in the same mode number as the string hinged at the current installation method. This results in less curvature and bending moments. It is evident that this leads to less fatigue damage.

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Wake influence on tidal turbine performance and tidal farm arrangements

Tidal currents are a potential source of clean and predictable energy. The increasing demand for energy stimulated the development of devices to generate electricity from tidal currents in the past decades. Most concepts involve rotating underwater turbines that are placed at sites with strong tidal currents.

At this moment, the development and testing of full-scale prototypes is ongoing. Plans for the near future are to install several tidal devices in clusters, similar to wind farms, to make energy production commercially viable. During design of such a ‘tidal farm’, the spacing between the turbines has to be determined.

Optimising the arrangements of turbines within the tidal farm is a trade off between different parameters. On one hand it is attractive to place the devices close together to reduce the required cabling and space on the seabed. On the other hand, it is known from wind energy that the wake, induced by a turbine, has a negative impact on the energy production of downstream devices. The wake is a zone with reduced velocity behind a turbine. Further downstream, the velocity recovers gradually by turbulent mixing with the ambient current.

The influence of wake effects on the performance of tidal devices and farm arrangements is subject to this thesis. The aim is to find simple relations that can be used to predict the energy output of a given farm configuration. The energy output of a turbine depends on its inflow velocity. Therefore, the strategy is to find a model that is able to predict the velocity field in the tidal farm. Such ‘wake models’ are available for wind turbines and thruster-thruster interaction. The applicability of these wake models for tidal turbines is studied in this thesis.

A CFD model of a tidal turbine is used to simulate the velocity in the wake and flow in a tidal farm. The obtained results are used for testing the wake models. The CFD model is validated with measurement data from the literature.

Comparison of the CFD simulations to the wake models shows promising results. The flow behind a single turbine is studied extensively and different cases for multiple wake interaction are assessed. Finally, a case study on a small tidal farm demonstrates the applicability of the models.

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Improve Set-down Operations during Removal Activities in the North Sea

The North Sea was once a large producer of oil and gas. During peak oil in 1999 almost 6 million barrels of oil were produced every day. Some of the oil reservoirs in the North Sea are entering the last phase of their field life. Regulatory regimes demand that all fixed platforms which are abandoned, with the exception of some gravity based structures, need to be completely removed. This means that the 500 fixed platforms installed in the North Sea are nominated for removal in the coming decades.

During one of these removal operations problems occurred with the Set-down of these large structures onto the barge. High peak loads were encountered and large load fluctuations were measured in the crane. This could damage the crane, barge or the removed structure. The weather restrictions for this operation are severe, resulting in a low workability. The objective of this thesis is to define solutions to improve the back-loading or Set-down operation and perform a feasibility study for the most preferred concept.

The Passive Motion Compensator consists of Hydraulic cylinders connected to accumulators. These accumulators with pressurized nitrogen will act as shock absorbers, compensating the heave motions of the barge and the heave motions of the object. The pressure in the cylinders is increased by the weight of the object resting on the cylinders. During the operation no active pressure regulation is needed. The cylinders are connected to each other, allowing a free roll and pitch motions of the barge without an increase in pressure in the Cylinders. The motions of the object and the force fluctuation in the crane are lowered with this technique.

A workability analysis showed that the set-down operation is increased with around 70%. The entire removal operation however is not influenced much (1-2%) by the improvement of the Set-down. The bottleneck is shifted from the Set-down to the Seafastening activity. The Seafastening needs to be improved to increase the workability. The installation of the Hydraulic system will result in a lower impact load and a reduction of the load fluctuations. This concept is for non financial considerations a good solution, which increases safety and allows larger objects to be lifted in the coming removal projects.

The Hydraulic Motion Compensation could also be used for the pick-up of pipe crates or heavy objects for installation. Further investigation needs to be performed to determine dimensions of the system. The effect of side loads acting on the cylinders on the workability also needs to be investigated.

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Torsion in offshore wind turbines and the effect of torsion on a jacket support structure

The waters in which offshore wind turbines are located are becoming deeper and further offshore. In water beyond 30m, the monopile will no longer be suitable as a support structure for offshore wind turbines. In deeper water an alternative support structure is needed. One of the alternatives is a jacket. The jacket however has a disadvantage: a lower stiffness in torsion. A wind turbine causes a torsional moment. To find out if torsion can be a problem, this thesis investigates the causes and magnitude of torsion in a wind turbine and the effect of torsion on the jacket support structure.

The study on the causes of torsion shows that turbulence determines the magnitude of torsion, in particular the variation of torsion. The order of magnitude results point out that a turbine standing partially in the wake of another wind turbine will experience the largest torsional and fore-aft bending moments at the yaw bearing.

Results show that certain joints of a jacket will have higher fatigue damage when supporting a wind turbine that is standing, partially in a wake of another turbine, than a turbine which is standing outside the wake.

The study on the effects shows that the torsional natural frequency should be taken into account. Resonance of the torsional moment will result in higher fatigue damage.

A parametric study on how to adjust the torsional natural frequency can also be found in this thesis.

Overall, it can be concluded that torsion caused by a wind turbine can be a fatigue issue for a jacket design with a torsional natural frequency that lays in a multiple of the rotor frequency band.

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Friction forces in pigging: a predictive model

Pigging has become a standard procedure in the Oil & Gas industry nowadays. A pig is a mechanical tool that is inserted into the pipeline for maintenance or examination, the pig is driven by the medium that is transported in the pipeline. To ensure pig performance, safe operations, plan pigging operations and evaluate pig design the industry uses pig motion models and full-scale test facilities. The existing models on pig motion all exclude the eccentricity of the pig motion and the friction force between pigging seals and pipe wall is over simplified.

The aim of this thesis is to define a steady-state pig motion model including eccentricity to predict the pig characteristics. By doing this, the goal was to show that eccentric motion and lubrication have an impact on the parameters concerning the motion of a pig through a pipeline and as such cannot be neglected. For this purpose the PIGPlus model was selected to implement eccentricity.

A mechanical model to predict the eccentricity has been developed. In it, the eccentricity is expressed as the vertical displacement of the centre of the rear and front of sealing disc. These displacements are determined from the resulting overturning moment around the pig. To achieve this the spring coefficients of the seals are needed. These are determined from a deflection analysis of the seal.

Besides eccentricity the following parameters are evaluated for the pig motion model: normal forces around the seal, deformation of the footprint on the pipe wall, film thickness around the seal and wearing rates.

Special attention was given to the lubrication analysis, to calculate the film thickness. With a simplified Reynolds equation and assumptions regarding the fluid pressure under the seal, a new analytical method for calculating the film thickness was developed and compared with other methods. This analytical method showed to predict the film thickness more accurately and was implemented in the new model.

The new developed mathematical model, Pigasus, is equipped to calculate the differential pressure against distance and velocity. The Pigasus model was compared with experimental data from another research program. The improvement due to eccentricity was not apparent. However the new film thickness calculation implemented in the model did show an improvement with respect to the experimental data. The eccentric module did show that the methods used, mainly for calculating the normal force, became less accurate for larger deformations. So eccentric motion does influence the pig characteristics but the values could not be calculated accurately with use of the current methods.

Finally the model assumptions and methods were evaluated. Estimates of improvements were carried out and implemented in the Pigasus model. These results had an overall better agreement with the experimental data.

This thesis work showed that modelling pig motion is a complex and dynamic subject. Leaving enough room for future work to be done.

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Validation of Hydrodynamic Load on Stinger of Pipelaying vessel Solitaire

Allseas’ Solitaire is the largest pipelaying vessel in the world. The world record of deep water pipelay is still held in her hand, which is 2775m. Stinger is one of the most crucial structures for Solitaire who works with S-lay method, since the stinger can guide the pipeline going into the water with a controllable bending curve. During the operation, the stinger will be submerged in the water. For that case, it is subject to large hydrodynamic loads. To predict this hydro-load on Solitaire’s stinger, Allseas works with AQWA-suite. As a computational program, AQWA-suite accepts several simplifications, which will influence its simulation accuracy.

In order to verify the accuracy of AQWA program, 3 phases of research have been done in this thesis. In the first phase, the AQWA program is assessed on the basis of fluid mechanic’s principle. Several small calculations are done within AQWA to study the influence of Solitaire’s DP system and tackle wire system on the stinger. Then, a method in frequency domain is developed to couple the pipe-string into AQWA’s simulation.

In the second phase of study, several models are built within MATLAB to take account of some effects which are not included in AQWA’s simulation. A critical evaluation is given based on the comparison between the MATLAB code and AQWA results. Since the stinger is constructed from many tubular elements, Morison equation is used to simulate the hydro-loads on it. Drag and inertia coefficients are two crucial parameters in that equation. But comparing with any other parameter, they hold very poor certainty, and accordingly very hard to determined. A proposal is given on the selection of these two coefficients. Another comparison is followed to find the different influences on the hydrodynamic loads between the proposed values and Allseas’ default selection.

To verify the validity of AQWA program, Allseas carries on a full-scale measurement in a certain pipelaying project. In the last phase of this study, the data from the measurement is processed. The comparisons between the measurement and AQWA result are made to show the accuracy of AQWA program.
Pieter Schelte - Jacket Lift System: Dynamic Analysis of the Initial Lifting Phase

The Swiss-based Allseas Group S.A. was founded in 1985. Specialized in offshore pipelay and subsea construction work, they grew to be one of the major companies in their field. Since the late 80’s Allseas Engineering has been designing the heavy lift and pipelay vessel “Pieter Schelte”. Pieter Schelte will have the capacity to lift topsides and substructures as a whole, reducing offshore man-hours, risk of personal injuries and environmental damage. For lifting substructures up to 25,000 [ton], a Jacket Lift System (JLS) is located at the aft of the vessel. The main elements of the JLS are the two Tilting Lift Beams (TLB) from which hoist blocks can be lowered and connected to the jacket hoist locations.

As the jacket lift operations will take place in open sea and probably during less favorable conditions associated with the North Sea, it is important to analyze the dynamic behavior of the vessel and the lift system at all stages. For investigation of key influences on this behavior during the initial lifting phase, a time domain model is created in Matlab/Simulink, in which vessel, JLS, jacket, seabed and other possible external forces are represented. During a parameter study the jacket and hoist system characteristics are varied, current and wave loading is applied, the effect of changing the jacket Centre of Gravity (CoG) position of the jacket as well as various influences of seabed and jacket foundation are investigated. All simulations are done for both still water and regular wave conditions applied on the vessel. To be able to analyze the effect of variation of a certain parameter on the dynamic behavior, several indicators are determined, such as the maximum hoist force and the Dynamic Amplification Factor (DAF) during the lift process. Also indicators to investigate the occurrence and possible severity of wire slack and jacket re-bouncing are used. Based on the analysis of these indicators, conclusions are formed which will now be described briefly.

The hoisting capacity of the Tilting Lift Beams and individual hoist wire configurations is only exceeded for some extreme cases. However, large hoist force variations and re-bounces are concluded for simulations done in regular waves. When decreasing the wave height to still water conditions, showed that these effects can be minimized.

Varying the jacket size has a significant influence on the dynamic behavior of jacket and JLS. Smaller jackets will lead to higher DAFs and more re-bounces. Larger jackets will lead to higher maximum hoist and re-bounce forces. Also increasing the hoist wire stiffness will lead to higher hoist forces, larger DAFs and more re-bounces. The CoG shift study showed that a CoG located close to the jacket centerline will lead to the lowest maximum hoist wire forces, lowest maximum DAF and a minimal amount of support point re-bounces.

Seabed and foundation characteristics showed to have both positive and negative effects on the dynamics. Variation of the jacket drag characteristics or applying wave forces on the jacket showed to have little or no effect. Current loading shows only a slight increase of hoist forces when applied up to the maximum velocity as prescribed for the lifting operation.

Recommendations for further consideration are made regarding the vessel, jacket and seabed representation in Simulink, and the used wave spectrum. Also the effect and severity of slack wires and re-bouncing deserves more attention. Regarding the lift operation recommendations are made considering the enhancement of the lifting velocity by implementing a fast lifting system and decreasing the crane tip motions by applying another vessel draught or TLB angle.

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Most of the future offshore oil and gas projects are located in areas with difficult conditions for installing pipelines. These difficult conditions can be characterized by deep water, arctic locations, harsh weather conditions or swell waves for example. This thesis is focused on the pipe supply logistics of future projects with harsh weather conditions and/or swell waves, like in West Africa, Australia and Brazil since many future projects are expected in these locations.

The types and length of pipelines that will be installed in these future projects can change. Moreover, the distance between the project locations and the onshore yard can increase significantly just as the diameters of pipelines. All these factors have a large impact on the complexity of the pipe supply logistics. The current pipe supply logistic process leads to low workability rates for future projects, especially caused by swell waves. In order to organize the bottlenecks for each individual operation, all the possible interesting future pipelay projects for Heerema are categorized in a logistic complexity matrix.

Solving one of the critical bottlenecks shifts the dominant bottleneck to another operation, resulting in small improvements of the total process. The most promising optimized concept is a combination of dedicated supply vessels which are also used as storage buffers; the Constant Tension mooring system; and a dedicated crane to transfer the pipes to the vessel. The pipes are stored on deck of the supply vessel and transferred to the pipelay vessel as individual double joint sections.

In the second phase of this thesis a detailed design of the dedicated supply vessels and implementation in the logistic pipe supply process is studied. Research is done to determine if a semi-submersible Heavy Transportation Vessel (HTV) can be developed which meets the requirements to ensure 100% pipe supply workability. Some assumptions are made to the characteristics of the mooring system and dedicated crane to calculate the improvements of the optimized pipe supply process.

The HTV is designed with; different drafts for the transportation and mooring/lifting operations for optimal motion behaviour; stability behaviour according to IMO regulations; a storage capacity of 24,000 tons of pipe sections; and a sailing speed of 15 knots. The HTV design results in improved operability criteria for all the individual operations, the lifting operation especially because of the individual stored pipes and dedicated crane.

Simulations for an extreme project in Australia show large improvements of the pipe supply workability compared with the old process, resulting in shorter project duration.

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The added mass effect in centrifugal pumps

An approximation formula for the added mass moment of inertia of logarithmic impellers

For torsional vibration analysis of centrifugal pump systems, i.e. determining the critical frequencies of the system, the system’s mass moment of inertia needs to be known. For centrifugal pumps this means both the impeller mass moment of inertia and the fluid effect on the pump’s inertia need to be determined. The fluid effect on the pump’s mass moment of inertia is called the added mass moment of inertia, abbreviated \( J_a \). To be able to predict the critical frequencies more accurately, the current method at use within IHC Merwede needs to be further improved. This thesis presents a new, more accurate approximation formula for the added mass moment of inertia of centrifugal impellers. The formula is based on the analytical solution of a two dimensional potential flow around a rotating elliptical cylinder. The added mass moment of inertia of this rotating cylinder can be transformed easily to the added mass moment of inertia of a flat plate of zero thickness, with an arbitrary length and unit width. In potential flow analysis, the only governing parameter is the geometry of an object: the added mass moment of inertia of a logarithmic centrifugal impeller then depends on the impeller geometry only. The geometry can be described by the impeller diameter \( D_{\text{impeller}} \), the suction diameter \( D_{\text{suc}} \), the impeller’s width \( W_{\text{impeller}} \), the number of blades \( Z \) and the blade angle \( \beta \). The fluid has an influence indicated by the fluid density \( \rho_{\text{fluid}} \). The model-impeller has been constructed as an ensemble of flat plates having the impeller dimensions mentioned above. The formula \( J_a (D_{\text{impeller}}, D_{\text{suc}}, W_{\text{impeller}}, Z, \beta, \rho_{\text{fluid}}) \) assumes behaviour of \( J_a \) in the diameters to the power four and linear behaviour in both \( W_{\text{impeller}} \) and \( Z \). The main differences between real practice and the two-dimensional model are the impeller blades being curved instead of being straight, and the flow through an impeller entering axially and leaving radially instead of only flowing radially. The approximation formula contains two correction factors, correcting for both the blade angle \( \beta \) and the presence of axial flow. Each correction factor contains a linear scaling parameter that needs to be tuned with experimental data. The model has been validated by carrying out scale model experiments with a series of logarithmic impellers. The experimental set-up has been optimised to induce torsional vibrations with one degree of freedom only. For each impeller, the natural frequencies in both air and water of the set-up with impeller are measured. The frequencies can be used directly to compute the impeller’s added mass moment of inertia. The first dataset is obtained for testing impellers in a large basin, simulating an infinite fluid domain. In real practice impellers are mounted in a volute, imposing both a lateral constraint as well as an axial constraint on the outflow. These are studied separately by testing all impellers in both an axially enclosed configuration as well as a laterally enclosed configuration. These experiments provide the data to tune the model’s correction factors. To study side effects of impeller vibrations in the suction pipe and discharge pipe, some scale model impellers have been tested in a scale model volute. Effects of upscaling the geometry have been studied by testing impellers of different sizes. In the experiments there is no flow through an impeller, but in real practice there is. For studying the effects of flow, water has been forced through vibrating impellers. The experiments in the ‘infinite’ fluid domain and the constraint configurations show higher order behaviour of \( J_a \) when varying the diameters and linear behaviour of \( J_a \) when varying \( W_{\text{impeller}} \). \( J_a \) proved to be degressive instead of linear. Lateral constraints on the flow did not influence the added mass moment of inertia significantly. Constraining axial flow however resulted in an increased \( J_a \). No side effects in the suction pipe and discharge pipe could be detected. Upscaling the impellers geometry with \([L]\) results in scaling \( J_a \) with \([L]^5\) according to the model. In the experiments it was found that \( J_a \) scales with \([L]^n\) with \( 4 < n < 5 \). At the moment of writing this subject is still studied however. Fluid flow through an impeller proved not to alter the added mass moment of inertia. Approximation of the added mass moment of inertia with the model presented in this thesis is within 12% accuracy on average compared to the measurements. The approximation formula can be applied directly to IHC impellers.

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**Student:** Elwin F. Bakker

Development of District Heating Networks in Urban Areas  
**Student:** Daan van Beekum

Towards an optimal (re-) construction of motorways  
**Student:** Christophe Egyed

Calibrating a traffic microsimulation model with a phase based algorithm to make the trajectories suitable for traffic emission predictions.  
**Student:** Frank de Groen

Verbetering vervaardigingproces GWPs  
**Student:** R.J. in ’t Hout

Optimization traffic control using route information  
**Student:** Jun Li

Assessment of the relationship between observed crashes and simulated conflicts at intersections  
**Student:** Paula A. Marchesini

Reducing Travel Time Loss in Financial Services  
**Student:** Ralph Otto

Optimal configurations for designs of bus stations  
**Student:** J. van Rossum

Network Performance Degeneration in Dynamic Traffic Assignment  
**Student:** Wouter Schakel

Vrouwezand, island in lake IJsselmeer  
**Student:** Bart Simon

A dynamic traffic assignment model based on social costs  
**Student:** E.A.J. Vendrik

High-frequency train service between Rotterdam and Leiden  
**Student:** R.H. van Vliet

A disaggregate freight transport model of transport chain and shipment size choice on the Swedish commodity flow survey 2004/05  
**Student:** Elisabeth Windisch

**Offshore Engineering Theses**

Discrete Element Modelling of Sand/Rock Cutting in Deep Water  
**Student:** Morteza Abdeli

The effect of fluid velocity on eigenfrequencies of FPSO piping systems  
**Student:** Sietze Douwe Akkerman

‘An investigation of squalls and their impact on in situ structures, using measured data from the Greater Plutonio Field, Offshore Angola’  
**Student:** J.J.R. Brokking

Grab Dredger Optimization  
**Student:** Rikrik Gantina

On-Bottom Stability of High Temperature Pipelines  
**Student:** J.M. van Hilten

Design of a floating offshore support structure for the Wave Rotor.  
**Student:** Reinder Jorritsma

Optimization of the Transport- & Installation Process of Offshore Wind Farms  
**Student:** Coen Kleipool

Method for real-time touchdown point measuring during pipeline installation  
**Student:** J.M. de Klerk

Wake influence on tidal turbine performance and tidal farm arrangements  
**Student:** Moritz Palm

Moorings and installation of wave energy converter Wavebob  
**Student:** B. Poppelaars

Fatigue Integrity of Mooring Lines on Offshore Production Facilities  
**Student:** W.F. van Rossem

Deep Water Subsea Heavy Lifting  
**Student:** W.J. Slob

Jack-up leg design for arctic operations  
**Student:** P. Smeets

Friction forces in pigging: a predictive model  
**Student:** M. Tillemans
Influence 90 degrees bends on the pressure losses in slurry transport

Student: A.R. Verschoor
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Structural Engineering

The feasibility of an integral bridge, with in detail the adiabatic shrinkage
Student: F. de Beukelaer, BEng

Modulaire Autobrug; In Vezelversterkt Ultra-Hogesterktebeton
Student: B. van den Broek

Influence of misalignment on the fatigue life of welded connections
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Research groups and professors within the faculty of Civil Engineering and Geosciences

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<tr>
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<th>Name</th>
<th>Telephone</th>
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<tbody>
<tr>
<td><strong>Design and Construction</strong></td>
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<td><strong>Construction Mechanics Research Group</strong></td>
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<tr>
<td>Construction mechanics</td>
<td>Prof. J.G. Rots</td>
<td>83799</td>
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<td>Dynamics</td>
<td>Prof. A.C.W.M. Vrouwenvelder</td>
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<td>Numerical mechanics</td>
<td>Prof. L.J. Sluys</td>
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<tr>
<td>Acting chairman</td>
<td>Prof. K. van Breugel</td>
<td>84954</td>
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<tr>
<td>Fund. and Applied Materials Science</td>
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<td>Road Construction</td>
<td>Prof. A.A.A. Molenaar</td>
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<td>Rail Construction</td>
<td>Prof. C. Esveld</td>
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<td>General Construction Design</td>
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<td>Concrete structures</td>
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<td>Prof. K. van Breugel</td>
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<td>Steel construction of buildings</td>
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<td>Prof. G.S. Stelling</td>
<td>85426</td>
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<td>Environmental hydro informatics</td>
<td>Prof. A.E. Mynett</td>
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<td>General Fluid Mechanics</td>
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<td><strong>Hydraulic and Offshore Engineering Research Group</strong></td>
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<tr>
<td>Probabilistic design and</td>
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<td>Hydraulic Structures</td>
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<td>85278</td>
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<td>84285</td>
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<td>Ports and Inland Waterways</td>
<td>Prof. H. Ligteringen</td>
<td>84285</td>
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<td>River morphology &amp; River Engineering</td>
<td>Prof. H.J. de Vriend</td>
<td>81541</td>
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<tr>
<td>Offshore Engineering</td>
<td>Prof. J. Meek</td>
<td>84777</td>
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</table>
Water Management

**Sanitary Engineering Research Group**
- Sewerage: Prof. F.H.L.R. Clemens 83347
- Waste Water treatment: Prof. J.H.J.M. van der Graaf 81615
- Drinking Water: Prof. J.C. van Dijk 85227

**Water Resources Research Group**
- Hydrology: Prof. H.H.G. Savenije 81433
- Water Resources: Prof. N.C. van de Giesen 87180
- Geohydrology: Prof. Th. N. Olsthoorn 87346
- Water Resources Management and Earth Observations: Prof. Bastiaanssen 87346

**Transport & Planning**
- Transport Planning: Prof. P.H.L. Bovy 84611
- Traffic and Transport Management: Prof. H.J. van Zuylen 82761
- Traffic and Transport Facilities: Prof. I.A. Hansen 85279
- Infrastructure Planning: Prof. F.M. Sanders 81780
- Traffic Flow Theory and Simulation: Prof. S.P. Hoogendoorn 85475