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Preface

Every four months we publish a collection of abstracts of the theses produced by our recent Master’s graduates. In this collection you will find the theses of students who graduated in February 2013.

We train our students to be more than just communicators of theoretical knowledge. We also teach them to be critical, make thorough problem analyses and take account of social contexts. We are convinced that a combination of theoretical knowledge and practical skills is needed to find effective solutions for social problems.

The graduation project and associated thesis form the culmination of our students’ degree programme. In their graduation projects they examine a concrete problem and are required to employ all the knowledge they have gained during the previous years. By successfully completing this last step they have proven that they deserve to carry the title of Master of Science and that they are ready for the challenges of professional practice.

In an age when the role and qualities of engineers are subject to more and more critical scrutiny, our graduates are still being welcomed with open arms by the labour market. They disperse to find jobs in various industries and most of them are offered work almost straight after their graduation. I see this as proof that a demand exists for the knowledge and skills of our graduates.

So it is with pride that I present you with this collection of thesis abstracts. They demonstrate the high level that our graduates have attained and the breadth of the subject matter they have mastered. I would like to thank all those colleagues who contributed to this work with such energy and commitment.

I wish our graduates every success with their careers and I trust that they will be just as enterprising in their future roles as they were during their studies. I hope that they continue to learn and create and keep testing the boundaries of the civil engineering industry.

Professor B.M. Geerken
Dean of the Faculty of Civil Engineering and Geosciences
What is the graduation book exactly?

"Master’s Theses February" contains summaries of the theses produced by various students who obtained a Master of Science degree at the Delft University of Technology. The students in question graduated in “Civil Engineering”.

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 realisation 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 February 2013", 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 specialisation:

The Civil Engineering Master’s programme has seven specialisations and one subspecialisation:

- Structural Engineering
- Building Engineering
- Hydraulic Engineering
- COMEM Domain
- Geo Engineering
- Water Management
- Transport & Planning
- Construction Management Engineering

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

The section containing the new summaries is followed by a comprehensive list of those produced last year. The layout of these summaries reflects that of the previous publications.

A Master’s programme spans several different departments, each of which corresponds to a specialisation within the programme in question. At the end of this book is a comprehensive list of specialisations, which includes the names of their respective professors.

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 by post. It is possible to download the complete theses. The theses can be downloaded from: www.citg.tudelft.nl/GraduationSummaries

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Civil Engineering theses

Building Engineering
Several collapses of buildings were published in the newspapers over the last few years. The collapse of the roof structure of the Grolsch Veste stadion and the concrete floor of the B Tower Rotterdam are the latest examples in the Netherlands. Both accidents occurred during the construction phase. The communication, control and collaboration within the several subcontractors failed during the construction phase. These kind of accidents has been occurring for many years, but the construction industry has not yet developed a sustainable solution to prevent structural failures.

The contractor Heijmans Utiliteitsbouw is almost entirely responsible for the bottlenecks within the (project) organization. The first problem is an unsatisfied and unsafe feeling experienced by employees during the construction phase. The second problem is the economic crisis. The failure costs are unacceptable high for a sector with very low financial margins. Following the mentioned issues, contractor Heijmans started this research to both guarantee the safety of its employees and to reduce the failure costs. The research question is: Which improvements are recommended for the contractor Heijmans to improve the structural safety in the design and construction phase?

This research uses the list of critical factors for structural failures (Terwel and Vambersky, 2012) to reveal the improvement opportunities for Heijmans. The hypothesis of the researcher is: the critical factor risk management has to be improved to realize projects without unexpected structural bottlenecks during the design and construction phase.

The critical factors for design and construction phases of Heijmans are determined by literature, analysis of case study projects and a questionnaire. The literature appoint the following critical factors: allocation of responsibilities, control mechanisms and safety culture. The research of the seven case study projects indicates the factors knowledge infrastructure and safety culture as being the key issues. The employees have chosen risk management as the most influential factor for structure failures. A comparison between successful and unsuccessful projects shows the following most influential factors: collaboration, allocation of responsibilities, risk management, communication, safety culture, control mechanism and knowledge infrastructure.

Above research results are based on the experience and opinion of the employees, we could say the mentioned factors are only probably determined for structural failures.

A more specified study to the factor risk management appoints the factors safety culture and knowledge infrastructure as being the key issues for the level of risk management during the design and construction phase. The safety culture can be improved by long-term attention at the value of risk management. The management team has to make risk management as the first priority for its organization. To do so, they should "practice what they preach". Also a better understanding between the three subcultures (management, engineering and operators) should being pursued. This mutual understanding will enhance understanding on shortcomings/possible improvement within the project organization. This also applies for risk management. The knowledge infrastructure can be improved by both implementing a transmission period between design and construction teams and by evaluating shortcomings of projects. Especially for risk management, an evaluation regarding the effectiveness of the measures taken is recommended.

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The Zalmhaven tower

Introduction
Commissioned by Zalmhaven C.V., Zonneveld ingenieurs started in 2004 with the structural design of the Zalmhaven tower. The Zalmhaven tower would be located in the centre of Rotterdam near the Erasmus Bridge, reaching a height of 202.25m with a tunnel system. Due to the financial crisis, the building hasn’t been constructed yet. Could precast concrete be the solution? Within this broad subject, the structural and logistical feasibility of precast concrete in a high-rise tower are the main focus. This research has been performed in cooperation with Zonneveld ingenieurs.

Problem Definition
The number of high-rise buildings and their corresponding height are increasing in the world. This also holds for the Netherlands although the maximum heights are considerably lower. However, compared to the world an interesting phenomenon occurs in the Netherlands: a clear increase of precast concrete high-rise buildings can be observed. The popularity of this building method is created by our prosperity, increasing the building requirements, working conditions but also the cost of labour. However, the highest building in the world with a load bearing precast structure is only 132m high (Het Strijkijzer in The Hague). Is this the maximum height of precast concrete or can we achieve greater heights with this building method? And how do the transport systems cope with the increased height of a precast structure?

Research
The feasibility of precast concrete in a high-rise building is investigated by creating a structural and logistical design for the Zalmhaven tower. By analysing and examining the differences between the precast and monolithic (cast in situ) structure, characteristic aspects of precast concrete have been denoted.

Results
The Finite Element Method provided the following result:
1. The stiffness reduction of precast concrete is marginal. This is the result of large concrete elements, a high concrete strength class and a large building slenderness.
2. The strength reduction is marginal. This is the result of the high dead load, creating compression in the connections.
3. The distribution of shear force is considerably influenced when the masonry element configuration is applied.

The logistical design created the following results:
4. Precast concrete is able to maintain a high amount of actions within a short time span.
5. The highest efficiency per transport movement is obtained when the maximum load is transported at every cycle.
6. The cycle times become independent from the building height when a separate transport system is applied.

Conclusions and recommendations
The research has shown that it’s structural and logistical feasible to construct a 202.25m high precast concrete tower in Rotterdam. Since this is only a preliminary design, several aspects still have to be considered. For example the second load bearing system (robustness), other precast element configurations and a more exact analysis of the behaviour of the precast connections.

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Feasibility study on extended high-rise buildings

Introduction
During a design competition held in 2010, a preliminary design was made for an extension on top of the Oval tower. The Oval Tower is an existing building with a height of about 100m. However, following that competition, this design was never put into practice. According to experts in the field, this project still has a great potential. It was therefore chosen to further investigate the feasibility of this extension project and the feasibility of extended high-rise building in general.

Problem definition
In the general building process, one of the first steps is to analyse whether a project is feasible, concerning the structural feasibility. The objective of this master’s thesis is to give insight in the multitude of factors which determine this feasibility and make-ability of an extension on top of an existing high-rise project.

Research
For the determination of these factors several reference projects have been investigated. Both existing research projects as well as existing extended buildings have been taken into account. Subsequently a Quick Scan of three buildings has been made. Using the results of the Quick Scan and the results of the research into existing projects and buildings several key factors were derived, of which an initial diagram was composed. In this diagram a division was made between a technical, a functional and a financial inventory. It was chosen to mainly focus on the technical feasibility factors in the further research. The most important technical factors were found to be: use of materials, loads, level of safety, load bearing capacity of structural elements and construction methodology. Further investigation has been done throughout these factors.

Results
As a starting point for the calculations on the Oval Tower case study the diagram was used. Using this diagram and remaining data, calculations were made for the existing Oval Tower structure. It was shown that the core and the columns subjected to wind loads are the leading structural elements. Next to that it turned out that various other elements contain overcapacity. Using the findings on the present overcapacity in the Oval Tower structure, three alternatives for the extension were derived. The design alternative that posed minimal structural adaptations was eventually chosen to be most suitable. For this design alternative three construction methods were compared with the help of a trade off matrix. Investigating the three construction methods through this matrix led to a choice on the most appropriate building method. A detailed plan for this construction method was composed.

Conclusions and Recommendations
Which factors determine the feasibility of an extension on top of a high-rise building? This question and its corresponding answer is the main topic of this master’s thesis. A diagram was composed in which the most important factors are shown and explained. Using the diagram as a starting point, a case study for the Oval Tower was conducted. The intention of this case study is to answer the question whether it is structurally feasible to extend the Oval Tower with two floors and a crown on top of the existing structure. Considering the Oval Tower extension case study it can be concluded that it is structurally possible to extend the tower with two additional floors as well as a crown structure on top. However the research also showed that structural strengthening of several building elements is neces-sary. For the functional and financial inventory several assumptions have been made, additional research on these inventories is needed.

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A Parametric Structural Design Tool for Plate Structures

Grasshopper Interface

Problem Statement
For shell structure, the shape is critical and plays an important role in structure. However, due to the form complexity, the load path and structural behavior is not easy to understand. Respected to the reason above, in conceptual design stage when determining the shell shape, an insightful visualization of the shell’s structural analysis will be beneficial for generating a qualitative design. To overcome these obstacles, a suitable tool needs to apply in the conceptual design phrase. Introducing real-time visualized figure can be easier for intuitive view of comparison. To modify the shape easily, and to become perceptive, parametric method is a solution. It is a project that needs long period to complete. This thesis is just one small part of the whole program. The thesis presents a parametric design tool for plate structural analysis.

Objectives
The goal of the thesis is to establish a real-time visualized program for structural calculation and to make it parameterized. The tool is based on a visualized drawing program Rhino with Grasshopper plug-in to generate the parametric environment for the plate structural analysis. In this thesis the tool are separated into two parts. One is out – of – plane calculation. The other is in – plane calculation. The objectives are to create two programs.

Solution
The solution of plate analysis is computed by membrane analogy. For out-of-plane behavior, such analogy generates the solution of sum of bending moment. Followed by rain-flow analysis, the relation between shear force flows and the structural geometry is presented. And for in-plane behavior, the solution is so-called stress function. With such solution other structural behavior results can be calculated by applied finite difference method.

Conclusions
The program of out – of – plane computation is obtained. The tool can be used to calculated the plate structure that subjected to the loads acting normal to its mid – plane, with different boundary conditions. The other program of in – plane is also complete. But the analysis case is confined with two boundary loaded, two fixed. And the results are verified with Finite Element Method program (TNO Diana).

Recommendations
For future research, the program needs to be developed to satisfy different structure geometry. Also the program should be developed from 2D structure to 3D (from plate to shell). And it is better to extend the program into more different types of boundary conditions. The final one is combine the out – of – plane and in – plane programs.

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Egress as Part of Fire Safety in High-rise Buildings

Introduction
The current knowledge and experience in the Netherlands on the topic of egress from fire is mainly based on simultaneous full evacuation by stairs. The requirements in the Dutch norm Bouwbesluit are meant for buildings up to 70 meters, fire safety design is relatively flexible for taller buildings and therefore, there is always room for improvements.

Problem definition
The process of evacuating some large high-rise buildings may take upwards of several hours. One question that needs to be asked is whether it is feasible and desirable to completely evacuate high-rise buildings in fires. My research seeks to remedy this problem by proposing several egress plans for a specific certain building: Koningin Julianaplein in The Hague, the Netherlands. Global investigations indicated that the integration of different strategies (e.g. simultaneous/phased evacuation, relocation and stay-in-place) and the application of vertical egress approaches (e.g. stairs, elevators, escape chute and helicopter) could optimize the egress process to some extent. My research aims to enhance the egress efficiency for Koningin Julianaplein from a worldwide perspective.

Research
My study focused on the integration of various strategies and vertical egress approaches, and the improvement of egress efficiency for high-rise fires. Three steps were systematically taken in order to develop several appropriate egress plans for Koningin Julianaplein:
1. Initially, the major task was to understand the Dutch way of fire safety design from all relevant aspects.
2. Phase two concentrated on synthesizing the state-of-the-art international literature and case studies in the field of egress design.
3. Several egress plans have been created for Koningin Julianaplein in the final phase, and followed by the assessment and recommendations for future projects.

Results
The following results are based on the assessment of all egress plans proposed for Koningin Julianaplein:
1. Relocation using stairs only is the most recommended strategy. Specifically, the relocation group is composed of five floors from the most affected area.
2. For the tower with high occupant density, phased evacuation is also advised. This strategy allows the fire floor, one level above and one level below evacuate first, the rest of the building start their egress 5 minutes later.

Conclusions and recommendations
1. This research found that for towers with low occupant load, phased evacuation is unnecessary, relocation and protection-in-place is therefore recommended. When employing phased evacuation in high occupant density buildings, it allows a reduction in the required width of the escaping stairs.
2. Elevator-assisted evacuation is economically unfeasible and not suggested for buildings below 25 floors.
3. The Dutch method of calculating egress time has several benefits, and that is sound and feasible, other international method is not recommended at the moment.

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Civil Engineering theses

*Structural Engineering*
Effect of different lab mixing procedures on mechanical characteristics of recycled asphalt mixtures

Because of increasing asphalt binder prices and because of environmental reasons, asphalt paving technologists have introduced recycling methods to reduce the demand on raw materials such as virgin binder and virgin aggregate for the production of hot mix asphalt (HMA).

There are several ways for hot mix asphalt recycling (HMA). One way is to cold feed limited amounts of RAP (up to 25%) to the drum or batch plant mixing unit. Another way is preheating the RAP up to 130°C in a parallel drum. This method is very popular in the Netherlands and allows RAP percentages of 50% to be used. Another way of HMA recycling is the Double Barrel Drum Mixer as developed by ASTEC in which virgin aggregate is superheated in the inner drum and mixed with cold RAP, virgin binder and filler in the outer drum. When designing recycled mixtures it is important that the mixing process as used in the lab simulates as closely as possible what happens in reality.

In this study the effect of different laboratory mixing procedures of HMA containing 60% RAP on the mechanical properties of the mixture was analyzed. The mixing procedures represented/simulated the Astec Double Barrel drum mixing process and the partial warming method which is applied when a parallel drum is used next to the batch plant. These two simulation processes, called UPG (representing the double barrel drum) and PW (representing the parallel drum) respectively, are compared with the standard laboratory mixing method (SM) which is currently used and prescribed in the Netherlands for the preparation of asphalt samples containing RAP.

Mechanical properties such as resilient modulus and fatigue resistance of samples prepared with the SM, PW and UPG methods were determined. Furthermore empirical tests such as the penetration and softening point test were performed on the recovered binder. Also DSR and FTIR tests were done for a more fundamental characterization of the recovered binder/bitumen. All results were compared with the results obtained earlier by Mohajeri (2010) and Mengiste (2009).

The above mentioned investigations showed that the resilient modulus of samples prepared using the three mix methods was slightly higher as obtained in a previous study Mohajeri (2010).

Also the fatigue life as determined by indirect tension tests on UPG samples is less compared to the fatigue lives of SM and PW prepared samples both for saturated and dry condition and less compared with previous study Mohajeri (2010). This is due to the fact that a shorter mixing time was applied in this study and the higher air voids content in the UPG samples of this study.

The outcome of the empirical tests on the recovered binder/bitumen shows that the recovered binder/bitumen is very stiff for all three mixtures (below 25 pen grade). In additions, the results of DSR and FTIR tests on the recovered binder showed that all the recovered binder was aged at the same rate and the presence of filler was observed. The observed ageing was due to the low RAP binder penetration.

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Sizing of structures in marine environment is governed by dynamic fatigue action. Commonly the lifetime of the steel elements is determined by an analytical calculation using S-N curves as design resistance to periodic action.

The damage due to periodic action varies directly with peak stresses generated. Stress concentrations due to detailing and to workmanship dominate the magnitude of the peak stresses. In view of these local effects inspection on fatigue damage at the peak stress spots is standard practice and its results frequently reveal tiny cracks which tend to grow in time. For relative thin walled structures such cracks rapidly grow into failure, but for thicker walled elements there is distinct time before collapse. Consequently crack growth control might provide an assessment tool in lifetime predictions and is commonly addressed as fracture fatigue assessment.

A fracture assessment not only request a more time consuming analysis compared to the analytical calculation, it also requires additional material testing (CTOD test). In the offshore construction industry, there is a growing tendency to simplify framing by reduction of the number of connections which consequently increases the stress level and requires thicker steel members. With respect to the crack growth phenomenon current fabrication codes (EMMUA, NORSOK, ISO) limit the validity of analytical fatigue analysis to 40 mm thick elements, for thicker members at least stress relieving by post welding heat treatment (PWHT) is a mandatory requirement.

In the construction practice PWHT is not beloved method. It is a time consuming and tedious procedure, delaying the assembly sequence. Its alternative is a minimum the fracture mechanical assessment; simply PWHT and/or the more elaborate fracture fatigue assessment which commonly provides an increased lifetime. Both assessment procedures are founded in the BS 7910 standard and lead my thesis.

The BS 7910 provides comprehensive information, but not specific to the structural engineering practice. In view of this aspect and unfamiliarity with the BS 7910 in structural engineering, the assessment guidance according to BS 7910 will be described in detail.

At first, the terminology related to fatigue and fracture mechanics is explained. Second, the required information for assessments is handled. Third, the fracture assessment is explained for the member under static load only. Forth, the fracture-fatigue assessment procedure is handled for the case of fatigue load. At end of the thesis, the assessments procedure is demonstrated by solved problems for fracture-fatigue condition where the structure is exposed to both static and fatigue load. Furthermore, the calculation procedure is programmed using the Mathcad environment.

Fracture Mechanics Assessment based on BS 7910:2005

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The feasibility of removable prefab diaphragm walls

A diaphragm wall is a cast in-situ reinforced concrete retaining wall applied in quay walls and in other structures. The advantages of this type of retaining wall are the fact that it can be made in almost any preferred length and it can resist very high structural loads. On the other hand, the disadvantages are: no guarantee of sufficient concrete cover and low sustainability due to the great amount of building materials that are applied and the difficulty in removing of the wall. The purpose of this study is to improve the diaphragm wall by applying prefabricated concrete elements.

The main goal of the study is to investigate the feasibility of applying removable prefab diaphragm walls. The constructability as well as the costs and environmental impact are considered. This is done for two design options: quay wall with prefab diaphragm wall in normal concrete and in lightweight concrete. As reference project the quay wall with cast in-situ diaphragm wall of the Euromax Terminal Rotterdam is used.

To realize the demountable horizontal connection between the elements of a wall section post-tensioning unbonded prestressing steel with dry joints is applied. To meet the conditions a large amount of prestressing steel is required. This amount is related to the dimensions of the cross-section of the elements and the position of the connection regarding the moment diagram of the wall.

The construction method of the removable prefab diaphragm wall is more complex than that of the cast in-situ option. Innovative solutions are taken to ensure the correct placement of the elements in the trench filled with bentonite suspension, the sand tightness of the vertical joint and the filling of the trench with sand to prevent instability. It is feasible to remove the prefab diaphragm wall with a pontoon crane. For the removing of the wall lifting anchors are applied. The removing is done per element per wall section in order to reduce the risk of instability of the prefab diaphragm.

Considering the construction costs of the entire quay wall, the reference case with cast in-situ diaphragm wall is more attractive than the design options. Application of lightweight concrete did not lead to a reduction in costs. The environmental impact, in terms of the carbon footprint, based on the construction of one quay wall, is more or less equal for the reference case and for the two design options. The difference in costs reduces when taking into account the maintenance and removal costs. Further optimizing the design options could lead to lower costs and increase the attractiveness of the design options over the reference case.

The design option in normal concrete becomes attractive, both in terms of costs and environmental impact, when considering the removal of the first quay wall before the technical lifetime ends and the construction of a second quay wall by reusing the prefabricated elements.

Hence, the construction and removal of the prefab diaphragm wall is feasible and regarding the costs and environmental impact of the quay wall, the design option does not differ much from the reference case. It is recommended to carry out further research on several of the applied innovative solutions in the construction and removal phase, e.g. on the dimensions, the effectiveness and the risks. Furthermore, research in the durability and sustainability, related to reusing, of the unbonded prestressing strands is necessary to increase the economic attractiveness of the prefab diaphragm wall. Finally, taking into account in the evaluation of competing designs and contractors, the potential removal costs of a structure and the size of the carbon footprint, increases the feasibility of applying such innovative, sustainable solutions.

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Prediction and analysis of vibrations due to the installation of sheet piles

Introduction
This report describes the research regarding improvement of the prediction model according to CUR 166. This model is often used in early design or construction stages of structures to gain an impression of the expected vibration levels in the surroundings induced by vibratory sheet piling.

Uncertainty prediction model according to CUR 166
First the uncertainty of the model is investigated. For this analysis measurement data from four cases where the vibration levels on the ground surface level for several distances form the sheet pile are measured is used. In 50 % percent of the cases the predicted value is a factor 6 (1/0.16) higher than the measured value. The model gives conservative prediction values for the vibration level. The results of this analysis show that improvement of the model could be considered. This research is limited to two situations (cases) for which the soil profile is in accordance with the characteristic soil profile Rotterdam as mentioned in CUR 166.

Background of the prediction model
From literature it is concluded that a simple model to predict vibration levels at different distances from the sheet pile is not quite possible on the basis of the wave propagation in soil. This is the result of complex processes in the soil (refraction, reflection and dispersion) that result in complex wave paths and patterns during propagation. During the development of the prediction model according to CUR 166 several empirical relations were evaluated. On the basis of evaluation with measurement data the current prediction model was determined. The model is based upon a "source - path- object" approach and consists of 3 sub models. In the models a reference principle is implemented. This means that the vibration levels are predicted in relation with the vibration level at a certain reference distance. In this research the sub model which describes the attenuation of the vibration level as a function of the increasing distance from the sheet pile is analyzed. This model is based upon attenuation of amplitudes due to attenuation of energy. The energy attenuation is a result of both geometric attenuation and material damping. The currently used model is according to the well-known "Barkan empirical relation".

Analysis of the prediction model
The attenuation of the vibration level as a function of the distance is investigated in two cases. With measurement data of measurements performed during this research (case Woudrichem) and during an earlier (other) investigation (case Rotterdam Noord), it is investigated in which degree the predicted values relate to the real measured values. From the investigation follows that the attenuation of the vibration level as a function of the distance is much faster than assumed according to the empirical relation according to CUR 166. In the current model geometric attenuation according surface waves only, are modeled. In this research a combined model is proposed. In the model for the geometric attenuation a factor a, is introduced to divide the attenuation of the vibration levels among the different wave types.

Conclusions
From the analysis of measurement data as a function of the distance it was concluded that the body waves (compression and shear waves) are dominating over the surface waves for the investigated soil profiles. The investigated distance varies from 5 m to 43.5 m. This is contradictory to the originally used model but in accordance with literature in which it is stated that the surface waves are important starting from large distances (20 à 25 m) from the sheet pile. Furthermore it is concluded from this research that the material damping cannot be implemented by a constant value for the empirical value α. This factor appears to be inversely proportional to the distance.
Masonry is a construction material that has been used for a very long time around the world and is still being used in the present day. However, very little is known about the global material properties of masonry due to the fact that very little experiments have been performed on masonry. It is therefore desirable to gain insight in the material behaviour of different types of masonry. This is done by recreating the experiments that were performed by Page (1981, 1983) and Dhanasekar et al. (1985) with a detailed micro model. In these experiments masonry panels were loaded under biaxial and uniaxial loads. In the numerical recreation it was chosen to take three variations per influence factor. From the performed analyses the following was determined: a yield surface, the Young’s modulus, shear modulus and Poisson’s ratio of the masonry and the stress-strain relations for uniaxial compression and tension for loading parallel and perpendicular to the grain. From this it was concluded that the strength of the masonry is mostly defined by the weakest link, which is in most cases the mortar. The amount of anisotropy is minimal, only some extra strength can be found when the masonry is loaded parallel to the bed joints. However when the yield surfaces are compared to an isotropic yield surface only a slight underestimation of some biaxial strength is found. For the Young’s modulus, Poisson’s ratio and shear modulus the found results were compared to those that can be calculated using the formulas by Pande et al. (1994), which gave a very good representation. Regarding the anisotropy only small differences are found for the modern masonry types, for the older masonries the differences are a bit larger. The stress-strain relations showed some more anisotropy, mostly for loading under tension. For tension parallel to the bed joints the stress-strain curves enter a plateau after first cracking, while for tension perpendicular to the bed joints a full exponential softening curve is found. When compared to the limited amount of experimental results on this topic some similarities were seen. However, most analyses resulted in very brittle failure which should not be the case. In some cases this could be explained by the fact that loading under compression can sometimes lead to failure due to tension. Also, since the masonry panels were modelled using the detailed micro model concept, tensional failure of the joints can for instance occur in both the joint itself as well as in the interfaces next to it. This might lead to some convergence issues and result in early divergence of the calculation. It was still tried to determine a procedure from this with which it is possible to determine the smeared material properties of masonry using the properties of the bricks, mortar and brick-mortar interface and the used masonry bond as input. This procedure is as follows: (1) determine the parameters of the masonry components, (2) determine the Young’s modulus and Poisson’s ratio using the formulas provided by Pande et al. (1994), (3) determine the stress-strain relations of the masonry for tension and compression by running four DIANA analyses, (4) use the found values to create either a Total Strain Cracking or a Rankine-Hill model.

In the final part of the thesis this procedure is tested using the experiments performed by Laefer (2001) as reference. In these experiments a scaled model (1:10) of a masonry wall is subjected to settlements that occur during an excavation. Three models have been created for comparison: a brick and joint model and a weak and a strong smeared model. All models were subjected to the soil movements that were measured during the experiments. For all analyses the deformations, crack pattern and maximum crack width were determined and compared with the values found in the experiments. Overall it can be said that none of the models gave a good representation of all criteria. The brick and joint model was able to give rather accurate vertical displacements, but was not able to give the right horizontal displacements or cracks. The weak smeared model was able to give a somewhat similar crack pattern and maximum crack width, but the calculations diverged already when only 60% of the full load was applied. The strong model gave promising results for the horizontal displacements but not for the vertical displacement or the cracks.

For further research it is therefore recommended to do the same analyses that were done in this thesis using the expanded brick model instead of the detailed micro-model. Furthermore it might be interesting to look into the expansion of the currently available material models. Also the expansion of numerical experiments might be interesting to look into, by taking more influence factor into account.
Feasibility study for FRP in large hydraulic structures

The gates in storm surge barriers and locks are currently mainly made of steel. In storm surge barriers and locks there are different types of gates that can be used. When a lifting gate is applied, a mechanism is needed to lift the gate. Therefore a reduced dead weight is important in lifting gates. These gates are exposed to heavy weather influences and to water from waterways. Corrosion is for these steel gates inevitable. Therefore this has to get treated with a coating. During the life cycle the gate should be recoated during maintenance periods. These maintenance operations are expensive. Therefore it would be cost-effective to build a maintenance friendly gate of another material. An example of a material with low maintenance costs is Fibre Reinforced Polymer (FRP).

In this master thesis the feasibility of FRP in large hydraulic structures is investigated, specifically the feasibility of FRP in lifting gates.

A literature study is done to investigate possibilities of FRP as a construction material. FRP is an anisotropic material and consists of a resin and fibres. The material properties can be estimated with the classical laminate theory. In comparison with other materials, FRP has a high strength, but a low stiffness.

Also a case study is done, in this case study a lifting gate is designed according to the requirements of the small gate of the Hartel Canal Barrier. The lifting gate is designed for two different applications. First for the application of a gate in a storm surge barrier, the gate is designed on strength. Second a lifting gate in a lock, which is designed with a maximum deflection and a high number of load changes.

To find a suitable construction for a lifting gate in FRP, a variants study is done. In the variants study different possible construction systems for lifting gates, with an expectation of the possibilities, for a FRP gate are listed. From this list the sandwich, box and arch girder are further evaluated. The arch girder came out to be the best variant, because it has the most potential to be technically and economically feasible. Although the arch girder was the best variant, it has some critical discrete joints where locally high loads occur, which could be difficult to manufacture. The arch variant is further designed in sub variants.

Three types of sub variants are reviewed. In the first sub variant the transverse plates are replaced by webs, which have the advantage of continuous joints. The second sub variant consists of a lens structure, which combines two arches. In the third sub variant the load distribution over four webs is being reviewed. Finally the lens structure with a double arch and four webs is further designed in the final design, because the lens structure required the least amount of material to bear the load.

In the final design all load combinations are reviewed. To enable the gate to sink, the possible locations for gaps in the webs were reviewed. This is done to enable the water to flow through the gate. With these gaps the upward water pressure was still higher than the weight of the gate. This problem is overcome by applying a core material with a higher density and sandwiches with a thicker skin. The strength of the gate was tested by a strain criterion.

The direct building costs for the strength criterion were less expensive than the building costs of the steel gate. After the life cycle the gate, which is dimensioned according to the fatigue criterion, is also less expensive. Even when the steel gate is dimensioned for less load changes, still the costs of the FRP structure are lower.

For this thesis the feasibility of FRP in large hydraulic structures is investigated. It can be concluded that FRP is technically and economically feasible. In this thesis only a lifting gate is evaluated, but FRP should also be applicable for other type of gates.

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A Comparison of prediction models for soil vibrations induced by underground trains

The problem of soil vibrations induced by underground trains has received great attention in the past few years. It is of importance for the engineers to be able to predict the levels of vibration in the soil and the characteristics of it.

Two different approaches to the problem are presented and the accuracy of one of them is estimated. The first is an analytical/quasi-analytical method and the second, used in practice by an engineering company, is a numerical method based on field measurements. For this graduation thesis project the quasi-analytical model is implemented in FORTRAN in 2D and 3D space. Afterwards, the method used in practice is briefly explained and the accuracy of the procedure is evaluated.

Initially, three 2D models are elaborated. At first, the fundamental case of a moving load on the surface of a 2D halfspace is examined. Secondly, a multilayered 2D model with a moving load is introduced and at the end, a multilayered 2D model with a non-moving load is examined. The integral Fourier transform is applied numerically to derive the steady state response both in frequency - wavenumber and time domain. The dispersion curves are derived and different load cases are examined (constant, time dependent, Rayleigh velocity). A 3D multilayered model for a moving load is also presented, by considering plane waves. For those models, the influence of the velocity in the results is examined and also the critical velocity of the load is defined.

What follow is the presentation and assessment of another method. For the identification of the load, this method uses transfer functions. The transfer functions are generated with the help of a 2D model (finite element method model), with a non-moving, time-dependent load. This model is 2D, in a sense that the plane is transverse to the direction of the movement of the train. With this model, it is possible to derive transfer functions for each point by applying a unit load. Field measurements are obtained at four receiver points in the soil, for several types of trains. The measurements contain information about the velocity of the train and about the layered soil structure. By combining appropriately the measurements and the transfer functions, the equivalent load is identified for each point. This is actually an attempt to transform the 3D force into an equivalent 2D force.

With the aim to assess the validity of this method, an imitation of this procedure is performed. At first, using the 3D model, as the most realistic, simulated response is produced which is considered equivalent to the measurements. Then, the 2D model with the non-moving load is used to derive the transfer functions. At the end, using the simulated response as an input, the equivalent forces are derived for each receiver point. The equivalent forces are compared to each other and the standard deviation between them is calculated for every case. The four equivalent forces are applied into the 2D model and the responses are presented for each point. The accuracy of the method is checked by calculating the error of the response. The error is equal to the difference between the initial simulated response and the response obtained by the equivalent forces.

A parametric study gives information about the influence of the velocity, the structure of the soil and the frequency spectrum of the load on the accuracy of the method. Finally, a real case is analyzed, based on the soil structure of Rijswijk train station and the receiver points which were used for the measurements. The transfer functions and the equivalent forces are derived for the specific location. A percentage of the error is also estimated for a certain load.

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The wear behaviour of arch bridge bearings

Structural bearings are connections between the substructure and superstructure of the bridge and may allow translations and rotations. They also transmit the external forces, acting on the superstructure, to the foundation. In the past years the traffic loads and intensity on the European traffic system has continuously increased. Bridge bearings are therefore more subjected to wear.

Structural bearings are not only designed and fabricated according to the European standards NEN-EN 1337, but they are also tested according to these standards. The bearings are however not tested with the forces, translations and rotations which occur in practice. To make a critical judgement regarding these standards, the wear behaviour of a large arch bridge, the first Van Brienenoord Bridge, is analysed. The analysis is performed by means of a linear-elastic finite element model.

The bridge model is then subjected to a modified fatigue load model based on the European standards for traffic loads NEN-EN 1991-2 and traffic measurements at the Moerdijk Bridge. Translations and rotations were consequently found along with the simultaneously occurring reaction forces. These results are compared to the qualification tests included in parts 2 (sliding elements) and 5 (pot bearings) of the European standards for structural bearings.

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Shear Capacity of Concrete Structures Influenced by Concrete Strength Variation in the Width Direction

Introduction
The structural capacity of many existing concrete bridges is often determined by the shear capacity of the slab deck. The increase of traffic loads leads to the need for re-checking of old bridges. This check many times leads to failure according to codes although these bridges show no significant damage in reality. This phenomenon has to do with the way the capacity of these bridges is calculated. The code formulas that are used are suitable for new structures and mainly based on experiments held on beams. The main difference in concrete slabs is that they have the ability for stress redistribution and therefore weak spots have smaller influence on the overall capacity.

Present Study
In order to investigate the influence of the weak spots on the capacity of concrete slabs an experimental procedure was planned. The use of Non Linear Finite Element Analysis helped to predict the experimental results and design a slab configuration according to the needs of the research. So an extreme slab case was designed and built in the laboratory in order to be tested. The slab consists of seven strips of weak (fc,cube= 20-30 MPa) and strong (fc,cube= 70-80 MPa) concrete mixture and the two materials are casted together with a ratio of 50-50%. At the same time to homogeneous, reference slabs are also casted. The load is applied as an equally distributed line load in a position that would give a shear failure.

Results
The experimental results are judged in terms of ultimate load and inclined cracking load vs. the mean concrete strength. The main observation is that mixed slabs behave in between the two homogeneous cases and the crack pattern and inclined crack load take mean values. So one of the most important results of the present study is, that the calculation using characteristic values underestimates the residual capacity of concrete slabs with big scatter in the material properties. Even when the mean concrete strength is used in the calculations there is still a safety margin to show that it is safe enough to use this value instead of the characteristic one, when assessing the residual capacity of existing structures. In the following graph the experimental results are plotted together with the Eurocode formula calculation for the mean concrete strength (red line) and for the characteristic one (orange triangles). The difference between the two gets bigger in the mixed slab cases.

Conclusion
Code formulas are designed to calculate the shear capacity of new structures and are mainly based on the behavior of concrete beams. The two differences in existing large scale structures, such as concrete bridges, is that they are old —so the material properties show large scatter- and they consist of concrete slabs —so they have the ability of stress redistribution-. These differences require a different approach in the calculation of the capacity of such structures. Experiments showed that it is safe enough to use the mean concrete strength instead of the characteristic one in this case.
Nonlinear dynamics of a crawler-VTS connector for the deep sea mining

The last two centuries the awareness dawned that the deep sea can provide mankind with a wealth of minerals. The reserves of minerals on land are limited, so that some of them will be exhausted within a few decades. But the amazing fact is that they constitute only a small proportion of nature’s riches. In order to meet the increasing demand for both expertise and exploitation techniques in the field of deep sea mining OceanfiORE (ORE signifying "Ocean Resource Extraction") was formed, which is a cooperation between IHC Merwede and DEME. To be able to excavate the minerals from the ocean floor IHC Merwede is planning to use a vertical hydraulic transport system (VTS), composed of a vertical pipeline system (riser) with intermittent booster stations installed over its height. Most part of the investigated vertical riser is a relative stiff part, which remains vertically orientated in time. Near the submerged mining tool (SMT), however, a flexible riser is applied so the relative stiff vertical riser won’t be affected by the large movements of the moveable SMT at the sea bottom.

The objective of this graduation study is to model the flexible riser to gain understanding of the behavior of the riser and the forces acting on the SMT and VTS. In order to do so a simplified model is made of the flexible riser. It is assumed that the riser will only bend in plane and so a 2 dimensional model can be made. The riser is modelled as an Euler-Bernoulli beam and so neglecting ovalization of the riser cross section. The axial deformation is calculated by integrating the tension over the length of the riser from the static equilibrium, assuming a constant Young’s modulus. Due to the symmetry of the riser torsional loads, and so torsion, is neglected. Due to the deep sea application waves also are neglected.

The 2 dimensional equation of motion is derived for the directions normal to the centerline of the riser and the direction tangent to the centerline. The non-linear equation of motion is solved using a boundary value problem finite difference solver. Using this solver the static equilibrium has been reached using two iteration steps. By iteratively changing the horizontal and vertical force at the SMT the riser will be forced to its correct static equilibrium. In order to verify the results gain from the static calculations a comparison is made with 4 cases calculated by Vuyk Engineering Rotterdam which used the program Orcaflex. However, because Orcaflex is not capable of introducing a slurry flow through the riser, also the results of calculations with and without the slurry flow are analyzed in order to determine the effect of the slurry flow.

Much work still has to be done to gain a full model for the behaviour of the flexible riser. A derivation therefore is made for the 3 dimensional model of the riser. Also a recommendation is made on how to solve the (linearized) equation of motion in the time domain.
Framework for a risk informed maintenance strategy for deteriorating hydraulic structures

Civil structures, especially hydraulic structures, are subject to influences from the environment around the structure. As a result of these influences the structure degrades, which lowers the strength of the structure. Several actions are available to lower the speed of degradation and/or restore the structure to a certain condition.

Within the operations and maintenance of a structure, the question is whether regularly small reparations or once a large replacement needs to be performed. In order to make a founded decision a quantification is needed. One of these is using risks as part of the decision making process. Risk is defined as the probability of occurrence times the consequences. Since this can be expressed as costs, it can be compared with the costs of the reparations or replacement to find the value of this action.

In this thesis, a framework is presented to aid in the development of a one replacement-multiple reparations-strategy. The method describes the steps needed to find all information to make a stochastic based deterioration model. Also the steps to calculate the costs for each strategy, where the moment of replacement and reparation interval are variable, are shown. The framework ends with an optimisation, resulting in the most optimal strategy within the set boundaries and assumptions.

Testing of the framework has been performed with a case study of a fictional lock. After collecting all needed information about the degradation models, distribution and parameters, several calculations have been performed. With both a level II as a level III method these calculations have been made. The framework proved to be a good guideline for the determination of sought-after strategy.

Since degradation models can have a more complex (than adding and multiplying parameters) shape, the level II method became significantly more complex than what it is used for (an indicative calculation). Even though level III method (the Monte Carlo method was used) requires more processing time (on a commercial laptop) than the level II method, the time it took to program was equal. A level II method is therefore only of use when a comparison with an analytical method is wanted.

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The thesis consists of two parts:

a. Investigation into the availability, application and mechanical properties of crushed demolition waste for road bases.

b. Comparative research between mix granulate 0/40 and Eifellith lava 0/40

In the first part have been described:
The stocks from different sources such as dumping places, industrial buildings, old buildings, renovation and new buildings. Besides, a distinction has been made between the stocks in national respect as well as concerning a number of big cities. This has been done for the reference year 1977 as well as over the period 1977 – 2000.

The volumetric need for the road plans in national as well as in regional respect. A distinction has been made in the composition out of masonry and concrete rubble, regarding the different traffic classes. Priority classes have been distinguished, being classes I and II, where class I concerns the new to be built roads to be constructed before 1990.
The experiences of road authorities in national respect as well as in a number of big cities and some smaller towns. The experiences of a number of contractors, being laboratory research as well as in situ measurements.

The suppliers of crushed rubble, regarding the different types of crusher mills inclusive the advantages and disadvantages, the number of suppliers, the distribution over the country, the production procedure, the removal of unwanted materials, quality control and the pricing.

Investigations by regional laboratories such as the NWL and OWL as well as by the WBD in Delft.
In addition a number of thesis have been reviewed, concerning "Investigation on unbound granular bases for roads" (Sweere), "Material testing" (Huurman), "Mechanical behavior" (Van Niekerk) and „Repeated load CBR testing and modeling" (Araya).

Crushed demolition waste
Evaluation of Stress Concentration Factors (SCF) in Multiplanar Tubular Joints

In order to improve the reliability of design for multiplanar tubular joints, especially with respect to fatigue loading, it is necessary to accurately estimate the Stress Concentration Factors (SCF’s). The SCF’s on uniplanar joints can be obtained by the parametric equations defined in the standards of classification societies (DNV). And their application has limitations concerning the joint types and geometry parameters. In the case of multiplanar joints, it is still unknown whether these parametric equations are applicable to generate equally reliable SCF’s. Therefore, the main objective of the research is to verify this. The research contains three major stages: (i) building the FE models; (ii) processing the measurement data to verify the FE modeling results; and (iii) comparing the verified FE modeling results with the SCF’s from the parametric equations.

First, the FE modeling as a general way to obtain the SCF’s on multiplanar tubular joints is adopted in the thesis. During the process of building up the models, the positions of the Mesh cinctures in the 3 dimensional space, which are hard to determine, are perfectly found by an innovative approach “the Mesh Cincture Formulae”. And the “Automatic Tubular Model Creator” has been programmed by Visual Basic and it is an efficient tool to build tubular FE models.

Based on the above innovative methods for modeling, more than 1500 FE models, including the most commonly used geometry parameters of uniplanar and multiplanar tubular joints, are built and solved. Therefore, the modeling results are compiled into a number of charts, from which the SCF’s can be directly read out when the joints share relatively similar geometry parameters.

Second, before using the SCF’s as the modeling results, it is necessary to safeguard their reliability. To do this, the FE modeling results are verified through comparing with the measurement data from a full-scaled multi-planar offshore structure. In this research, the measurement data are processed and analyzed. It shows that the distributions of the movement amplitude of the float offshore structure conform to the Rayleigh distribution. In addition, the comparison proves that the SCF’s from the FE modeling are reliable.

Finally, the verified SCF’s are compared with those obtained from the parametric equations defined in the DNV. Through the comparisons, it is safely to conclude that the parametric equations can be applied to multiplanar tubular joints but the geometry parameters should fall in a certain range. In addition, the comparison illustrates that the FE modeling is more suitable and reliable than the equations in the DNV in terms of calculating the SCF’s on multiplanar tubular joints.
Civil Engineering theses

Hydraulic Engineering
The interaction between bed-load transport and dune orientation

Background
Bedforms play an important role in the sediment transport of a river. Because of their importance many experiments have been carried out to better understand bedforms. Most experiments concern transverse bedforms (with crests aligned perpendicular to the flow direction). However, bathymetry measurements show many instances of oblique dunes. Oblique bedforms induce flow and sediment transport in the transverse direction.

Based on the flume experiments of Talmon [2009], Sieben & Talmon [2011] proposed formulae to determine the bed-load transport direction over oblique dunes. To apply these formulae the dune orientation has to be known. Therefore, Sieben & Talmon [2011] proposed to derive the dune angle by relating it to the relative dune migration rate along the dune crest. This was applied in the preliminary work of Weij [2012]. It was found that the current formulae give unrealistic results. The main objective of this thesis is to improve the prediction of dune orientation angle for large-scale modelling.

Mechanisms of Oblique Dune Formation
The mechanisms involved in the formation of oblique dunes are investigated in a simplified environment. For the simplified environment we created a model based on the model created by Jerolmack & Mohrig [2005]. The model calculates the bed level change in one-dimensional slices, which are then coupled with transverse sediment transport to create a quasi 2D model.

The results of show a dune orientation that eventually finds an equilibrium. Two explanations were given: (1) A gradient in transverse sediment transport can decrease or increase the dune migration rate, (2) Dune crests break up, and merge before reaching a larger angle.

Based on these findings, the calculation of the dune angle is adapted in three ways: (1) The effect of transverse sediment transport on migration rate, (2) a reduced dune height for larger angles, (3) a limited dune orientation angle.

The first measure is promising; it reduces the calculated dune orientation angles to more realistic values. However, the current implementation is problematic. The second measure is simple to implement and also reduces the dune orientation angle to more realistic values. However, the factor used to reduce the dune height has no physical basis. The third measure did not lead to satisfying results, but can be combined with the other measures.

Sediment Transport Direction
In the simplified environment cross-stream sediment transport was based on just the transverse slope. However, the flume experiments by Talmon [2009] show that sediment transport also depends largely on the changed flow pattern near the bed.

We analysed the flume experiments carried out by Talmon [2009]. These experiments were carried out to quantify the transverse sediment transport over oblique dunes. Furthermore, we carried out detailed three-dimensional flow simulations. We used the detailed model of Nabi [2012] to carry out these flow simulations.

Sieben & Talmon [2011] derived formulae for the mean sediment transport direction based on the experiments of Talmon [2009]. During our analysis of the flume experiments and three-dimensional flow simulations we found three main improvements of the formulae by Sieben & Talmon [2011]: (1) The length of the zones as proposed by Sieben & Talmon [2011] are inconsistent with the lengths seen in the flume experiments. (2) The near-bed flow direction on the stoss side of the dune (outside the transition zone) was assumed to be equal to the main flow direction. We found that there is a small but noticeable effect of the dune angle on the near-bed flow direction.
Due to climate change, it is expected that the design river discharge of the Rhine will increase from 16000 m$^3$/s in 2015 to 18000 m$^3$/s in 2100. In order to make the Dutch water system climate proof, dikes must be reinforced and raised and/or the design water level must be lowered. In this study, a flood channel as a measure to decrease water levels has been investigated, and has been compared to dike reinforcements.

**Flood channel design**

The investigated flood channel runs from the Afgedamde Maas towards the Biesbosch and Bergse Maas. This flood channel has been designed by architect Robbert de Koning, and is part of a larger plan to make the Dutch lower rivers climate proof until the year 2100. The length of the flood channel is approximately 20 kilometers, and the flow width is 600 meters. The flood channel is designed for a use of once every hundred years.

**Model**

The flood channel has been analyzed first by a simple one-dimensional model, in order to get a first estimation of the results. The second step was to model the flood channel in a two-dimensional model. This model is based on the WAQUA Rhine-Maas Estuary model, calibrated for the Hydraulic Boundary conditions 2011 (RMM-HR2011 model). This two-dimensional model has been updated to the reference year 2015. In order to add the flood channel, a new numerical grid has been created, because the flood channel lies outside the existing numerical grid.

**Results**

At a 18000 m$^3$/s Rhine discharge, the flood channel’s discharge is 2707 m$^3$/s (23% of the Waal’s discharge). As a result, the discharge through the Amer increases up to 32%, while the discharge through the Nieuwe Merwede decreases up to 28%. The maximum water level decrease at the Waal is approximately a meter, and the maximum water level increase at the Maas is 0.44 meter. The results showed that the performance of the flood channel is significantly lower than the expectations, and that the lower performance of the flood channel is mainly caused by the discharge capacity of the outlet channels.

**Costs**

Based on the water level results and flood channel design, the costs have been calculated. The calculated costs for the flood channel are 1567.6 million euros. The cost-efficiency is estimated on 18 m$^3$/10$^6$ €, which is low for such a large measure. Due to the flood channel, the costs for dike reinforcements until the year 2100 are reduced with 266 million euros. However, practical limits to dike reinforcements and values related to landscape, nature and culture are not taken into account, which is expected to change the cost-benefit balance.

**Conclusion**

Based on the water level results and costs calculations, the investigated flood channel is not hydraulically optimal, and not a cost effective alternative for dike reinforcements. However, hydraulic optimization of the channel is possible, and when values of landscape, nature and culture would be taken into account, the cost effectiveness could be more positive.
Port master plan for the Port of Beira, Mozambique

*Including an optimization of the access channel and a case study for the Adaptive Port Planning framework*

The port of Beira is an essential driver for economic growth in Mozambique. Its location, with strong connections to the hinterland, creates a promising future for the further development of the port. The port authority requires a new port master plan in order to optimise throughput over available ground and (wet) infrastructure, and to extend its capacity in the coming decades. This report presents in structured way the development of a new port master plan for the Port of Beira.

In Beira, waiting times are known to be very long and the port authorities have the desire to improve the port performance on this matter. Therefore a Harboursim model of the present situation of the Port of Beira is built, which is used to simulate the maritime traffic. For Beira Port, processes are added to the Harboursim model code to make a good representation of the reality. Furthermore, the Harboursim model is improved, by fixing errors in the model code. The adaptions made in the code are generally applicable for all future Harboursim models.

This study is a case study for the ‘Adaptive Port Planning’ (APP) framework, which is an addition to the master plan development. Using the framework, differences in the robustness of the master plan alternatives are determined. Furthermore, the robustness of the chosen alternative is increased, because actions for dealing with the vulnerabilities and opportunities associated with each alternative are determined.

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A generic quantitative damage description for rubble mound structures

Breakwaters are used for reducing wave height in harbours or divert sediment. One of the types of breakwaters is the rubble mound breakwater. These structures are constructed with smaller quarry rock as core and larger quarry rock as outer layer. For economical reasons, the design allows some damage to the armour layer. The amount of damage is objectively and quantitative determined by damage parameters. There are several different damage parameters which describe all different unique characteristics of the erosion hole. For a straight slope with a constant cross section, extensive research is executed for reliable design values of some of these parameters. For a 3D geometry such as a roundhead such design values are not formulated. This thesis is about roundhead model tests, executed at Deltares research institute. Four tests with increasing wave height are executed to eight identical roundheads. The roundheads weren’t repaired in between test so progressive damage occurred.

The damage was analysed with the use of digital stereo photography (DSP), this high-resolution measurement technique creates a computer model of the physical model with a resolution of one mm. By subtracting the computer models of before and after a test, the erosion and deposition is accurately represented. The damage level is quantitatively determined by comparing different damage parameters. The compared parameters consider all different aspects of the erosion, the number of displaced stones (damage percentage Nd), the number of displaced stones per stone width (Nod), eroded area (van der Meer damage parameter S), nominal erosion length (L) & the nominal erosion depth (E).

Before the results are being analysed, the data gathered from the DSP must be processed to smooth the individual stones but keep the erosion profile intact. The optimal smoothing process is based on a convolution or moving average principle. The size of the optimal smooth factor is two times the median nominal stone size (Dn50).

The results show three erosion holes at the roundhead, the first erosion hole between 0~10° from the incident wave direction, the second between 60~70° from the incident wave direction and the third between 105~115° from the incident wave direction. The most damage was observed at the first and third erosion hole. The damage in the third erosion hole was slightly higher and more variable between the eight realizations compared with the first erosion hole.

By comparing the different damage parameters it appears that only the erosion depth E, is representing the realizations correctly; the highest values in the third erosion hole with the largest deviation. Therefore design values of this damage parameter are proposed for roundheads with a slope of 1:2 and an armour layer thickness of two times Dn50.

Initial damage:   \[ E = 0.2 \sim 0.3 \]
Intermediate damage:   \[ E = 0.5 \sim 0.6 \]
Failure:   \[ E = 1.0 \sim 1.1 \]
Collapse:   \[ E = 1.5 \sim 1.6 \]

To come to a generic damage parameter further research is necessary to validate the proposed design values for roundheads with different configurations, such as different slopes and different radius.

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Stochastic effects of dredge plumes

Dredge plumes and ecology have become increasingly intertwined in recent history; one of the more prominent reasons behind this is the influence of clouds of fine sediments released in the open water due to dredging (`dredge plumes') on for `sensitive receivers' such as coral, seagrass and mangroves. An Environmental Risk Assessment (ERA) in combination with a cost-benefit analysis could be a valuable instrument for deciding on ecological impact. When dealing with ecology, it is important to realize that nature is not a harmonious, calm state: in fact, it could be considered to be at best only approximately in equilibrium, where small scale changes could lead to a completely new equilibrium. In the case of dredging operations and ecological effects, this is even more relevant because ecological effects occur constantly; not just due to dredging. An ERA consists of a description of the system and its components, hazard identification, effects assessment, exposure assessment, risk characterization and an evaluation which provides feedback for a possibly updated system description. Globally following the steps in an ERA, exposures are looked at first. Relevant dredging exposures are suspended sediment concentrations and sedimentation. The source of this is the dredging equipment, which spills fine sediments in the open water. These sources lead to dynamic plume, which consists of interacting, complex three-dimensional fluid motions: sediment characteristics, bathymetry and dredging equipment type are just a few of the influencing factors. Because there motions are often still too complicated to model, the dynamic phase is captured in conservative estimates. These estimates serve as a source term for the passive plume phase. During the passive plume phase, advection and diffusion are dominant processes which are well understood processes. MIKE 21/3 or Delft3D, both hydrodynamic and transport models, can be used to schematize the passive plume. Once a passive plume reaches a sensitive receiver, in this document assumed to be coral, seagrass or mangroves, effects can occur. It is important to realize that these effects do not have to be induced solely by dredging: other background effects can also provoke effects in sensitive receivers. Effects can be classified in discrete classes, ranging from growth to mortality. To which extent a receiver exhibits a certain effect depends on the receiver characteristics, the shape of a temporal variable exposure and the type of exposure. In an attempt to properly catch the effect of temporal variable exposures, several models are discussed with most prominent being two originally toxicological models. Given their background these models appear to be limited to exposures which mimic a toxic exposure, although they are relatively easy to implement. At the other end of the spectrum are the energy budget models: models which try to describe important processes which together form an individual. While this is a more complete and holistic approach, there is concern regarding the uncertainty of the final answer given the large number of parameters (relative to the toxicological models) and the attributed uncertainties. Combining these exposure and effect models in dredging practice and explicitly stating their (combined) uncertainties leads to a risk assessment for dredging practice. A part of this risk assessment was applied to field data regarding coral cover for a number of coral reefs, but the field data showed no strong correlation between exposure and changes in coral cover. Nonetheless, for a quantitative assessment of ecological risks, a probabilistic analysis is invaluable. This can lead to a proper valuation of the risk of effects, which in turn can be used in a cost-benefit analysis to properly weigh these risks if they are acceptable or not when compared to the benefits.

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The gates in storm surge barriers and locks are currently mainly made of steel. These gates are exposed to heavy weather influences and to water from waterways. Corrosion is for these steel gates inevitable. Therefore this has to get treated with a coating. During the life cycle the gate should be recoated during maintenance periods. These maintenance operations are expensive. Therefore it would be cost-effective to build a maintenance friendly gate of another material. An example of a material with low maintenance costs is Fibre Reinforced Polymer (FRP).

In this master thesis the feasibility of FRP in large hydraulic structures is investigated, specifically the feasibility of FRP in lifting gates.

The thesis consists of a literature and a case study, in this case study a lifting gate is designed according to the requirements of the small gate of the Hartel Canal Barrier. The lifting gate is designed for two different applications. First for the application of a gate in a storm surge barrier, the gate is designed on strength. Second a lifting gate in a lock, which is designed with a maximum deflection and a high number of load changes.

A variants study is done to find a suitable structure. In the variants study different possible construction systems for lifting gates, with an expectation of the possibilities, for a FRP gate are listed. From this list the sandwich, box and arch girder are further evaluated. The arch girder came out to be the best variant, because it has the most potential to be technically and economically feasible. Although the arch girder was the best variant, it has some critical discrete joints where locally high loads occur, which could be difficult to manufacture. The arch variant is further designed in sub variants.

Three types of sub variants are reviewed. The first sub variant the transverse plates are replaced by webs, which have the advantage of continuous joints. The second sub variant consists of a lens structure, which combines two arches. In the third sub variant the load distribution over four webs is being reviewed. Finally the lens structure with a double arch and four webs is further designed in the final design, because the lens structure required the least amount of material to bear the load.

To enable the gate to sink, the possible locations for gaps in the webs were reviewed. This is done to enable the water to flow through the gate. With these gaps the upward water pressure was still higher than the weight of the gate. This problem is overcome by applying a core material with a higher density and sandwiches with a thicker skin.

The direct building costs for the strength criterion were less expensive than the building costs of the steel gate. After the life cycle the gate, which is dimensioned according to the fatigue criterion, is also less expensive. Even when the steel gate is dimensioned for less load changes, still the costs of the FRP structure are lower.

For this thesis the feasibility of FRP in large hydraulic structures is investigated. It can be concluded that FRP is technically and economically feasible. In this thesis only a lifting gate is evaluated, but FRP should also be applicable for other type of gates.

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Sediment transport on the ‘Holland Coast’ shoreface

Introduction
The scientific foundation to maintain the Holland Coast shoreward of the -20m depth contour is limited. It is assumed that profile perturbations shoreward of the -20m depth contour influence the coast within a time scale of 50 to 200 years. Hence, seaward of -20m NAP dredging companies are allowed to dredge sand. The dredged material is amongst others applied in nourishments near the beach. Coastal policy in The Netherlands prescribes that the sediment volume of Holland Coast should be preserved shoreward of the -20m depth contour. The volume required to accomplish this can be significantly reduced in case a shallower depth contour can be assumed. In order to investigate the influence of perturbations shoreward of -20m NAP and to validate the scientific foundation of the -20m depth contour, cross-shore sediment transport on various depth contours will be analysed. The emphasis of this research will lie on sediment transport on the lower shoreface (deeper than -10m NAP).

Research
Sediment transport will be evaluated with the model Unibest-TC. First, sediment transport sensitivity on a straight slope due to varying parameters is analysed. In the analysis the dominance, direction and magnitude of the wave related and current related transport of both the bed load and suspended load is investigated. Subsequently, sediment transport due to variable wave conditions on various depth contours is examined from the shoreface profile of Noordwijk. Also the situations with a variable wave angle and a tidal current was considered. Finally, morphological simulations, including a 100-year profile evolution and profile perturbations (e.g. sand pits) located on the lower shoreface, were performed.

Results
Shoreface sediment transport depends on the wave steepness in combination with the slope steepness for every depth contour. This was concluded by analysing sediment transport sensitivity for a range of parameter settings. Sediment transport due to wave action is particular present on the upper shoreface. Although, the onshore directed bed load transport is dominant on the lower shoreface, its relative contribution is negligible in case a tidal current is included. It was found that low amplitude waves are responsible for the largest profile changes. On the lower shoreface, the tidal current induced offshore sediment transport is dominant. Onshore transport on the upper shoreface and offshore transport on the lower shoreface induce a lower shoreface flattening and an upper shoreface steepening. Perturbations located at the -15m, -20m and -25m NAP depth contours propagate shoreward caused by tidal current induced concentration gradients (see submitted figure). Sediment transport induced by waves result in diffusion of profile perturbations and a limited shoreward shifting. A situation including a tidal current, results in a larger shoreward propagation of the sand pits/artificial ridges at -25m NAP than at -15m NAP. A larger depth dependent tidal velocity induced sediment transport gradient at -25m NAP is responsible for this phenomenon. So, the interaction of waves and tidal currents is of great importance on the entire shoreface profile and may have a large impact on cross-shore sediment transport.

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Wave overtopping at rubble mound breakwaters with a non-reshaping berm

The research was aimed at gaining insight into the influence of a permeable berm on the overtopping behaviour. Moreover it was desired to validate existing prediction methods for the spatial distribution of overtopping for breakwaters with a non-reshaping berm.

Wave overtopping was investigated by means of a physical model. The breakwater scale model was divided into 8 collection bins. Overtopped volumes were collected and pumped into floating tanks further down the flume. After the experiment the mass of the floating tanks was measured and the mean overtopping discharge could be determined for 8 horizontal positions on the breakwater. The measured total overtopping discharges cannot be predicted accurately by existing prediction methods. On the basis of experimental data a new prediction method was proposed that achieves an excellent fit for total overtopping. The crest freeboard definition was adjusted to account for the permeability of the crest. The reduction factor accounting for slope roughness was made dependent on the Iribarren number. For Iribarren numbers higher than 6, this method calculates no reduction of overtopping due to slope roughness. The effect of a permeable berm on total overtopping was found to be remarkably different from the effect of an impermeable berm. Permeable berms below Still Water Level (SWL) lead to less reduction of overtopping than impermeable berms below SWL. Berms above SWL lead to wave breaking on the slope in front of the berm. Contrarily to impermeable berms above SWL, a permeable berm above SWL leads to significant reduction of overtopping.

The measured spatial distribution of overtopping is associated with a lot of seemingly random behaviour. Large differences were found with the experimental data of Lioutas (2010). It is suspected that the used experiment setup gives rise to significant model effects for the spatial distribution of overtopping. An experiment setup was recommended that is expected to more accurately model the behaviour of the prototype situation. Data on the spatial distribution of overtopping could not accurately be predicted by existing prediction methods. In some cases existing prediction methods provided an upper limit for overtopping (Juul Jensen, 1984) but none led to a good fit with the experimental data. A new reduction factor was found that reduces the amount of scatter and provides a conservative prediction of the experimental data.

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Nederrijn recanalization design using and testing Systems Engineering

The Nederrijn and Lek are dammed by three weirs which are located near the village of Driel, Amerongen, and Hagestein after which they are named. Weir Driel regulates the distribution of water at the IJsselkop for dammed conditions. A minimum discharge of 285 m$^3$/s has to be diverted into the IJssel by weir Driel for the fresh water supply of the northern part of the Netherlands and for generating sufficient draught for commercial shipping. The weirs Amerongen and Hagestein regulate the upstream water levels for commercial shipping; minimum levels of +6.0 m NAP respectively +3.0 m NAP are maintained by these weirs. The water levels of the IJssel decrease to 1 metre or lower when weir Driel fails in dry summers which results in an obstructed waterway for commercial shipping and an insufficient fresh water supply to the northern part of the Netherlands.

**Problem statement**

ARCADIS made an assessment for the reliability and availability of the weirs in the framework of the project RINK-SSC (Risico Inventarisatie Natte Kunstwerken Sluis Stuw Complexen). The assessment indicated that the weirs do not meet the reliability and availability norms for the present situation and that structural parts of the weirs have exceeded their technical life span. Therefore, the weirs need to be renovated or replaced within ten years from now.

Furthermore, a secondary problem statement is present which concerns the application of Systems Engineering for large scale design projects. Presently, a major ‘transition’ of the substantiation of design choices made in the political domain and design choices which are made by engineering firms, which are based on the Systems Engineering methodology, is present. Design choices made before the ‘transition’ are not well traceable and results in ambiguities during the design process.

**Results of the recanalization design**

The result of the research is an alternative design of the present canalization. The Nederrijn and Lek are chosen for recanalization due to the lowest impact for the implementation of the recanalization with respect to the other rivers. It is possible to canalize the Nederrijn and Lek using two weirs when the reach located in between the Amsterdam Rijnkanaal and the Lekkanaal is downgraded to a recreational river. The upstream weir is located near the village of Driel and has to maintain the present dam regime to reduce the implementation works and time. The downstream weir is located at a floodplain near the village of Culemborg and has to regulate a minimum upstream level of +5.0 m NAP. The weir is subdivided in three gaps of 41 metres wide each. Three fibre reinforced polymer submerged segment gates have to control the discharge and the upstream water levels. The gates are composed of sandwich panels and four shear webs which are located in between the panels.

**Results of the developed and tested SE methodology**

The application of separate design levels with a limited set of requirements each turned out to be applicable for large scale hydraulic design projects for the first four design levels. So, the SE methodology could also be applied for decision making on a large scale which are normally made in the political domain. A well-structured and clear design methodology is obtained, which performed well for these levels. The method had to be adjusted for the structural design level because the set of requirements exponentially expands which results in a non-clear design method. Furthermore, using a functional analysis for the structural design results in a non-meaningful definition of the functions of the elements.

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Study on barriers in Mekong Delta Vietnam

Project objective
The Mekong Delta is located in the South of Vietnam and is responsible for producing half of the national food volume. Development has encountered several restrictive factors: flooding, shortage of fresh-water and salt-water intrusion from the East Sea during low-flow discharges. The Dutch Delta Commission has recommended closure of the Cung Hau, Co Chien and Ham Luong branches of the Mekong River, all part of the Tien River. This recommendation has not been substantiated yet. Unfavourable effects like severe erosion in connecting channels and increasing flood water levels upstream might occur. The following project objective was therefore defined:

"To determine and design the preferred type of closure of the Cung Hau, Co Chien and Ham Luong branches, that reduces salt-water intrusion in the Tien River estuary, minimizes erosion of the connecting channels and prevents unacceptable increases of flood water levels".

Salt-water is currently intruding 60-70 km inland. Navigation is mostly present in the Tieu and Dai branch to My Tho harbor and Cambodia.

Closures and requirements
For the closures proposed, requirements with respect to salt-water intrusion, morphological changes in the connecting channels, water levels, protection of floods from the East Sea and retaining fresh-water, are present.

Two types of closure structures, e.g. closure dams and/or discharge sluices are considered. Furthermore, four closure cases are considered. The closure locations defined by the Commission were based on the following aspects: protection of agricultural areas, navigation, construction costs of primary dikes and supply of salt-water to the aquacultural areas.

Analytical calculations supplemented with numerical calculations made by means of a 2D numerical model in Delft3D were used to determine the effects of the different closure cases. Therefore, permanent closure of the Cung Hau and Ham Luong branch by means of closure dams, and temporary closure of the Co Chien branch, with a discharge sluice of 5000 m² and closure dams to close off the rest of the Co Chien branch is recommended. Small navigation locks are recommended in the Cung Hau and Ham Luong closure dam, to provide navigational access from and to the shrimp farms near the East Sea. Salt-water intrusion was decreased to 20 km inland, and the increase of flood-water levels was negligible. River bank and dike protection against erosion was determined necessary though in several connecting channels.

Closure design and planning
The Co Chien discharge sluice has been designed in detail, based on local Vietnamese experience. A pier system is recommended for the Co Chien discharge sluice. The concrete piers are constructed in situ in separate drained construction pits in between sheet pilings. The weak clay top layer is removed in this construction pit and replaced by a sand layer which is compacted afterwards. Gates, sills, bridge slabs and gabions are prefabricated.

In general, first the Cung Hau and Ham Luong closure dams are constructed simultaneously with the Co Chien discharge sluice. After completion of the discharge sluice, the Co Chien closure dam is constructed. The complete project is estimated to take approximately 3.5 years.

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‘The deltadike concept and the effectiveness of various dike reinforcement alternatives’

The second delta committee introduced the deltadike concept in 2008 by claiming that deltadikes are ‘either so high or so wide and massive that the probability that these dikes will suddenly and uncontrollably fail is virtually zero’. Currently, there is no consensus about the meaning and design of deltadikes. This problem is addressed by the following main research question of this study: ‘In what way can a dike be transformed into a deltadike by various dike reinforcement alternatives under different types of loading conditions?’

In the definition of the deltadike, the delta committee implicitly stated that a deltadike should have a low probability of failure (first requirement, similar to dikes) and low consequences of failure (second requirement, distinctive of dikes). In case a dike does not fulfill the deltadike requirements, dike reinforcement measures may achieve these requirements by respectively firstly decreasing the probability of failure and secondly decreasing the consequences of failure. It is assumed that the consequences of failure reduce when the predictability or mildness of failure increases. The predictability of failure increases when the load is certain in advance of a loading event and the certainty of the dike strength increases. The mildness of failure increases in case the physical consequences (for example the final flood depth) are lower. The probabilistic Dike Reliability Model, developed and validated by the author, is used to quantify the probability, predictability and mildness of dike failure. The breach growth in sand-dikes model developed by Visser (1998) was used to compute the effect of increasing the crest width.

Several entrenched views on the deltadike concept are not supported by the outcomes. First, non-structural failure (dike failure without dike breaching, for example by overflow of the dike) may result in flood damage of the same order of magnitude as structural failure (failure with dike breaching) in case of river dikes. Second, increasing the crest width is an ineffective measure to make a dike breach-resistant. Third, increasing the critical discharge is an ineffective measure for dikes designed for and loaded by small waves. Lastly, increasing the crest height is in most cases of great importance in transforming a dike into a deltadike.

The first requirement is generally fulfilled by increasing the strength of dike elements. The achievement of the second requirement depends on the type of loading conditions. A river dike can be transformed into a deltadike as the predictability of failure can be increased; the load is predictable with certainty and the strength of a river dike can be made certain by decreasing the domination of the uncertain failure mechanism ‘piping’ by increasing the seepage length. An estuary dike cannot be transformed into a deltadike; the load is not predictable with certainty and both structural and non-structural failure can be severe (not mild). A sea dike can be transformed into a deltadike; the load is not predictable with certainty but the mildness of failure can be increased by increasing the domination of non-structural failure by increasing the critical discharge.

In case the research is continued it is recommended include the influence of the predictability and mildness of failure on the consequences of failure; in other words to perform the study in a risk-based framework. A follow-up research project could investigate how cost-effective a deltadike actually is compared to a dike. Furthermore, new research could be aimed at investigating which real-life river dikes could actually be cost-effectively transformed into a deltadike based on a risk-based design method.

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A probabilistic design of a dike along the Senegal River

Problem
In the North of Senegal, on the border with Mauritania, the 1800 km long Senegal River (Fleuve Sénégal) is located. In response to great draughts in the nineteen seventies and eighties, two dams were built; the Diama dam in the river Delta near the embouchure and the Manantali dam approximately 1200 km upstream. The Diama dam was built for water level regulation, irrigation and navigation purposes and the Manantali dam was built for generation of electricity. The construction of the Diama dam resulted in the formation of a water reservoir upstream of the dam up to approximately 350 km land inwards (BCEOM, 1999), with a water level of 2.25 m IGN (Institut Géographique National) in the dry period, and in the blocking of salt sea water flowing upstream into the river. These two effects caused the growth of Typha Australis in the floodplains of the Senegal River Delta. The negative side effects of this plant are multiple, like the non-accessibility to the river for the local people, the threat to public health by the development of water related diseases, and reduction of food production as irrigation canals are blocked.

Solution
Many attempts were done to solve the Typha problem, like the chemical and mechanical control, but none appeared successful. The proposed solution to this problem is to transform the floodplains of the river into polders. The aim of this solution is the sustainable control of Typha. The goal of this thesis is to determine the economic optimal dike height for the new polder dikes in a probabilistic manner. A first step towards this goal is to get an adequate understanding of the Senegal River system as a whole, and especially of the river Delta. For this purpose, hand calculations based on hydraulic theory were done and a one dimensional hydrodynamic Sobek model of the river Delta was created. The model is used to get insight in the river’s functioning in normal and high discharge situations. The probability of malfunctioning of the Diama dam is not analysed in depth, but is investigated through a sensitivity analysis. The model is also used to investigate the influence of the construction of polders on the water level. A second step is to define the failure probability for various dike heights. In this study, the failure mechanism of overflowing is investigated. When considering the present value of amount of loss due to flooding, depending on the kind of crop, and the construction costs of the dike, the economic optimal dike height is determined. This is done by using the economic optimization model of Van Dantzig (1956). This model adds the present value of the amount of loss due to flooding to the construction costs. The optimal dike height is located where the sum of these two aspects is minimal. The costs for polder preparation are not taken into account. This study results in an optimal dike height and flooding frequency.

Result
The analysis of the economic optimal dike height shows that this optimum corresponds to a flooding frequency ranging from 1/8 years in case the dike height is 2.7 m IGN to 1/20 years in case the dike height is 3.5 m IGN considering different kinds of crop and the amount of polders built. These frequencies are relatively high as they are related to a limited amount of expected loss due to flooding. The polders will be used for agricultural purposes and therefore the loss due to flooding is limited and smaller than for instance the loss for an urban area behind the dikes.

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Convex coastline induced rip currents at the Sand Engine

Introduction
This study investigates the hydrodynamics at a convex coastline. The Sand Engine, a man made peninsula in the Netherlands, is used as a case scenario. It is hypothesized that a rip current can develop under certain wave conditions due to the change in coastline orientation. The main goal of this research is to obtain a better understanding of the relevant processes for this rip current to develop near convex coastlines and to investigate if these currents pose a hazard for swimmer safety.

Field observations and a hindcast
On March 8, 2012, a field experiment was conducted at the Sand Engine to measure flow velocities in the surfzone. In this experiment GPS tracked buoys were released in the surfzone. Two drifter deployments are presented in this study, one of these showed a circular flow pattern, the second a large offshore directed current, with a maximum velocity of 0.8 [ms⁻¹]. The data set, from the fieldwork, was then used to optimize and test the abilities of a numerical model, Delft3D. A hindcast, of the conditions during the field experiment, in Delft3D gave results that were in good agreement with the field data. Furthermore the model results showed that the offshore current from the second deployment was partly due to the coastline convexity.

Conceptual numerical model
A simplified alongshore uniform model is constructed in Delft3D to test a variety of scenario’s. Most scenarios focused on coastline convexity (between 35.5 and 0 [deg]) and wave directions as it was found likely that these are the most relevant processes. Other scenarios tested the influence of a tide, a rip channel, wave height and bottom profile.

For this model it was found that the most relevant processes for a rip current at a convex coastline are; (1) Wave direction, when waves approach the shore along the mean shore normal the offshore velocity is highest. (2) Coastline convexity, a more convex coastline inducing a higher offshore current velocity and has a larger range of wave direction that induce a rip current. (3) Wave height, higher waves give more offshore flow. (4) The tide, tidal current extends the range of wave directions that induce a rip current. Moreover it was found that a rip channel induces higher rip current velocities.

Implications for swimmer safety
The implications for swimmer safety were examined by predicting the rip current strength under typical wave conditions during summer beach days. It was concluded that a convex change in coastline orientation larger then 15 [deg] results in an enhanced risk for swimmer safety. Up to a 5 times higher rip current frequency is anticipated on summer beach days due to coastline convexity.

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New container ports are mostly constructed on low lying coastal areas or in shallow coastal waters. The quay wall and terminal yard are then raised to a level well above mean sea level to insure safety against inundation. The resulting ‘conventional terminal’ requires large volumes of good quality fill material often dredged from the sea which is costly. Royal HaskoningDHV developed the concept of a container terminal with a “polder yard”. The yard would lie below the outside water level and be surrounded by a combined quay wall flood defense structure. A water drainage system is required to drain excess water from the polder. This master thesis investigates the technical and economic feasibility.

Important conditions for the feasibility of a polder terminal are low conductive (impermeable) subsoil, which limit the amount of seepage water entering the polder, and high reclamation cost. The polder terminal is technically feasible; a conceptual design is made for a case study in Tuas, Singapore.

The ‘polder terminal’ could save 10 to 25% of the total cost (investment and risk) due to the lower reclamation cost. The exact saving depends on the polder depth which is bounded by uplifting failure of the polder yard. The increase in cost due to the risk of inundation and water drainage system is insufficient to counteract the large savings possible. The investments, risk and total cost of both the conventional and polder terminal are shown in the graph, where the minimum total cost of the polder terminal are lower than those of the conventional terminal.
Numerical and experimental research of wave interaction with a porous breakwater

The design formula for rubble mound breakwaters by Van der Meer has an unclear Notional Permeability term. This term causes a lot of confusion for designers. In the past many people have tried to derive a better formulation for that term by experimental and analytical research. The goal of this study was to obtain a better formulation along a numerical way. This study explores the numerical possibilities and tries to define which direction has to be taken in future research.

As a first step, a very simplified case is taken with a vertical homogeneous breakwater which interact with monochromatic waves. In total six different blocks were made of epoxy and elastocoast. Only 4 out of the 6 blocks were tested. Also the porosity (n), laminar friction (α) and turbulent friction constant (β) of the blocks were determined experimentally. This way the experimental results could be compared with computations.

These experiments have been done in the large flume of the Environmental Fluid Mechanics Laboratory of the TU Delft. Two types of data were collected: pore pressures and water levels in front and behind the block. The water levels seemed to be the most reliable data. The main deficit of the setup was the wave absorber at the end of the flume. The wave absorber is not able to sufficiently absorb long waves. So the dataset had to be corrected for that effect. The created dataset was in line with results from earlier experiments.

Results were compared with an analytical solution and the numerical SWASH model. Comparisons with the analytical solution showed a reasonable fit without any calibration. The SWASH model showed in first instance large deviations using the same dataset. By calibrating the turbulent flow resistance $\beta$, it was possible to generate a decent fit. However, the used $\beta$ constants are 6-10 times higher than the measured $\beta$ constants. This is physically unrealistic high. Therefore the most likely explanation is an error in the transition between the water and the porous medium. During the experiment discontinuities can occur on this transition while SWASH uses an continuity requirement.

Numerical tests were performed on some multi-layered combinations of the different blocks in order to derive a “Vertical P” value in a similar way as Van der Meer determined his P=0.4 structure. The results showed, nevertheless, quite some different patterns as the computations done by Van der Meer. However, taking into account all the problems with calibrating the SWASH model the results for the notional permeability seemed very promising. This numerical method shows the possibility of numerically calculating a notional permeability and should be investigated further in the future.
Suspended Sediment and Light Attenuation Characteristics in Singapore Waters

Light is attenuated by materials present in the water column by scattering and absorption. The knowledge of light attenuation and its contributing factors influencing visibility/turbidity is unknown in Singapore waters. This MSc thesis consists of field measurement, laboratory experiment and numerical modelling in 3 parts; parameterisation of light attenuation coefficient \( K_d \), numerical modelling of underwater light field and visibility. The objectives of this thesis are; a) to determine the dynamics of optical properties in Singapore waters, b) to investigate factors contributing to light attenuation in Singapore waters and c) to model underwater light field and visibility using Hydrolight and Delft3D WAQ.

This first part addresses the dynamics of light attenuation (in relation to low/high tide), the spectral nature of optically significant constituents (water, CDOM, phytoplankton and sediment) as well as the effects of particle size distribution (PSD) to light scattering.

For PSD with a higher slope \( j \) in \( N(D) = KD^(-j) \), the \( d_{50} \) ranges from 7.11 to 9.90 \( \mu \)m in Singapore Strait representing sediment dominated environment. Higher TSS during low tide is advection dominated while lower TSS during high tide is suspension dominated. Relative contributions of CDOM, chlorophyll and sediment to light attenuation coefficient \( K_d \) is 1.4 – 6.5 % (average of 3.3 %), 1.3 – 62 % (average of 24 %) and 31.3 – 95.2 % (average of 70 %) respectively. Four (4) empirical equations to predict \( K_d \) was developed depending on its optical and physical characteristics.

Underwater light field modelling shows that light attenuation depend mostly on the concentration of optically significant constituents and only weakly dependent on light structure, cloud cover and fluorescence. The modelled \( K_d \) from Hydrolight ranges from 1.2 to 2.3 m\(^{-1}\) with lower \( K_d \) in chlorophyll dominated waters while the empirical estimations underestimate \( K_d \) compared to the modelled \( K_d \) from Hydrolight. The modelled Secchi depth, \( S_d \) ranges from 0.6 – 1.4m corresponding to euphotic depth \( z_{eu} \) of 2.0 – 3.8 m with deeper \( z_{eu} \) for chlorophyll dominated waters. The modelled visibility is generally lowest during NE followed by SW monsoon and IM period with evidence of spatial homogeneity for all monsoons.

The visibility model reproduces the recorded \( S_d \) reasonably well except for Johor Strait and sheltered areas in WCP due to the fact that some processes are not unaccounted in the model. The \( K_d \) variation coincides with SSC variation with no phase difference; the visibility is lowest during spring low tide and highest during neap high tide. Convective interaction between the diurnal and semi-diurnal components is important in offshore locations while the non-linearity of tidal propagation contributes in the shallow water of Johor estuary. The residual turbidity in Singapore waters is due to tides (semi-diurnal and diurnal spring neap interactions) and non-tides (monsoonal effect) in approximately equal magnitude during monsoons. The results from this thesis are applicable in coastal engineering, ecological and remote sensing.

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Effectiveness of sensors in flood defences

A study with emphasis on macro instability

Introduction

The popularity of monitoring dikes with sensor techniques is rising. It is claimed that sensor techniques lead to significant cost savings and can predict an upcoming dike collapse. But a technical foundation to use the sensor monitoring information in flood safety assessment is lacking. This research investigates the contribution of sensor monitoring information to flood safety and the cost-effectiveness of sensor monitoring. Sensor techniques have been tested in full-scale dike failure experiments at the IJkdijk, trying to predict an upcoming dike collapse. The sensor techniques are capable of monitoring deformation, temperature, water pressure, vibrations and moisture. The state of the sensor techniques is doubtful due to subjective analyses, controlled test conditions and a wide variety in failure prediction times: from 1,5 to 102 hours.

Implementation of sensor information

Water pressure is the only variable that constitutes an input for dike safety assessment models. Monitoring water pressures affects the epistemic uncertainty of the water pressure schematization which is caused by the translation from the hydraulic load to water pressures. One must be aware that sensor monitoring either leads to an increased assessment of flood safety if the prior schematization turns out to be done conservatively or a decrease in flood safety if the prior schematization turns out too optimistic. One would expect an increased assessed flood safety due the intended conservative approach. But prior schematization mistakes imply a decreased assessed flood safety. Moreover, monitoring water pressures has minimum impact on the flood safety assessment if other uncertainty aspects dominate the stability assessment. A case study of the canal of Nauerna denotes that the water pressure has resulted in a higher assessed flood safety, but the uncertainties regarding the soil conditions dominate the stability assessment. However, sensor monitoring on itself does not affect the real flood safety: only physical measures affect the real risk of flooding. Important information is obtained from monitoring high water events such that water pressure models can be calibrated to determine design loading conditions for the periodic safety assessment. Also, an additional application is to identify unforeseen risks.

Cost-benefit analysis

Conceptual cost-benefit models have been set up to determine the cost-effectiveness of sensor monitoring over the long-term. The monitoring costs consist of installation, maintenance and operational costs. The benefit from permanent dike reinforcements is gained from specifying the long-term optimal investment strategy based on the minimum sum of flood risk and reinforcements costs. The monitoring information from relevant high water events affects the assessed flooding probability. If the sensor monitoring reduces the assessed flooding probability, the assessed flood risk lowers and savings on permanent dike reinforcements. If a higher flooding probability is obtained by sensor monitoring, this financially leads to additional investments and negative benefits. But the value of knowing this higher flood risk is rationally beneficial. The benefit from temporary measures is gained from timely execution of emergency measures based on the early warning of the sensor system. This benefit depends on the prediction time of the sensor monitoring system and the reaction time to execute the emergency measure. Additional costs for executing the emergency measure must be incorporated. The cost-benefit models have been worked out in case studies for dike-ring 48 and 14.

Conclusion

The conclusion of this research is that sensor monitoring can be implemented in the flood safety, by specifying dike reinforcements in both the periodic safety assessment, as well as the operational situation. However, the investments in sensor monitoring have to be made while a long waiting time is expected before benefits turn out. Then these benefits can financially be disappointing, but do have a certain value of information.
The influence of suspended sediment on effective hydraulic roughness from tidal damping aspect

The objective of this project is to assess the influence of suspended sediment on hydrodynamic properties in the study area from tidal damping aspect. Firstly, through conducting tidal amplification factor analysis based on real time measured data, seasonal variation in sloping tendency has been observed. The difference in sloping tendency revealed in tidal amplification factor analysis is a result of flow velocity and water depth interaction. In wet season, the sloping tendency in analysis result suggests that tide with higher amplitude experiences less damping as the tidal wave travels upstream than which with lower amplitude; in dry season, tide with higher amplitude experiences more damping than which with lower amplitude.

Secondly, a two dimensional clear water flow model has been set up. By comparing the tidal amplification factor analysis result based on model result and with which based on measured data, a disagreement in sloping tendency has been observed in wet season, which indicates that the pattern of flow velocity and water depth interaction in clear water flow is different from which in the reality. Through extensive sensitivity analyses, the disagreement in sloping tendency in tidal amplification factor analysis result persists. Therefore, the conclusion can be drawn as follows: the suspended sediment which has not been considered in the model does have an influence over the hydrodynamic properties.

By performing analysis over tidal amplitude and effective Chezy coefficient, the result reveals that the value of effective Chezy coefficient has a high correlation with the tidal amplitude, as higher tidal amplitude associates with higher value of Chezy coefficient and vice versa. In addition, the analysis result suggests that the value of effective Chezy coefficient for this study area should fall in between 60 for neap tide period to 70 for spring tide period. This finding conforms to the explanation proposed from buoyancy destruction aspect: higher tidal amplitude associates with higher suspended sediment concentration and better mixing, which would induce more buoyancy destruction effect and result in a lower bed roughness. Therefore, through analyses conducted in this project, the buoyancy destruction theory has been indirectly supported.

I addition, since insufficient sediment information is obtained, this project fails in predict the future situation in a detailed manner. However, as which has been reported in previous literatures, the concentration of suspended sediment would decrease in the future. Some primitive estimation can still be done. As the sediment concentration drops, the hydrodynamic properties in the study area would be more prone to the clear water flow as presented in the model, such that tide with higher amplitude would experience more damping in Jiangyin-Xuliujing reach and less damping in Zhenjiang-Jiangyin reach.

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Scour below the toe of breakwaters

Investigation of scour formation through a geometrically open filter configuration located at the toe of a rubble mound breakwater lying upon sand.

Scour formation at the toe of a rubble mound breakwater can lead to abrupt failure. Nowadays, counteraction of scour is accomplished via geometrically closed filter rules, geotextiles or combinations. Alternatively, the use of geometrically open filters can save significant amount of time and decrease constructional costs. As a primary step, the prediction of scour formation through a geometrically open filter can provide important information.

Equilibrium maximum scour depth was reached for less than half the data set; thus erosion process was still in progress. Two approaches were developed to investigate temporal evolution of scour; separately for tests with and without equilibrium maximum scour depth. Furthermore, important parameters that have affect scour formation were combined to the form a scour prediction tool.

The derived tool is an empirical expression with limited physical background and range of validity. It overestimates maximum scour depth due to a serious model effect; the different buoyancy between filter and base layer that was causing damage exaggeration. Nevertheless, it is capable of delineating the relative contribution of each parameter in scour depth formation.

For an overall view of scour formation, further research will be needed to provide a more accurate quantification of the interrelation between parameters and to implement the effect of missing parameters. Consequently the use of the derived expression as a scour prediction tool in real life is not yet recommended.

Objective of the present thesis is to get insight into scour formation and development through a breakwater toe lying upon sand and designed as a geometrically open filter. Thereby, research aims in drawing the link between scour characteristics with wave loading and filter configuration properties.

In order to accomplish the research objective 2D physical model tests were conducted in the wave flume of Delta Marine Consultants. In total, 23 tests were executed to investigate the effects of relative grain diameter, relative filter thickness, grading of filter layer, base layer properties and storm duration. Furthermore, a lightweight material was used to simulate the sandy seabed.

Despite the highly spatial character of scour formation, in tests with identical boundary conditions the averaged maximum scour depth was converging. In addition, in the majority of tests an S-curve erosion/deposition pattern was shaped and erosion started immediately at the downstream side of the box.

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Effectiveness of Silt Screens

Dredging and reclamation works are known to generate significant amounts of turbidity. In most coastal zones around the world, the resulting clouds of suspended fine sediment bring along environmental risks. Dredging contractors take mitigating measures to prevent free spreading of turbidity, which is usually also demanded by their clients and the local authorities. One possibility is the application of hanging silt screens, which are flexible, virtually impermeable screens. They are intended to divert the sediment-laden current towards the opening between the screen’s lower edge and the bottom, which is thought to result in rapid settling of the dredging spill.

The effectiveness of hanging silt screens when subjected to cross flow is doubted by those parties experienced with their application, because sediment can still pass the screen by horizontal or vertical diversion (around the screen’s side edges and below the screen’s lower edge respectively). Hence this research aims to obtain insight into the most important processes determining transport of suspended sediment in the vicinity of hanging silt screens and to determine the effectiveness of hanging silt screens under varying circumstances.

A large series of numerical simulations with varying flow velocity, screen height, screen width, settling velocity of the sediment, water depth and upstream sediment concentration profile is conducted. The process of vertical diversion is investigated in a 3D modeling approach using large eddy simulation (LES). Performance of this numerical model is validated by means of laboratory experiments. The process of horizontal diversion is assessed with a two-dimensional horizontal (2DH) modelling approach.

It appears that the turbulent structures resulting from flow separation at the screen’s lower edge give rise to intense downstream mixing. This process prevents the screen from being effective when compared to a reference situation (without a screen) in terms of reducing the environmental threat posed by suspended fine sediment. The figure illustrates this finding.

Furthermore, significant amounts of horizontal flow diversion occur when lateral restrictions are absent. This counteracts the intended use of silt screens as a vertical current deflector. Finally, flow contraction around the screen’s lower edge causes high near-bed flow velocities, which enhances erosion if erodible bed material is available. Efforts should be made to convince all parties involved in dredging practice of these findings, so that protection of the marine environment can make another step forward.
A parametric study concerning estuary mouth dynamics and inlet closure

With the development of a process-based model (Delft3D) of the St Lucia Estuary inlet, a first approach is made with regard to the estuary mouth dynamics and closure mechanisms that are observed at St Lucia inlet. The purpose of this thesis is to get a better understanding of the hydrodynamic and morphological behaviour of the St Lucia inlet with the additional effect of the Mfolozi River discharge. The focus in this thesis is on the period after 2001 till present, where the management policy is to let the St Lucia inlet function in its natural state and with the possibility to join with the Mfolozi River. A model with a schematized situation of the estuary with representative inlet geometry is forced with representative waves and tide conditions. Important factors determining the inlet stability such as tidal prism, longshore sediment transport, inlet geometry and river discharge are investigated in this thesis. The Mfolozi River mouth and St Lucia Estuary entrance are situated in a seasonal varying climatic regime with long drought periods with low riverine flows followed by wet periods and cyclonic events. A high energy wave climate in combination with a micro-tidal regime and a high rate of longshore sediment transport are the most important factors of the instability of the St Lucia inlet. According to Bruun (1978) inlets that are classified with a P/M ratio below twenty are found to be unstable and the inlet may be closed by deposition of sediment during a storm event because the tidal prism is relative small. In line with Bruun, the St Lucia inlet can be classified as an unstable inlet with a low P/M ratio of approximately two.

Three scenarios were developed with different estuary dimensions; a small, a medium and a large basin. The inlet geometry is the same in the scenarios and each scenario is modelled with five different simulations. The simulations are forced at the boundaries by a varying range of tide and wave conditions. The tide is varied from average to neap and spring tide. The wave height is varied from average to higher and extreme wave heights. Higher waves are responsible for a higher rate of longshore sediment transport and with both varying tide and wave conditions a wide range of P/M ratios are modelled. In addition the influence of a lower D50 was investigated, and the influence of the Mfolozi River was simulated.

The results of the simulations show that they are in line with expectations. Small P/M ratios show that inlets are unstable and different closure mechanisms are observed. Similar to what is found in nature regarding the A-P relationship, a decreasing cross-sectional area with a lowering tidal prism, is also found with the Delft3D models which suggest that the model is capable of giving a good representation of the morphodynamics.
Mangrove forests have been proven to be an efficient system in attenuation of the wave energy. Therefore, they may be incorporated in the construction of coastal dikes and contribute to decreasing the total cost of such a project. Each location where a coastal dike is to be constructed is characterized by its specific, bathymetric and met-ocean conditions. Different mangrove vegetation fields also affect the extent of wave height decay and have an impact on the total costs of a dike construction. Prior to making the decision about including mangroves in a coastal dike project, a question must be answered whether or what magnitude of these savings will be made.

The analysis made in this study showed that the costs of a coastal dike construction in Vietnam can be effectively reduced by incorporating mangrove vegetation. The extent of this reduction is subjected to the vegetation pattern, which is a function of various parameters i.e. growth stage of the trees, length of the forest, as well as the met-ocean conditions such as tidal amplitudes and storm surge levels. A 0.25m reduction in wave height leads to the total savings of around 0.25mln Euro per one running kilometer of a 3m high dike, when utilizing a hard revetment. If the 0.25m wave height reduction results in the possibility of applying soft revetment such as the Vetiver grass, these savings dramatically increase to the value of 0.9mln Euro per kilometer of a dike. These construction cost savings can already be achieved by planting 200m mangrove vegetation, where the sparsely distributed mangrove trunks (0.2-0.6 unit/m²) of varying diameters from 0.2 to 0.7m will be the elements obstructing wave propagation.

The graphs and formulas developed in this research may serve as a first approximation during feasibility studies or conceptual designs of a coastal dike incorporating mangrove vegetation. They allow calculating the design wave height attenuated by a site specific or planned for the restoration mangrove forests for different design met-ocean conditions. Examples can be seen in the figures below. Calculated wave reduction coefficient can be later on translated to the cost savings of a "Vietnamese" coastal dike raised behind the mangrove forest.

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4.

Civil Engineering theses

Geo Engineering
Reconstitution of sensitive clays

In this thesis a method is developed to regain the geotechnical behaviour of undisturbed quick clay by reconstitution of remoulded natural quick clay samples. Quick clay is characterised by a high sensitivity; the ratio between the undisturbed and remoulded strength is very high. Because of the high water content they behave fluid-like after remoulding. As the change of material structure during remoulding is irreversible, a special method is required to rebuild this structure. Such a method could be useful for creating samples for physical model testing or investigation of sample disturbance.

The theoretical framework is used to set up an experimental programme. Firstly, the used natural quick clay material is characterised. Hereafter the influence of the depositional environment (influence of mixing methods, water content and varying salinity) and consolidation under self-weight in a geotechnical centrifuge (with varying loading rates and sample thickness) are studied. Finally, the influence of leaching (both by diffusion and by application of a hydraulic head in a geotechnical centrifuge) is investigated.

It is shown that increasing salinity increases the sediment void ratio, both after settling and consolidation at 1-g and 87-g. The loading rate during consolidation appears to be unimportant. The reconstituted salt material has significant strength and behaves only slightly sensitive. Careful leaching with an hydraulic head decreases the undisturbed strength with almost 90%. However, because the remoulded strength is reduced to immeasurably small strengths the sensitivity is increased drastically.

The result of this reconstitution method is a very sensitive and weak clay ($c_u=1.2$ kPa, when $e=2.4$), which behaves like a quick clay upon remoulding. This low undisturbed strength is the main limitation of the proposed method. However, based on the experimental results it is expected that by adjusting the consolidation conditions the method can be improved.

In this study the geological genesis, the geotechnical characteristics and the development of sensitivity is discussed. Furthermore, it is shown that approaching quick clays from a colloid chemical perspective provides a useful framework to understand development and breakdown of structure and sensitivity.

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The observational method; a safe application of the method for building pits

The observational method is a design and management method in which the construction method, construction planning and the final design is determined by using measured data from the construction phase. In previous studies it is concluded that this method can be successfully applied to building pits, by optimizing or saving on temporary construction elements.

inverse modelling is combined with the old parameter distribution to form an updated parameter distribution upon which the safety standards may be applied. This leads to an observational method approach which is always in compliance with the safety standards.

For the observational method it is important to interpret the measurements in an unambiguous way. This is very hard if the soil shows time-dependent behaviour. A smaller measured displacement for instance, can be explained by partial consolidation of these soft layers or by a higher strength of the soil than expected on beforehand. This time-dependent behaviour also limits the use of the observational method on building pits.

A case study is used to review the suggested way of using the observational method. An important conclusion is that the described method is strongly influenced by the measurement error in the currently used measurement systems. This made it impossible to gain new information about the soil parameter distribution after the first construction phase. This greatly reduced the reaction time of the method.

The observational method is a design and management method in which the construction method, construction planning and the final design is determined by using measured data from the construction phase. In previous studies it is concluded that this method can be successfully applied to building pits, by optimizing or saving on temporary construction elements.

Schematic drawing of the way measurements can be used to optimize the construction

However, the observational method in the standards and guidelines is not yet developed to a level where it is applicable in practice. Previous research states that the method is most useful if in the initial phase an acceptable risk is taken, for instance by assuming more favourable initial design parameters. During construction, measurements will show whether this assumption is correct. By requiring, but not defining this acceptable risk, the current Dutch standards and guidelines fail to give a starting point for the design and application of the observational method. To cope with this ambiguity in the standards, the observational method is based on a standard design procedure.

This way, the safety of the construction, based on the available information, is always on an acceptable level. Performing and processing measurements is then of great importance. A lot of potential to calculate a new parameter distribution is seen in so-called inverse modelling, a technique in which current design models are adapted to calculate individual soil parameters based on measurements. Through a statistical analysis called Bayesian updating, the result of the

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On the modelling of installation effects on laterally cyclic loaded monopiles

Monopiles are used more extensively for offshore wind turbine foundations. Current guidelines on the construction of fixed offshore foundations still base the design of laterally loaded piles in sand on empirical data (p-y curves), from the oil and gas industry (Reese (1974) on 0.61 m diameter piles). However, short and rigid large diameter monopiles rotate rather than bend when subjected to lateral loads. As a result, numerous experimental studies have been performed on the response of monopile foundations by means of a geotechnical centrifuge. However, there has been no consistency in installation conditions (low stress levels (1g), elevated stress (Ng) levels or pre-installed), partly because the effect of the pile installation is still not completely understood.

This research contributes to (i) investigate the effect of pile installation on the lateral response of an open-ended pile in sand and (ii) increasing reliability in the interpretation of existing and future centrifuge research to similar investigations. The main objective of this thesis is to investigate the effect of monotonically jacked open-ended pile installation, at low and elevated stress conditions, on the large strain lateral soil-pile response during two-way cyclic loading. A series of tests was executed to compare the differences on the lateral pile response from monotonic jacked pile installation at low stress levels (1g) and at elevated stress levels in the geotechnical centrifuge (Ng).

In order to study the effect of pile installation on the cyclic lateral capacity a novel actuator, which allows installing the pile in-flight and subsequently loading the pile laterally without interrupting the test, was developed. The load mechanism on the free pile head was designed in a way that no bending moment was transferred to the pile head by means of a hinged connection between pile and actuator. The load mechanism - instrumented with strain gauges - was calibrated for stiffness (static, in the laboratory) and hysteresis at 1g and Ng in the geotechnical centrifuge. The brass model pile was designed to properly scale the lateral bending stiffness and prevent plugging during installation.

In order to investigate influence of the soil state on installation effects a total of two sets tests have been performed with varying installation conditions and relative densities. The first set (76g and Id = 60 +/- 3%) was executed in duplex to determine the consistency and the accuracy of the preparation method. In the second set (48g) the relative density was varied (60 +/- 3% and 80 +/- 3%), this test provides clear load - displacement cycles.

The results indicate that elevated stress installation of an open-ended pile has a small positive (1 - 5%) effect on the lateral capacity. This effect is visible during primary lateral loading of the soil and decays with the number of load cycles. Hence for open-ended model piles the installation effects are negligible. Moreover, these tests indicate that in all cases the stiffness and lateral capacity increase with the number of load cycles, stress level and/or initial density. These gains in capacity and initial stiffness are more substantial than the differences between 1g and Ng pile installation.

Figure: Novel Actuator and Geotechnical Centrifuge (f.l.t.r.)
Civil Engineering theses

Watermanagement
Stepwise improvement of topography driven conceptual model structures in the Mahurangi catchment, New Zealand

Introduction
Topography driven conceptual model structures based on landscape classification have recently been developed at the Hydrology section of the department of Water management and several studies have been performed in China, Europe and Africa to assess the validity of this concept. For my research, I went to the National Institute of Water and Atmospheric Research (NIWA) in Christchurch, New Zealand to evaluate landscape classification based on topography in the Mahurangi River Catchment (50km²) in the north of the North Island.

Problem definition
Conceptual models are easy to implement and therefore widely used in hydrology. They however suffer from a loss of process representation and spatial information. Landscape classification in different hydrological units representing different dominant mechanisms in runoff generation might be a solution to retain maximum simplicity while taking into account readily available spatial information in a lumped way through parallel conceptual models. This would possibly enable to represent processes in a more realistic way in order to obtain the right answers for the right reasons.

Research
My research mainly focused on (1) finding a realistic model conceptualization through a stepwise improvement of the model structures of the three parallel classes hillslope, wetland and terrace. The performance of the created topography driven models was assessed and compared to the benchmark model HBV-92. Besides, I also evaluated if I could (2) correlate different hydrological signatures with the percentage of each class in the 28 subcatchments of the Mahurangi. Finally, (3) I evaluated the sensitivity of the model to different precipitation input (either including interception or not and through an averaging process or not).

Results
1. The realism of the best topography driven model structure was comparable to that of HBV based on consistency and performance of eight evaluation criteria during the validation period. The model also seemed to represent processes originating from the different parts of the landscape in a realistic way: during very high peaks, most runoff originated from the hillslope (subsurface flow) and the wetland (saturation excess overland flow) gave a smaller peaky response.
2. The rising and declining limb densities increased as the percentage of wetland increased in the catchment. Relatively large values for the rising and declining limb densities are characteristic for the fast needle-shape response expected in the wetland.
3. It was found that averaging rainfall yielded a poor performance for low flow indices when it was not preprocessed with interception.

Conclusions and recommendations
Landscape classification has shown to be able to represent catchment behavior adequately, however, some aspects such as timing and realism in the evaporation time series can still be improved in the conceptualization of the three classes model hillslope-terrace-wetland. Furthermore, similar behavior was found for the classes hillslope and terrace and therefore combining them into one class might yield a decreased complexity and an improved performance.

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Artificial wetlands are used at different locations in the world as a treatment facility for wastewater of different composition. In order of Rijkswaterstaat several artificial wetlands are constructed for road runoff treatment. In all cases the artificial wetland is preceded by a sedimentation basin / storage buffer. One of them is located along the A1 near ‘t Gooi. A research on the purification efficiency of this wetland shows higher metal concentrations in the effluent in wintertime (Tromp, Heloptytenfiltratiesystemen voor zuivering wegwater, 2005). This is probably due to de-icing salts. The given solution is to bypass the artificial wetland in wintertime to avoid metal flush out. This research strives to deepen the insight into metal mobilisation in artificial wetlands under the influence of de-icing salts. The main question of this research is worded: “What is the influence of de-icing salts on the remobilization of heavy metals in an artificial wetland?” For this research six artificial wetlands located at traffic junction Raasdorp, A5 and A9, are available for easurements. Visual inspection reduced this amount to one due to various deficiencies in the other five. This resulted in a sub question: Does the filter function hydraulically as it is designed for? By use of a water balance, visual inspection and gathered data by use of divers an indication of the hydraulic functioning is made. Since high iron concentrations were measured it is concluded that groundwater is leaking into the artificial wetland. The other option, iron is leaching out of the filter substrate, is rejected by the column test results. Here the iron concentrations are decreasing which should not be the case if it is originating from the substrate. Artificial wetlands are characterised by enhancement of treatment performances because of the presence of vegetation. The main processes which are introduced by vegetation are summarized by the term phytoremediation. Vegetation is able to bind heavy metals in the root zone and also storing them into their biomass. To get insight into the heavy metal concentrations in several parts of the treatment facility water samples were took. The question in relation to the water samples is: “Do heavy metals and PAH occur in the influent of the artificial wetland?”. The results of the measurements display a pattern where in general the pollutant concentrations are highest in the influent of the sedimentation basin, followed by the influent of the artificial wetland. The lowest concentrations were in general measured in the effluent of the artificial wetland. This proves the expected behaviour of the treatment facility. The goal of measuring the conductivity at location is to get an answer onto the following question: “Can the presence and movement of de-icing salts be quantified and evaluated based on the measured conductivity into the treatment facility?”. An increase of dissolved salt causes an increase of the conductivity. In wintertime rise of the conductivity in the treatment facility was measured and the results are providing insight in the movement of deicing salt through an artificial wetland. As a last step a column test is carried out to investigate the influence of de-icing salt on a possible flush out of heavy metals. The column test is filled with a soil sample what is took out of the original artificial wetland. Four different runs are carried out where for each consecutive run the de-icing salt concentration in the influent is increased. The question on which an answer should be found here is: “Is for the column test effluent an increase of heavy metal concentrations measured by increasing conductivity of the influent per run?”. The results of the column test did not show the expected increase of heavy metal concentrations into the effluent of each run.

The first two runs did show elevated concentrations of copper and zinc but for the last two runs concentrations were considerably lower. For the third run an significant elevated concentration of lead is measured where this concentration is for the other three runs near the detection boundary. The effluent of the fourth run should according to the hypothesis contain the largest heavy metal concentrations, but this was not the case. The measured concentrations of the de-icing salt related ions did show the expected behaviour for the four runs. The concentrations in the effluent were increasing for each consecutive run as was also expected based on the conductivity measurements.

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The influence of DE-ICING salt on the remobilization of heavy metals in an artificial wetland
Subsurface water recovery in the Amsterdam Water supply Dunes

Introduction
The Amsterdam Water supply Dunes (AWD) are an important ecological area and an important part of the drinking water treatment process of Waternet. Water is collected, pre-treated, transported to the dunes and then infiltrated into the dunes, resulting in improvement of the water quality. After dune passage, the water is collected and transported to the post-treatment by a system of canals, open to air. Here, the water can be recontaminated. An improvement for this situation would be to make the recovery system underground. This is also an improvement for some of the problems that are currently experienced in the ecological system of the dunes. It leads to less interaction between the water treatment system and ecology.

Research
When the system is changed to an underground system, the quality of the water that enters the post-treatment changes. This research focuses on the following research question:
Which adjustments to the water treatment process are needed when the recovery system in the AWD is changed from an open to an underground system, how can these adjustments be implemented and what are the expected costs and savings?

Results
There are two possibilities for the design of an underground recovery system: freatic or deep infiltration and recovery. With the freatic underground recovery system the disinfection capacity of the water treatment process is higher compared to the current system. The water that enters the post-treatment has a higher iron concentration and a lower oxygen concentration. With deep underground recovery the disinfection capacity increases more than with the freatic option. The water that enters the post-treatment has no oxygen, a high iron concentration and the concentrations of phosphate and ammonium are higher. Based on these changes, four different drinking water treatment schemes are designed. Two schemes are adapted to the freatic alternative, the other two are adapted to the deep alternative.

Conclusions and Recommendations
The deep alternatives lead to a higher water quality than the current system and the freatic alternatives. The deep system has the most possibilities for improvement of the ecological system. However, the costs for deep infiltration are higher than for the freatic alternatives.

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Hydrodynamic Models

Introduction
Hydrodynamic models are often the main source of information used to judge the performance of urban drainage systems with respect to the occurrence of flooding. If the performance is deemed insufficient, adequate measures are to be determined.

Problem definition
Since hydrodynamic models are subject to uncertainties stemming from various sources, the reliability of the results obtained are limited. Previous research has shown that these uncertainties can be addressed by calibrating the models against field data. However, it has been found that the set of model parameter values acquired by calibration varies over different storm events, limiting the "lifespan" of the obtained parameter values. Moreover, the process of calibration imposes requirements with respect to the monitoring data. Potential monitoring locations need to be identified and a measuring frequency has to be determined, in order to obtain sufficient information for calibration.

Research
This thesis focuses on the application of data assimilation in order to reduce uncertainties in model results for continuous time series. The process of Data Assimilation (DA) combines measurements and models by continuous updating the set of model parameter values. Is the applied DA method feasible for application in the field of urban drainage? A monitoring network is designed that is able to provide sufficient information for DA to be applied. How can important model parameters be identified and where should monitoring sensors be placed?

Results
For two simple examples, the DA method proves to be robust with respect to changes in the system, initial parameter value estimations. One example is compiled in a Matlab environment, while the other consists of a Sobek model in combination with OpenDA for the implementation of the DA method. An algorithm is proposed that is used to identify potential monitoring locations, while incorporating some form of overlap in the information gathered for cross validation and to increase the overall robustness of the system with respect to sensor failure.

Conclusions and Recommendations
Although more research is needed on large scale application of DA in the field of urban drainage, the first small scale experiments are successful. The algorithm proposed is able to produce a set of monitoring locations with the ability to collect information on the parameters of interest, while incorporating some form of redundancy.

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The significance of flood duration for flood damage assessment

Introduction
Flood risks can be reduced by either reducing the probability or the consequences of a flooding. These consequences can be quantified with flood damage models. Such models determine flood damage based on the water depth and the land use. This thesis will investigate the need to also use the flood duration as input parameter.

Problem definition
Besides the water depth, also other factors determine the resulting flood damages. These factors are often not taken into account in flood damage models. One of these influences is the flood duration. The longer a flooding lasts, the larger the material damage, and especially damage due to interruption will be. Flood duration causes interruptions and extra material damages. Taking into account flood duration can, therefore, theoretically make flood damage models more accurate. Flood duration predictions are, however, at the moment rarely done. This thesis aims to get both a qualitative and quantitative understanding of flood duration and the importance of flood duration for damage assessments.

Results
1. Development of a better understanding of flood duration. By looking at different areas and flood threats, a flood type categorization was developed and durations were estimated for each flood type
2. Exploration of the influence of flood duration on damage. A modeling method to roughly estimate the duration-dependent damage was developed. The framework of this method may also be useful for future duration dependent flood damage models.
3. Two case studies were carried out to study flood duration and its influence on damage in more detail: First the Betuwe and Tieler & Culemburgerwaard area was studied and secondly the area threatened by a breach at the Parksluizen in Rotterdam was focused on. Different scenarios were used with varying breach locations, measures and use of outlet and drainage structures.

Conclusions and recommendations
Flood duration can be significant for large floods in low and endyked areas. In these cases flood duration can also have a significant impact on the damage. However, a complex economic model is necessary to quantify this. Therefore, flood duration can only reach its full value as an input, in combination with better economic modeling.

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Influence of variation in the natural water quality matrix on advanced oxidation processes

Experimental research concerning degradation of organic micropollutants

Introduction

Since the last few decades organic micropollutants (OMPs) have been regularly detected in Dutch surface waters at very low concentrations of ng/L to several µg/L. Moreover, as surface water is the source for drinking water in the western part of the Netherlands, OMPs have occasionally been detected in drinking water. Although OMPs have probably been present in surface waters for many years, they have recently become an issue for drinking water production as result of the increased awareness for the chemical quality of drinking water and due to improved analytical methods and measuring techniques. As result, OMPs nowadays can be detected at extremely low concentrations. Although OMPs in drinking water at concentrations of ng/L to µg/L do not result in a direct health threat OMPs are undesired in drinking water and as current drinking water treatment is inadequate for a sufficient removal of these pollutants, they are of concern for drinking water companies.

Research

The Dutch drinking water company Dunea Duin en Water is doing research with advanced oxidation processes (AOP) for an enhanced degradation of OMPs in combination with subsequent removal by dune soil passage. In previous pilot plant research, Dunea has proven that AOP, based on serial O₃/H₂O₂ - UV/H₂O₂ treatment, is able to degrade OMPs to a convenient level. However, the degradation efficiency of OMP fluctuates due to variations in the water quality matrix. In this master thesis research the influence of (variation) in the water quality matrix on AOP has been examined, by means of a literature study and experimental research with a pilot plant installation. The experiments have been conducted with rapid sand filtrate (RSF) from the full-scale pre-treatment plant of Dune in Bergambacht. For various experiments, in which the water quality matrix of RSF has been kept either unaffected or individual water quality parameters have been manually changed, the influence on the degradation of OMPs and bromate formation has been examined.

Conclusions

Based on the results of the experiments, it can be concluded that hydrogen carbonate and natural organic matter (NOM) are the most important parameters that influence the OMP degradation capacity of AOP. These two parameters are responsible for a variation of 15% to 25 % in the OMP degradation efficiency. Variation of other parameters (nitrate, bromide, acidity and temperature) count for a fluctuation of about 5% in the OMP degradation efficiency. The AOP-mechanism has been simulated with a chemical kinetics model, in which the most important water quality parameters are included. Although the model has to be further improved, the model will be able to simulated and predict the OMP-degradation sufficiently.

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Removal of organic micro pollutants in batch experiments mimicking riverbank filtration

Introduction
Since several decades organic micro pollutants (OMPs) have been detected in surface water and groundwater near rivers. OMPs include compounds with known pharmacological actions in humans and animals, amongst others birth control and natural hormones, antibiotics, antimicrobials, pain relievers, and caffeine, but also pesticides. Although quantities of these contaminants in surface water may be low (ng/L to µg/L), they constitute a threat due to their constant presence. Effects of these compounds on human health and the environment have not been fully characterized. However toxicological studies have shown that OMPs might have an effect on aquatic life. A large part of the drinking water produced in the Netherlands is gained from the river Rhine and Meuse by drinking water treatment plants. Due to the aging of the population, more and more pharmaceuticals will be used in the future. This may lead to higher pharmaceutical concentrations in the river water and to the need for measures to improve the drinking water treatments in the Netherlands, to be able to secure safe and healthy drinking water in the future.

Research
Riverbank filtration (RBF) has shown to be able to (partly) remove many OMPs, both in laboratory and field studies. However it is still unknown what happens exactly during RBF. Therefore the objective of this study was to determine the main mechanism (sorption and/or biodegradation) responsible for the removal of OMPs during RBF. Laboratory experiments were performed to mimic RBF using sixteen different OMPs, river water and riverbank sand from the river Lek at the RBF site of drinking water company Oasen at Bergambacht.

Conclusions and Recommendations
Results showed that both sorption and biodegradation occurred during RBF. This was dependant of the kind of OMP, but no clear relation between physio-chemical properties and their removal was found, this should be investigated further. Furthermore, OMP removal did not vary significantly between different experimental conditions. This may indicate that the OMP dose per mass of sand was too low in the batch bottles; meaning that not enough OMPs were available for microorganisms to be able to determine differences in removal. Finally, it was concluded that the amount of proteins and carbohydrates present in the biofilm in riverbank sand was directly related to the bioactivity, which is interesting for further research.
6.

Civil Engineering theses

*Transport & Planning*
Alternatief voor het Schenkviaduct:

Effecten op de robuustheid van het wegennet van Den Haag en woon- en leefklimaat

The municipality of The Hague wants to improve her position as international city of peace, justice and security. To reach this ambition, the municipality focuses on the creation of robust infrastructure networks, reliable accessibility of the economical locations in the city and providing a good residential climate. Robustness means the ability to fulfill the function, even in highly anomalous situations. Reliability means the level of assurance a traveler can estimate his travel time. This thesis investigates how these ambitions can be applied to the area of the "Schenkviaduct", an important link in the urban road network near the city centre of The Hague. This link connects the city centre of The Hague with the national road network via the national road A12 / Utrechtsebaan.

The important motivations for an investigation into the Schenkviaduct are summed up below:

1. The most important motive of this study is the technical service life of the Schenkviaduct, which ends around 2020.
2. The Schenkviaduct as an urban main road does not have a connection with other urban main roads, as the city-ring. It ends at the "Rijswijkseplein", a big square in the city where car traffic and public transport (tram) flows are crossing each other, causing congestion. In 2020, this will become a major bottleneck in the public transport network.

This thesis has focused on the creation of a desirable road network structure within the framework of the research area for the period 2020 – 2030. This is in line with other spatial developments in the research area and matches the ambitions of The Hague.

Based on the criteria robustness, accessibility, livability and spatial quality, alternatives for the Schenkviaduct have been examined. Finally the thesis has led to a recommendation for a 'Schenktunnel as urban main road' alternative. Based on robustness the function of the Schenk connection cannot be missed. A Schenktunnel will connect the regional main road "Utrechtsebaan" to the city-ring (urban main road) and create more routes from the outskirts of the city to the economical districts and vice versa. Moreover, it creates more exchange possibilities between the Utrechtsebaan and the city-ring in case of calamities.

Furthermore, through-traffic will make more use of the regional and urban main road network in the Schenktunnel alternative than in the reference situation, while the amount of through-traffic passing over the "Rijswijkseplein" will decrease. These effects will improve the livability in the vicinity of the current Schenkviaduct and the Rijswijkseplein.

A Schenktunnel alternative will also enhance the urban connection between The Hague Southwest and "Haagse Hout" (The Hague Northeast). More urban traffic will use the new Schenktunnel, which is the intended function of this connection.

Regarding the spatial quality, opportunities does exist in the Schenktunnel alternative to downgrade the "Rijswijkseplein" area, which creates more space for public transport, pedestrians and cyclists. Furthermore, all spatial aspects can be realized in the available space.

Based on all criteria, a Schenktunnel as urban main road that connected the city-ring to the Utrechtsebaan / A12 is being proposed as alternative for the current Schenkviaduct.

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A modelling approach on roadside accidents

A research on the correlations between the cross-sectional design and roadside accidents, plus a prospect on future developments of accident prediction models with the help of new geospatial databases like the BGT.

The goal of this research is the development of a roadside accident prediction model (APM) for rural roads with a speed limit of 80 km/h in the Netherlands, with the use of readily available or newly to be discovered data resources. With this goal set, the research aims in providing traffic safety policymaking with tools for a preventive traffic safety policy and tools for the road design process for making design choices with respect to traffic safety. The first result of this research is the development of an APM for roadside accidents for rural roads for the provinces Drenthe and Gelderland in the Netherlands. The second result is the discovery of a new data resources which offer the chance of building a new research database.

The developed model is an APM of singular roadside accidents in the provinces of Drenthe and Gelderland, for two directional rural roads with a speed limit of 80 or 100 km/h. This model offers the possibility to identify roads or road stretches which are relatively unsafe, compared to other roads, even if accidents did not occur on a specific road stretch due to chance. The model output is an estimation of the accident frequency of road stretches of a 100 meter, based on the annual average daily traffic, the presence of an obstacle within a distance of 2 meters to the roadside, the presence of a road side barrier and the curvature (which is actually a visual interpretation of the curvature).

An extension of this model or the development of new APMs relies heavily on new sources of data on road characteristics, as the scarcity of data is an important factor in the slow pace of the development of APMs in the Netherlands. New data sources are discovered within this project. These consist of the development of geospatial databases, based on the development of the "Basisregistratie Grootschalige Topografie" (BGT). This development looks promising for future research, but depends on voluntary extensions on the spatial model of the BGT by road administrators.

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Reliability of travel times is an important indicator of the performance of a traffic system. Existing methodologies to forecast travel time reliability can be improved because in practice rough estimations with a rule of thumb are used. The congestion caused by incidents is an important cause of the unreliability of travel times. Travel time reliability should be incorporated in social cost benefit analyses for infrastructure investments. With an accurate forecast of travel time reliability a well-educated decision of the consequences of infrastructure investments on travel time reliability, can be made.

A large number of incidents (car accidents and breakdowns) are simulated in marginal traffic models MIC (marginal incident computation) and MaC (marginal computation). The concept of marginal traffic simulation is that the outcomes of an equilibrium situation in a dynamic traffic model is used as input for the marginal traffic models, because of this less computations are necessary for the simulation of the consequences of an incident. Traffic flows only have to be calculated in that part of the network where the simulated incident results in a flow different from the equilibrium situation. A significant reduction in calculation time can be achieved. In MIC and MaC travel times can be calculated. These travel times are used to calculate travel time distributions. The calculation time of obtaining travel time distributions in the performed case-study would take 2 weeks if dynamic traffic model INDY would be used, with marginal traffic model MaC this could be reduced to 96 hours and with MIC to 5.5 hours. The smaller calculation time comes at the expense of a loss in accuracy. If the procedure using MIC and MaC are compared, the loss of accuracy in MIC is relatively small compared to the gain in calculation time. The developed model using MIC is recommended.

In this research a problem in MaC with the deactivation rules and the simulation of flows downstream of an incident is discovered. The developed model still performs weak on the predictive validity. It is recommended to improve the developed model with a kind of rerouting behavior in case of an incident.

The research shows that it is possible to forecast travel time variability from door to door in case of an incident, with explicit simulation of incidents in a dynamic traffic model within reasonable calculation time. This could be done because of the usage of marginal traffic models, MIC and MaC, reducing the number of calculations needed and therefor the calculation time.

Forecasting door-to-door travel time variability caused by incidents

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Performance comparison between the Dutch and European signalling system at bottlenecks

In this research a comparison has been made between on one side the Dutch signalling system with ATB-EG train protection and on the other side the European signalling system ETCS Level 2. The minimum feasible headway times at bottlenecks for both systems have been compared. A selection has been made of the 22 most relevant train sequences on six often occurring infrastructure layouts. For each layout, the positioning of signals (for ATB) or block limits (for ETCS) has been sought that leads to the lowest feasible headway time for between one and four train sequences. To enable fast calculation and comparison of the headway times at different signal positionings a spreadsheet calculation model has been developed for both signalling systems.

In 15 of the 22 train sequences, the European system ETCS L2 yielded a shorter headway time than the Dutch system ATB-EG. The improvements ranged from 1,1s to 21,3s, which corresponds to savings of up to 21%. In the other 7 train sequences, the headway times found in this research for ETCS L2 were higher than those that could be reached in the Dutch signalling system when applying the appropriate signal positions. When averaged over all 22 train sequences, ETCS L2 gives a 4,5% reduction of the headway time. When only averaging the 16 train sequences that don’t involve freight trains, the reduction more than doubles to an average of 9,3%. The main differences between the two signalling systems that contribute to the better performance of the European system are the fact that the braking curves are block-independent, train-dependent and speed-dependent and that there is a very low minimum block length.

The research presented three types of limitations that could prevent signals from being placed on the exact location where they would be needed (level crossings, overhead section breaks and neutral overhead section breaks) and investigated the sensitivity of the found minimum headway times, which showed that the values found for ETCS L2 are much more robust and that the required block limit positionings contain much more flexibility. The results from the research were applied on the corridor Weesp – Almere Oostvaarders, showing again that ETCS would bring more buffer time increases and require less infrastructure adaptations.

To improve the accuracy of future studies comparing the Dutch and European signalling systems, focus should be put on obtaining more certainty about the ETCS braking curves of the representative Dutch passenger rolling stock.

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The Variability of Traffic in Congestion Forecasting

Congestion on the Dutch motorway network is an actual problem, which originated over the past decades. Over the past few years, the extent of congestion is decreasing, though still very significant. Road authorities therefore show interest in traffic congestion forecasting. In this way they can inform road users or undertake other strategic actions. This thesis is therefore dedicated to the variability of traffic in congestion forecasting.

The main objective is to develop a methodology operationalized in a model, which is able to predict congestion on motorways without knowledge of the actual traffic conditions. The model takes the variability of traffic into account and is substantiated with a solid theoretical framework relating the predictability of factors and their effects to traffic supply and demand.

The research shows that the developed methodology is suitable for predicting travel times or other performance indicators. The model results show relatively large uncertainties in the travel times as congestion was probable to set in (i.e. peak periods). This implies that, even though the occurrence and effects of the identified influence factors are very accurately available, uncertainties in travel times can still be significant.

Using the acquired knowledge a research methodology is developed. The model approach makes use of the basic principles of traffic flow theory based on the conservation of vehicles and first order traffic flow theory. To take the variability of influence factors into account, an intelligent sampling technique is used: Latin Hypercube Sampling. The developed model makes use of traffic demand profiles and traffic supply.

Before the model processes the traffic demand profile and traffic supply variables, these are corrected for the identified influence factors. The occurrence of these influence factors can be defined manually. However, to be able to incorporate the variability of traffic, a sampling component is added to the model. In this way the occurrence of the influence factors can be determined through a probability function. After multiple runs, the output indicators are collected.

The model is calibrated and evaluated using data from the A27 motorway between Hooipolder and Gorinchem.

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Thesis Committee: Prof.dr.ir. S.P. Hoogendoorn, Dr.ir. J.W.C. van Lint, Ir. J.W. Goemans, Dr.ir. P.H.A.J.M. van Gelder, Ir. P.B.L Wiggenraad

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Email: transport.planning@citg.tudelft.nl
Problem definition and objective
The performance of work zones with specific layouts cannot be accurately determined, because changes in individual driving behaviour at work zones are unknown. Therefore, the research objective is:
"Gain insight into possible adaptation effects related to the layout of work zones, in empirical individual driving behaviour and subsequent in macroscopic effects, by presenting the applied method".

Data analysis and results
For each configuration, empirical variables, e.g. time headway distributions, and the speed - following distance relationship are analysed and compared with consistent results: Driving speeds at corresponding following distances decrease by applying a work zone (and even more when also applying a reverse curve). Macroscopic effects are analysed by performing simulations, using a calibrated car-following model (the extended IDM) with individually estimated model parameters:
• Smaller lane widths and a barrier as channelizing device reduced capacity with 1.5%;
• When also applying a reverse curve, the reduction was even 6.2%.

Unmanned helicopter and observed layouts
Empirical individual driver data have been collected using an innovative method: the unmanned helicopter instead of a manned helicopter (to reduce costs and collect more data). The three observed configurations vary in lane widths, channelizing devices, and presence of reverse curves.

Data processing
To analyse individual driving behaviour, vehicle movements have to be extracted from stabilized frames, but difficulties appeared by stabilizing imagery and detecting and tracking vehicles. Therefore, new methods are introduced to detect vehicles:
• 'Edge detection';
• A program identifying mouse clicks locations;
Also a method is implemented for tracking vehicles:
• A shortest-path algorithm: the Dijkstra algorithm.
Running time supplements in the train timetable: 
*Energy-efficient operation versus robustness*

Commissioned by the Dutch Railways Operation (NS Reizigers) research has been conducted on the possibilities to better incorporate energy-efficient train operation into the timetable. The motivation for this research is based on the fact that energy-efficient operation is not yet optimally included in the timetable design. This is because of the fact that the running time supplement is not optimally divided. Running time supplement or slack time is the running time above the minimal running time between two timetable points.

The objective of the research is to develop a model which determines the optimal coasting point and the optimal cruising speed for trains and the associated running time supplement distribution; taking into account the desired robustness, the possibilities for energy-efficient operation and the desired punctuality during the execution of the timetable.

The behavior of a train is described by four driving regimes: acceleration, cruising, coasting and braking. With these driving regimes this study considers two driving strategies: time optimal and energy-efficient. The time optimal driving strategy requires a train to drive as fast as possible from A to B using the driving regimes acceleration, braking and possibly cruising. The energy-efficient driving strategy requires a train to drive also from A to B using as less as possible traction energy given the available time from the timetable. The coasting regime is an important part in this strategy. The energy-efficient driving strategy is determined by the optimal control theory. The algorithm which is applied in MATLAB determines the energy-efficient driving strategy by calculating the optimal coasting point and the optimal cruising speed given the time from the timetable.

The model has been applied on the section Utrecht Central – Rhenen for sprinter train series 7400. The results of this research show that there are yearly energy savings possible of almost € 26,400 if the energy-efficient driving strategy is used instead of the UZI (‘Universeel Zuinig rijden Idee’) method of NS Reizigers. Moreover the results show that using a uniform distribution of the running time supplements leads to extra energy savings and an improvement for the punctuality compared to the method of tightening the timetable. Tightening the timetable means that the running time supplements are placed as much as possible short before stations where the punctuality is measured. These yearly extra savings which are possible by the uniform distribution instead of the current slack time are almost € 44,000 for the energy-efficient driving strategy and are almost € 27,500 for the UZI method on the total section.

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**Student:** G.M. Scheepmaker

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Prof. dr.ir. B. van Arem, Prof.dr.-Ing. I.A. Hansen, Dr. R.M.P. Goverde, Ir. P.B.L. Wiggenraad, Ir. R.S. Luijt, Dr. R.R.P. van Nooyen

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<td>Time dependent processes on passive loaded piles</td>
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<td>Performance assessment of tree-based model predictive control</td>
<td>Student: P.M. Stive</td>
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Master’s Theses June 2011

Civil Engineering theses

Building Engineering

Structural feasibility of the Rotating Tower Dubai
Student: P. den Besten

Double curved precast load bearing concrete elements
Student: B. Janssen

The effect of steel plate girders with a high slenderness upon the fire resistance
Student: R. Wiersum

Parkeerkelder met een pneumatisch caisson
Student: S.P. Rodrigues Monteiro

Verlevendiging van de binnenrotte door multifunctioneel marktsysteem
Student: M.Zoons

Cellular beam-columns in portal frame structures
Student: J.G. Verweij

Structural Engineering

Plate buckling in design codes
Student: M. van der Burg

Wind load and high-rise:
Student: N. Narain

Loading capacity of laterally restrained prestressed concrete slabs
Student: R.F.C. de Rooij

The effects of the interaction between the substrate and the superstructure of the buildings of project Erasmuspoort
Student: R. Soemeer

Extension and Verification of Sequentially Linear Analysis to Solid Elements
Student: L.O. Voormeeren

Stability of a concrete pedestrian bridge with load bearing railings
Student: V.M. Weidema

Ultra High Performance Fibre Reinforced Concrete for bridge constructions
Student: L.W.H. Bouvy

Hydraulic Engineering

The cause of coastal erosion on a nourished beach in Kololi, The Gambia
Student: E. Bijl

Influence of the armour layer and core permeability on the wave run-up
Student: P.J.M. van Broekhoven

Feasibility study on the use of a floating breakwater to protect a new artificial beach in Balchik, Bulgaria
Student: R. Drieman

Design of berth n. in the port of Ventspil, Latvia
Student: P. Gatta

Mooring facility ‘Cruiseport The Hague’
Student: H.J. van der Giessen

Space intensification EMO-peninsula
Student: T.M. Henneveld (MSc Hydraulic Engineering)

Modelling the equalizing process of rockfill dumps with a plough
Student: W. Kranendonk

Morphodynamic analysis of the Ecobeach project
Student: M. de Lange

Probabilistic design of settling basins for environmental compliance
Student: W. de Lange

Verzandingsprobleem in de vluchthaven Wijdenes
Student: E. Lee

Comparison of quay wall designs in concrete, steel, wood and composites with regard to the CO-emission and the Life Cycle Analysis
Student: T. Maas

Providing current forecasts for the Olympic Sailing Competition
Student: S. Poortman

The Effects of The Ike Dike barriers on Galveston Bay
Student: M. Ruijs

Relatie tussen unity check en faalkans
Student: J. De Vlieger
Invloed van zandeigenschappen op het piping proces  
*Student: R. van der Zee*

The morphological effects of Sediment diversions on the  
Lower Mississippi River  
*Student: M. Bos*

Stroming van beton in diepwanden  
*Student: J. Mulder*

### Hydraulic Engineering – COMEM Domain

Modeling the Evolution of the Wax Lake Delta in  
Atchafalaya Bay, Louisiana  
*Student: K. Hanegan*

The appraisal of climate adaptation measures and  
coastal management strategies for Durban, South Africa  
*Student: M. A. Geldenhuys*

Impact of acces of channels geometry on wave penetration in harbours  
*Student: C. G. Mardones*

Low Frequency Wave Resonance on Fringing Reefs  
*Student: A. W. Mackay Pomeroy*

### Geo-Engineering

Experimenteel modelleren van horizontale belastingen  
op grote diameter monopaal fundaties in zand  
*Student: A. Alderlieste*

Piled embankment with Geosynthetic Reinforcement  
*Student: T.J.M. den Boogert*

Grondvervormingen ten gevolge van het maken van bouwputten  
*Student: J. Kimenai*

Toepassing spanningspadmethode op een horizontaal gronddruk vraagstuk  
*Student: G. Peeters*

Negative Skin Friction; Design challenges in Singapore  
*Student: P.J. Spruit*

### Transport & Planning

Micro dynamisch verkeersmanagement  
*Student: I. Bouma*

Effect van verkeerslichten op turborotondes  
*Student: B. Granneman*

Line design of the future  
*Student: N. Guis*

Redesign of the bus station Groningen assisted by a new simulation tool for bus stations  
*Student: J.J.F. Hoogenboom MSc.*

Futures of Rotterdam South  
*Student: R. Hoogerwerf*

De overgang van km/uur naar km/uur op de grens bebouwde kom  
*Student: M. de Jong*

Separation of Freeway Traffic Flows by Dynamic Lane Assignment  
*Student: A.M.G. Soekroella*

Regional effects on road safety of the RijnlandRoute  
*Student: L.M. van Dijk*

Around the metro - Research intro the potencies of the metro stops in Rotterdam  
*Student: R.G. van Huet*

### Watermanagement

A Decision-Support System based on Real Time Control and Data Assimilation  
*Student: A.L. van Breukelen*
Research groups and professors within the faculty of Civil Engineering and Geosciences

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