Master’s Theses
June 2011

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Research groups and professors within the faculty of Civil Engineering and Geosciences
Preface

For graduates is the master thesis the final part of their study. With their thesis they prove that they are ready to receive the title of Master of Science. The previous years of study at our faculty have given them the skills and the knowledge to complete this important task. All the theses presented in this book reflect the high quality of our graduates. They have not only addressed relevant problems of society, but also presented innovative solutions. Their theses reflect their capabilities and their readiness to start their careers.

For the faculty of Civil Engineering and Geosciences the presented thesis are important to prove the societal relevance and quality of our educational programme. The high standards we pursue at our faculty can be found in throughout this book. Relevant issues like coping with climate change, sustainable design and are skillfully addressed by our graduates. By also providing solutions they reflect one of the aims of our faculty, to contribute to the progress of society.

Currently I am very proud to present our graduates in this book, and I wish them good luck in continuing their valuable work in society.

Prof. ir. Louis de Querelij
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” or “Transport, Infrastructure and Logistics”.

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 2011”, whether they are merely average or truly outstanding.

The aim of the book

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

Further details

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

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Civil engineering theses

Building Engineering
Structural feasibility of the Rotating Tower Dubai

The main objective of this master thesis was designing a feasible load bearing structure for the Rotating Tower in Dubai, within the set boundary conditions given by the architectural design (the dimensions of the storeys, exterior design etc.).

Dynamic architecture
The concept “dynamic architecture” is developed by the Italian architect David Fisher. The main idea behind this concept is: the building of the future. Mr. Fisher translated this idea into the design of the Rotating Tower: a tower with separate rotating floors. The tower consists of multiple (non-circular) floors that can rotate independent around a common axis. Since all floors rotate independent, the building can (theoretically) transform into every shape imaginable. Different architectural designs were made for the Rotating Tower for different target cities. The thesis report is based on the architectural design for the city of Dubai.

Reference projects
The original design of the Rotating Tower (designed for target city Dubai) has a height of approximately 435 meter. To get a more detailed view of previous designed load bearing structures 3 reference project with comparable height were analysed. These three projects are: Burj Khalifa, Taipei 101 and Shanghai World Financial Centre. It could be concluded from this analysis that wind load was governing for all projects and that the structural design of the projects consisted of a core with an additional structure (outrigger or perimeter super truss).

Load cases
Different load cases were analysed and used in the calculation for the structure: dead load, live load, wind load and earthquake load. In this analysis local conditions for Dubai were taken into account.

Current design
The current structural design of the Rotating Tower consist of a concrete structural core with a round shape, a diameter of 30.5 meter and a wall thickness of 1 meter. With the different analysed load cases the original architect’s design of the concrete core was checked with a global calculation. It turned out that the original design for the stability structure did not meet any of the requirements given in the codes (deformations are 8 times larger than the maximum allowed value).

Optimization analysis
The current design of the stabilizing core for the Rotating Tower does not meet any of the requirements given in the codes. Therefore different solutions for stiffening and strengthening the structure were investigated. Most striking solutions are: higher concrete grade, thicker core, activating steel structure of the storeys and active systems.

Alternative designs
With the results of the optimization analysis 5 different feasible designs were made for the stability structure of the Rotating Tower. All these designs have one or more adaptations from the architects design. 3 of the 5 alternative designs are considered to be the most relevant for the project and are presented as “final designs”. These 3 final designs are worked out to a more detailed level.

Conclusion
The main conclusion of this thesis report covers the structural feasibility of the project. For several designs it is shown that the project is feasible from a structural point of view but not without adapting the architectural design. All alternatives contain one or more adaptations to the architectural design, but keep the main concept of the project unchanged.
Double curved precast load bearing concrete elements

Introduction
The construction of free form building stagnated, due to the high construction cost of it. Double curved surfaces are only applied at projects with a high profile and projects above average budget during years. The problem with double curved surfaces is mainly the formwork. The present days used techniques to construct these formworks are statically. For example: wooden, steel or milled EPS formwork could only be used for one shaped elements. The lack of repetition and so the reusability of the formwork, which means that for a free form surface for every element a unique formwork is needed, makes the construction very expensive.

Problem definition
A feasible way for mass production of unique shaped double curved elements could be achieved by a flexible formwork: a formwork that can be adjusted in every desired shape. It consists of a flexible layer that can be deformed into the desired curved surface by adjusting for example pistons, actuators or pins. Recently K. Huyghe and A. Schoofs have executed a series of experiments with a flexible formwork (Figure 1), build earlier by D. Rietbergen and Dr. Ir. K. Vollers. The purpose of this master thesis was to solve more aspects of the flexible formwork, and to make it a feasible system. The main focus was the behavior of the flexible layer. As seen in Figure 1, at some places the flexible layer did not though the actuators. Predicting the behavior of the deformed flexible layer makes an accurate production possible.

Research
To be able to determine the behavior of the flexible layer some models are proposed. With these models the reaction forces at the supports could be determined, compression forces means that the flexible layer though the supports. The first model that is proposed, is for a single curved element. For the double curved mould surface two models are proposed, a plate model and a strip model. With tests at the Stevin Laboratory these models are verified, and some other aspects are tested, for example the flexible border of the formwork. Tests indicate that a plate is not suitable for the flexible layer, it buckles due to the plate stresses. The strip mould consists of two layers of strips, perpendicular to each other. The top layer of the strips is the mould surface. Tests showed that it is possible to produce double curved elements with the strip mould, see Figure 2 for an example of a produced element.

Conclusions and recommendations
The models that are proposed in this thesis describe the behavior of the flexible layer well. A plate does not fulfil the function of a flexible layer. Tests have shown that it is possible to produce double curved elements with the strip mould as flexible layer. To cover the strips an additional layer is needed. In these tests polyether is used, as well for the borders. The protection of the polyether with sealant made the concrete element very rough. Another material has to be found as elastic layer, or to protect the polyether.

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The effect of steel plate girders with a high slenderness upon the fire resistance

Introduction
In the structure of industrial buildings, steel plate girders are frequently been applied as roof girders. A steel plate girder is composed from steel plates that are welded or bolted to each other and forming a high I-profile shape. Applying a steel plate girder in a structure can have economic benefits, compared to a castellated or truss girder. By increasing the maximum slenderness of girders, the steel can be more efficient being placed in the gauge.

Problem definition
However there are reasons to look critical at the fire resistance of slender plate girders. In this thesis the effect of steel plate girders with a high slenderness upon the fire resistance is researched. The scope of this research has been narrowed down to steel plate girders applied as roof girder within industrial halls. The main reasons for the assumption that a girder with a higher slenderness ratio is negative related to the fire resistance are:

• The section factor of steel plate girder will increase. A higher section factor will lead to a faster warming. The critical steel temperature will be reached faster, and the girder will succumb relative faster;

• Because of stability problems, it is assumptional that during a fire, the critical steel temperature of steel girders with a high slenderness ratio, will be reached fast.

Results
A higher slenderness will, as proved in the research, mostly lead to a higher section factor ($A_m / V$). The standard fire resistance of steel plate girders with a section factor above 250 m$^{-1}$ is less than 10 minutes (based on the presumed working hypothesis in this thesis, it is insufficient). An section factor above 350 m$^{-1}$ is usual for plate girders with a high slenderness ratio. This is, without complementary requirements, insufficient to apply safely in structures of industrial halls. It is necessary to look critical at the fire resistance of steel plate girders with a high slenderness ratio.

The research
By setting-up a model of a more realistic temperature course in a fire compartment, is determined which time the steel temperature under the critical steel temperature will stay. In this research the course of the temperature is examined of a large fire compartment (35m width, 40m length, 8m height). There is identified that the time for reaching the critical steel temperature is depended on the expansion speed of the fire. The fire expansion speed is characterised by the time within the surface of the fire growth up to a surface with an effective amount of warmth distribution of 1 MW, the so called time constant ($t_{α}$). A low time constant means a faster fire expansion.

Conclusions and recommendations
In a fictive fire compartment, the critical steel temperature (of 350 °C) will reached after 20 minutes (after ignition) with a time constant ($t_{α}$) of 160 seconds. With this time constant the users have (following the working hypothesis) sufficient time to escape, and for the firefighters to research the building. In case the purpose of industrial hall is to storage materials with a higher time constant, then there can be expected that the fire resistance will more than 20 minutes. Based on this research it is recommended to accept steel plate girders with a high slenderness ratio in the main structure of industrial buildings. Regards to planning application for industrial halls, with an expected $t_{α} ≤ 160$ seconds, a justification is needed from the designer that the structure contains a minimal standard fire resistance of 10 minutes.

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Parkeerkelder met een pneumatisch caisson

Om aan de toenemende vraag naar parkeerplaatsen in binnenstedelijke omgeving te voldoen zijn meer parkeergarages noodzakelijk. De uitstraling en het ruimtegebruik van bovengrondse parkeergarages zijn niet meer van deze tijd. Gebruikers ervaren deze als onprettig en eigenaren van de grond zouden deze graag herontwikkelen, maar dan moeten er wel een evenredig aantal parkeerplaatsen voor terugkomen. Dit is een eis van de gemeente bij nieuwbouw van woningen.

Om de beschikbare ruimte efficiënter te gebruiken is mechanisch parkeren een goed alternatief. Een volautomatische parkeergarage gebruikt tot 60 procent minder ruimte per parkeerplaats en verkort de in- en uitrijtijd van 10 tot 3 minuten. Een ander voordeel is het lagere energieverbruik omdat ventilatie en verlichting kunnen worden beperkt. De CO₂ uitstoot wordt verminderd omdat de voertuigen weg worden gezet en niet meer naar een parkeerplaats hoeven te rijden.

Omdat in binnenstedelijke omgeving weinig ruimte beschikbaar is loont het ook om te kijken naar het ruimtegebruik van de constructiemethode voor de parkeerkelder. De meest gangbare methoden tot nu toe voor een bouwput zijn de stalen damwanden en de diepwand methode. Doordat het materieel van beide methodes maar tot een bepaalde afstand van bestaande bebouwing kan komen gaan veel vierkante meters van het beschikbare oppervlak verloren. Een oplossing die dit ruimteverlies tot een minimum kan beperken is het pneumatisch caisson.

Het grootste voordeel van de caisson methode is het gegeven dat er geen bouwput gemaakt hoeft te worden. De constructie is tegelijk fundering en bouwput. De ruimte wordt daardoor nog efficiënter gebruikt. Doordat deze methode direct de verwijderde grond vervangt door een grondkerende constructie die een geheel vormt is de kans op lekkage veel kleiner.

Gelet op de hoge prijs die men bereid is te betalen blijkt dat het alleen in Amsterdam rendabel is om een parkeerkelder te realiseren met een pneumatisch caisson. Door de financiële en technische beperkingen is een caisson hier mogelijk van 10 meter tot 20 meter diepe. Het goedkoopst is het echter om een caisson in zandgrond af te zinken, zoals in Den Haag en Utrecht het geval is. Wanneer een kelder van meer dan 20 meter diep gewenst is in stedelijk gebied komt het caisson in een gebied waar geen concurrenten meer zijn. Bij de andere methoden zijn de kosten en risico's dan te hoog om de betreffende methode te gebruiken.

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Verlevendiging van de binnenrotte door multifunctioneel marktsysteem

Transformeerbaar plein door een innovatief marktsysteem

Aanleiding
De Binnenrotte huisvest enkele dagen in de week een van de grootste weekmarkten van Nederland en trekt dan vele bezoekers. De andere dagen is het plein echter een verlaten ruimte en een onaantrekkelijk plein. Voor veranderingen, nodig om het plein aantrekkelijker en levendiger te maken, zijn er weinig mogelijkheden omdat dit snel voor belemmeringen voor de markt leidt. Daarom is onderzocht hoe een innovatief marktsysteem kan zorgen dat pleinen zoals de Binnenrotte omgevormd kunnen worden tot een aantrekkelijk plein dat de gehele week levendig is.

Ontwerpen
Uit een uitvoerige functieanalyse waarin de omgeving en de belangen van stakeholders zijn meegnomen volgde dat er een aantal functies zowel mogelijk als gewenst zijn op de Binnenrotte, namelijk bomen & ander groen, zitmeubilair en verschillende waterfuncties. Op basis van de stakeholder- en functieanalyses zijn enkele varianten opgesteld voor het stedenbouwkundige aspect van de Binnenrotte en voor de marktkramen middels een morfologische methode. Hierbij in acht genomen dat beide uiteindelijk gecombineerd moeten worden.

Voorkeursvariant
Om uit alle varianten de beste voor elk deel en de beste combinatie te kiezen zijn een tweetal evaluatie methode gebruikt, een multi criteria analyse (MCA) en een evaluatie door een aantal groepen stakeholders.

Stedenbouwkundig
Hieruit kwam duidelijk naar voren dat stedenbouwkundig gezien een combinatie van bomen, water, LED-verlichting en terrassen de beste combinatie is om de Binnenrotte om te vormen tot een levendig en aantrekkelijk plein. De plaatsing van de aspecten hangt samen met de verschillende gedeeltes van het plein. Zo sluiten de terrassen aan op de horecagelegenheden en is de LED-verlichting toegepast op de drukke verkeersruimte aan het zuiden van het plein. Daarnaast zijn ook de bomen zo gesitueerd dat deze goed aansluiten bij de ingangen en zijstraten rond het plein.

Marktkraam ontwerp; telescopische marktkramen
Van de marktsystemen is als beste variant, de telescopische marktkraam naar voren gekomen waarbij het stedenbouwkundig element ook direct het dak van de kraam is. De telscopische kramen scoren het beste op basis van de waarde/kosten als ook op basis van de voorkeur van de stakeholders. Sterke punten zijn de compacte benodigde ruimte in de grond, de esthetische waarde, de snelheid van het systeem en de gebruiksvriendelijkheid. Tevens zijn er goede mogelijkheden voor de elektriciteitsvoorziening en de waterafvoer van de kramen. Bijkomend voordeel voor de bewoners is de geluidsreductie van het systeem tegenover het opbouwen van de huidige kramen.
Cellular beam-columns in portal frame structures

Introduction
Cellular beams are steel I-shaped structural elements with circular web openings at regular intervals. Due to the material savings, their flexibility and the possibilities for increased spans and service integration through the web openings, cellular beams have been applied widely for both roof and floor structures.

Problem definition
The application of cellular beams in portal frame structures is appealing from the perspective of both material savings and aesthetics. However, while in the past many investigations have been carried out on the behaviour of cellular beams, no attention has been paid to the behaviour of column members with web openings.

Theoretical and numerical research
In order to analyse the influence of an axial force on the structural behaviour of cellular members, two failure mechanisms have been identified that required additional research:
1. member flexural buckling
2. local web-post buckling
For both failure modes a theoretical analysis has been carried out first, followed by an extensive parameter study using the finite element software SAFIR. For checking the ultimate flexural buckling load capacity of cellular columns, a simplified design rule has been proposed and shown to be safe. The present available design models for checking against web-post buckling do not allow for the influence of an axial load. However, from the parameter study it appears that an approximately linear relation exists between the web-post buckling capacity and axial force.

Case study
The approach as developed in the ECSC project Large web openings for service integration in composite construction together with the previously acquired results from the numerical research has been applied to a case study of a portal frame consisting entirely of cellular members. For that purpose a design tool has been developed in Microsoft Excel using Visual Basic for Applications, and validated against 2D and 3D finite element analyses for different load cases.

Results
The flexural buckling behaviour of cellular columns has been shown to be similar to that of plain-webbed beams, and the proposed design rule can be applied safely. Even although the influence of axial force is not effectively accounted for, the present available models for web-post buckling turn out to be sufficiently conservative to be applied in column design.

Conclusions and recommendations
Cellular columns can be analysed similar to cellular beams, but with a modified flexural buckling check. Further research is needed on reduction in stiffness due to the presence of web-openings, and the performance of the web-post buckling model can be improved by accounting for the effect of an applied axial force.

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Civil engineering theses

*Structural Engineering*
Plate buckling in design codes

The difference between NEN 6771 and NEN-EN 1993-1-5

Slender steel plates loaded in compression will buckle out of plane before their cross-sectional capacity is reached. Precisely determining the failure load in an analytical way is an impossible exercise. Therefore many researchers have put effort into finding a simple design method, which would still predict the plate buckling load with the required accuracy. Many different methods have been developed, some of which have been adopted in the currently valid design code in the Netherlands. Some preliminary calculations showed that the Eurocode (NEN-EN 1993-1-5) gives much more plate buckling capacity then the Dutch code (NEN 6771). This observation was the start of my thesis, of which the main goal was to find and explain the differences between the two design codes. A secondary goal is to formulate an advice as to what method in the Eurocode is the best to use.

Most of the simple methods for plate buckling can be classified as either an effective cross-section method or a reduced stress method. There are fundamental differences between these two methods, which are analyzed and clarified in my thesis. It is found that in general the effective cross-section method delivers a higher buckling capacity, but this method is also more labour-intensive. An important element in every method is the reduction factor to the stress or steel area that is used. Again different researchers came up with different reduction factors, so the influence of those reduction factors is also analyzed.

With the use of some example cross-sections the difference in plate buckling capacity between NEN 6771 and NEN-EN 1993-1-5 in practical design situations is explored. Indeed the Eurocode always gives more capacity, which was to be expected when analyzing the methods in detail. Later in the thesis the plate buckling capacities have been verified using a finite element calculation in Ansys. In all studied cases the design capacity according the Eurocode matched with the capacity according the calculations in Ansys.

The fundamental principle of the effective cross-section method is the deformation capacity of slender steel plates. This deformation capacity is needed in built-up members, to let slender plates remain at capacity while more stocky plates deform further to their own buckling load. Ansys calculations have been used in this thesis to confirm this fundamental phenomenon. In analyzing the several plate buckling verification methods in the design codes it came to attention that there are no requirements given for plate edges. This is in sharp contrast to stiffeners, which are analyzed rather thoroughly. With the help of more finite element calculations to clarify this subject, it was found that the global buckling verification ensures stability of the edges of plates in built-up members.

As a final subject all understanding gained while working on this thesis is combined in giving a guideline as to what method in NEN-EN 1993-1-5 is best used in what situation. Which method is best depends on the goal of the plate buckling analysis.

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Wind load and high-rise: 
*Determination of wind loads and their impact on the two towers of project ERASMUSPOORT.*

As space in the Netherlands is becoming increasingly scarce, and many cities no longer expand, project ERASMUSPOORT is searching for other solutions in big cities, such as tall buildings. Project ERASMUSPOORT examines the possibility of building two towers side by side in Rotterdam. One of the towers has a height of 300 meter and the other tower 250 meter. The highest building in the Netherlands till now is 165 meter. So there is no experience with buildings of 300 meter height. There is also insufficient knowledge about the effects of wind on tall buildings, especially when two tall buildings are side by side.

The goal of this study is to determine the wind loads and their effects on the towers of project ERASMUSPOORT, which parameters influence these effects and how these parameters can be positively influenced. The available standards NEN 6702 and NEN-EN 1991-1-4 (Eurocode) are used to determine the wind loads on the towers. Also the NTA (Nederlands Technische Afspraak) is used to determine the wind loads. The NTA provides additions to certain factors specified in the Eurocode. From the results obtained from the codes it can be concluded that the wind load according to the Eurocode is higher than the wind load according to the NEN6702. This difference is due to the use of higher values of certain factors by the Eurocode. Also wind tunnel tests were done to determine the wind loads and their effects on the towers. The research in the wind tunnel is fully prepared according to the guidelines specified in the CUR-Aanbeveling 103.

Three measurements are performed in the wind tunnel:
- A measurement of forces and moments at the foot of the 300 meter building, with the 250 meter building at its side;
- A measurement of forces and moments at the foot of the 300 meter building, without the 250 meter building at its side;
- A measurement of forces and moments at the foot of the 250 meter building, with the 300 meter building at its side.

The results obtained from the wind tunnel are also compared with the results obtained from the codes. The main conclusion is that the results for the forces and the moments for the 300 meter building obtained from the wind tunnel have lower values than the results obtained from the codes. Also wind interference of the buildings is considered. The wind interference on the 300 meter building is determined as follows (Interference Factor):

Similar studies on wind interference are compared with the study of wind interference on the buildings of project ERASMUSPOORT. It can be concluded that there are a lot of parameters influencing wind interference on buildings. Some of them are dimensions, orientation and spacing of the buildings. The main conclusion from the similar studies is, that two buildings have positive effects on wind interference by placing them next to each other. From the results of the wind tunnel tests it can be concluded that the 250 meter tower has positive effects on the 300 meter tower. Due to the 250 meter tower the values of the forces and the moments on the 300 meter tower were lower than the values of the forces and moments on the isolated 300 meter tower. It is also concluded that the Eurocode has more parameters than the NEN6702 to determine the wind load on a building. According to the parameters influencing wind interference, an ideal situation is given for the towers of project ERASMUSPOORT.

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Loading capacity of laterally restrained prestressed concrete slabs

Introduction
The older bridges in the Netherlands have to be checked if they still meet the requirements set by today’s standards. These standards do not take into account the reserve capacity that is available by using compressive membrane action. This thesis investigates the influence of prestressed concrete in relation to compressive membrane action.

Problem definition
The influence of compressive membrane action is known for reinforced concrete slabs. It showed that it enhances the bearing capacity of the slabs when taking this mechanism into account. Less research has been done on prestressed concrete slabs. Therefore, research is needed to see what the influence is of prestressing the concrete slab and if it has a positive influence on the bearing capacity.

Research
First a preliminary research was done to investigate what is written in the existing literature. This resulted in a few research documents, which showed experimental results related to the subject. The experimental results where used to compare with the findings in the thesis. Three approaches were done, these are:
1. A comparison with the New Zealand code. Also a calculation by the Eurocode is done to see what the enhancement is of compressive membrane action with the lower bound solution from the New Zealand code.
2. An analytical approach to show the behaviour of the concrete slab. Two failure modes are considered. These are: failure by bending and failure by punching shear. Calculations are performed using these theories and compared to experimental results to see how they hold up.
3. The last approach is the use of a FEM analysis. The enhancement of prestressing the concrete in relation to a reinforced concrete model is investigated. The reliability of the model is checked by comparing it to experimental results.

Results
1. A comparison with the New Zealand code. It can be concluded that the prestressing of the concrete slab has a positive influence on the bearing capacity. In the same chapter it was shown that the Eurocode was on the conservative side even with the lower bound solution found with the New Zealand code.
2. An analytical approach was found. It showed promising results in comparison with the experimental results. More research is needed to see if the analytical approach still holds for other dimensions and properties of the concrete slab. The relation between the prestress level of the concrete and the restraint factor was found linear.
3. The model used for the FEM-analysis was build with 2d axisymmetric elements. It was found that this method does not give a good indication of the behaviour of a lateral prestressed concrete slab.

Conclusions and recommendations
An enhancement in bearing capacity of the concrete slab is visible when applying a prestressing force. The current regulations underestimate the bearing capacity of the current bridge decks. When checking existing bridges a calculation that includes compressive membrane action could therefore save out unnecessary repairs.

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The effects of the interaction between the substrate and the superstructure of the buildings of project Erasmuspoort

Introduction
Rotterdam is a city which is trying to develop high-rise in the downtown. Tall buildings are typical for Rotterdam. The highest building in the Netherlands till now is 165 meter which is also located in Rotterdam. In these cities the urban development is increasing while there is lack of space. Project Erasmuspoort is doing research whether high-rise is a solution for this problem. In this project the intentions are to build two towers side by side in Rotterdam nearby the Erasmus University. One of the towers will be 300 meter high and the other one 250 meter high.

Problem definition
Due to lack of space it is necessary to build an underground parking garage under the two towers of project Erasmuspoort. However this will cause problems. When two buildings with different heights will be built on an underground parking garage, this will lead to difference in the settlements. Those differences in settlements will cause deformations. The questions are: What will be the settlement due to the towers of project Erasmuspoort? Are those settlements allowable? What will be the influence of the settlements on the surroundings?

Research
The goal of this research was to determine the effects of the interaction between the underground and the buildings of project Erasmuspoort. The research was based on the interaction model of STUVO’97. On the basis of this interaction model two computer programs were used to predict the behavior of the underground and the superstructure of the buildings. Msettle was used to predict the behavior of the underground and Scia Engineer was used to predict the behavior of the superstructure. The output of Msettle was used as input for Scia Engineer. In Scia Engineer the underground was considered as linear elastic springs. The stiffness of the springs was derived from the model in Msettle.

Results
The results showed that the tower of 250 meter will settle about 27 centimeters in the middle and the tower of 300 meter will settle approximately 40 centimeters in the middle. These settlements will not cause damage to the surrounding areas.

Conclusion
From the research it can be concluded that the settlement of the surrounding area does not dependent on the stiffness of the buildings. By comparing the results of both computer programs it can be seen that by modeling the superstructure in Scia Engineer the settlements and the settlement differences are reduced. By modeling a façade stiffer in Scia Engineer the model gives a better distribution of the settlements.

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Extension and Verification of Sequentially Linear Analysis to Solid Elements

When analyzing three-dimensional problems with nonlinear finite element analysis (NLFEA) often problems are encountered such as bifurcation and divergence of the solution. In particular, cases subjected to tension softening tend to encourage the emergence of multiple equilibrium paths. In order to overcome these problems the Sequentially Linear Analysis (SLA) method has been developed for three-dimensional solid elements. SLA is an alternative for incremental-iterative solution schemes to model the nonlinear fracture behavior of quasi-brittle materials. It is an attractive method since it avoids the well known convergence and bifurcation problems that are often encountered when using incremental-iterative schemes such as Newton-Raphson. SLA uses a series of linear analyses to model the nonlinear behavior of the structure. By directly specifying a damage increment in each linear analysis, extensive iterations within the load or displacement increment can be avoided.

The main objective of this research was to see how the Sequentially Linear Analysis approach could be extended to solid elements, so that it could be used for three-dimensional fracture problems as well. Although three-dimensional geometries such as masonry structures have been analyzed before using SLA, it was always restricted to two-dimensional finite elements only (shell elements). Therefore, first a theoretical constitutive model for three-dimensional stress-strain states has been developed that served as the starting point. Implementation in DIANA was the major second step from which the third and last step could be started: the verification on various fictive and real cases. A single element pull test was used to solve programming errors, whereas the notched beam offered the possibility to check how the newly developed SLA-code would perform for larger models. Both cases showed excellent agreement with the experiment. However, most attention was dedicated to the verification and physical interpretation of a real reinforced concrete slab. The results were critically evaluated, interpreted and compared to results from the experiment and the incremental-iterative Newton-Raphson method. It was concluded that the Sequentially Linear Analysis is able to properly capture the quasi-brittle behavior of the reinforced concrete slab. Especially in comparison to the three-dimensional Newton-Raphson results, SLA turned out to be more robust and accurate.

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Stability of a concrete pedestrian bridge with load bearing railings

Introduction
Usually, concrete bridges contain a ‘thick’ bridge deck. For various reasons, bridges are constructed with railings. This thesis discusses the stability problem of concrete bridges, which are designed with integrated railings into the carrying construction. The most important advantage, using load bearing railings, is a thinner bridge deck. This was also one of the requests of Public Works Rotterdam.

Problem definition
The load bearing railings have to endure buckling. This phenomena is not very common in massive concrete bridges. Since the request for to alternative bridges with a thinner bridge deck, like this one, is becoming larger and larger, there is need for a simple rule of thumb. This indication is necessary for estimating the dimensions of this kind of bridge without a complicated calculation.

Research
For this thesis, the stability of a concrete pedestrian bridge with load bearing railings, has been checked in three ways. There has been focussed at the compression zone of the bridge, the handrails.

1. First the buckling force is calculated. Using the buckling force and the actual normal force in the handrails, it is possible to calculate the second order effects.
2. The total resisting moment in the handrails must be large enough to withstand the external first and second order moments. The resisting moment is based on uncracked concrete, therefore no tension stresses in the handrails are aloud.
3. If stability isn’t the problem, strength is. Hence the external normal force in the handrails most be lower than the normal force resisted.

Results
The problem has been analysed. The three checking’s are visualized in graphs over various dimensions. These graphs were used as a starting point of a parameter study to get a rule of thumb, which can be used for concrete pedestrian bridges with load bearing railings. There is also concluded that bridges with load bearing railings are more sensitive to local forces (on bridge deck and railings), than plate bridges are.

Conclusions
The rule of thumb is applicable for bridges larger than 14 meter and smaller than 23 meter, depending on the applied concrete strength. Using this indications gives a correct estimation of the dimensions of a concrete pedestrian bridge with load bearing railings.
Ultra High Performance Fibre Reinforced Concrete for bridge constructions

There is an increasing interest in the application of “Ultra High Performance Fibre Reinforced Concrete” (UHFRC). Some countries like France and Japan have already experience with this material. This experience has not lead to applications in the Netherlands and the feeling arises that the Netherlands are getting behind. Experiments and study showed that the use of UHFRC can lead to slender, economic and sustainable structures. The application of UHFRC is not treated in the Eurocode so there are no juridical guidelines. Because of this the use of UHFRC remains very limited. In France the “Association Française de Genie Civil” (AFGC) had made a recommendation (2002) on the use of UHFRC.

The first goal of this study is to investigate if this recommendation is safe to use so it can directly be implemented in the Eurocode. The Japanese recommendation (JSCE) is not used in this study because this recommendation is almost similar to the AFGC. The second goal of this study is to investigate how the shear, bending and fatigue behaviour of UHFRC can be modelled and if it is more efficient than conventional concrete.

At TU Delft already research and experiments on UHFRC have been conducted. W. Pansuk researched the shear behaviour. Result of this research is that the addition of fibres increases the shear capacity. Although these tests have given a good view on the effects of certain parameters, not all the effects could be studied. E. Lappa did research on the fatigue behaviour of UHFRC. Result of this research is that UHFRC is not sensitive to fatigue.

The first step of the main study is to make a model using a “finite element method” (FEM) program. This model is calibrated to the test results of W. Pansuk. The results of the FEM model and the experimental results agree quite well. The model gives a good representation of reality and can be used to investigate certain effects without conducting expensive experiments. The FEM model is also used to investigate if the French recommendation (AFGC) on UHFRC is safe to use. Another model made is the Multi-Layer model. This model describes the bending behaviour of fibre concrete. A small adjustment on the Multi-Layer model made the model also suitable for describing the fatigue behaviour. Results of this adapted model showed an accurate approach of the experimental results. The Multi-Layer model will be used to investigate if the strength verifications from the AFGC are safe and suited.

With the use of FEM models parameters like fibre volume, shear reinforcement, prestress forces and the effect of a hybrid mixture (both small and large fibres) on the shear capacity were studied. The study on the parameters showed that the use of fibre concrete increases the shear capacity in such a way that shear reinforcement can be prevented. If shear reinforcement is used in combination with fibres synergy does occur. Prestressing enlarges the shear capacity but further increase of the prestress force is of little influence. A higher fibre volume enlarges the shear strength but a real increase can be observed with the use of a hybrid mixture. The bending and fatigue behaviour can be modelled very well with the Multi-Layer model. Results of the fatigue analysis showed that both fatigue life and strength are much higher compared with conventional concrete.

Results on the shear behaviour showed that the AFGC is safe to use and is a bit conservative. This study gives some small adjustments on the AFGC to make the use of UHFRC more efficient. Other aspects of recent importance are the sustainability and the environmental properties. Analyses on these points showed that use of UHFRC yields more favourable results where the emissions and costs can be reduced enormously compared with conventional concrete.

Ultra High Fibre Reinforced Concrete is the building material of the future. The French recommendation gives a good guideline for design engineers. Implementing the recommendation in the Eurocode stimulates the use of UHFRC giving the building industry a new boost.

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Civil engineering theses

*Hydraulic Engineering*
The cause of coastal erosion on a nourished beach in Kololi, The Gambia

The erosion problem at the Senegambia area (The Gambia) is the subject of this thesis. The Senegambia area is the largest Tourism developed area which contributes significantly to the economy of The Gambia. In November 2003 Royal Haskoning has constructed a beach nourishment of 1,000,000 m³ as an erosion buffer with a lifetime of 10 to 15 years. In 2010 this nourishment has been eroded almost completely. The processes that drive this ongoing high erosion are not known; therefore two research questions have been defined: (i) What happened to the nourished sand, where has it been transported to? and (ii) Which processes cause the high erosion rate at Kololi Beach?

To gain insight in the coastal processes in front of the Senegambia area field data have been collected and analysed, the nearshore wave climate has been modelled using SWAN and sediment transport capacities and shoreline movements along the coast have been computed using DHI software.

The most important results are: Nourished sediment contains 10-20% of shell fraction with a maximum of 30% for the lowest quality of sediment; these shell fractions wash out very easily and do not contribute to the total volume of the sediment in case of erosion, increasing the erosion rate. Shoreline movement for the 2004-2009 period has qualitatively the same trend as the shoreline movement for the undisturbed period 1964-1983, however a factor 5 to 8 larger. According to the computations two direction reversal points are present along the coast causing a large area of small accretion and a small area of large erosion. This was not indicated during the large-scale study in 2000 on which the design of the nourishment has been based. The computed net sediment transport is southerly directed between south of the Senegambia area, north of this area the sediment transport is northerly directed. The water level and a changing wave climate for the period 2007-2009 have a large influence on the sediment transports. These transports have been computed for the recent bathymetry and wave data, which can differ from the conditions between 1964 and 2000.

These results lead to the following conclusions: The largest part of the nourishment has been transported to the stretch south of the Senegambia area. The accreted volume along the coast is approximately 50% of the total nourished volume. The cause of high erosion rate at Kololi Beach is an enumeration of multiple processes. The combination of a large amount of shell fractions in the nourished sediment, spatial placement of the nourishment, sand deficit due to sand mining and the effect of sea level rise as the water level has a high influence on sediment transport. The reason why erosion rates are 5 times higher than before 1990 is not exactly known. The modelling study on which the conclusions have been based is performed using the present bathymetry and the wave climate from 2000 to 2009. It is possible that both the bathymetry and wave climate have changed over time; this could have large influence on the sediment transport along the coast.

A Combination of a “hard” structure with initial nourishment in front of the Senegambia area may be considered as a mitigation measure for the present erosion.

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In JUMELET [2010] a method to determine the 'notional' permeability coefficient \( P \) of a rubble mound breakwater was developed (so called "Volume Exchange model"). The 'notional' permeability coefficient \( P \) was previously introduced in the stability formula of the armour layer, see VAN DER MEER [1988]. In this latter study this coefficient was empirically based for three different structures. Due to the limited validity it is difficult to apply a coefficient for different breakwater configurations. The Volume Exchange model determines the permeability coefficient by computing the ratio between the surface wave run-up on an impermeable core and a permeable core. This ratio is the so called run-up reduction factor.

The objective of this study was to improve the insight in the physical process related to the influence of the core permeability on the armour layer stability. Therefore, the difference in wave run-up between an impermeable core and a permeable core was investigated. Also, the separate influences of the slope surface roughness and the permeability of the armour layer on the reduction of the wave run-up were investigated. Lastly, the wave run-up at the surface of the core was of interest since this determined the length over which inflow took place. To this aim physical scale model tests were conducted. The tests were carried out in the wave flume of the water laboratory at Delft University of Technology.

From the results of the experiments it could be concluded that for surging waves the surface roughness of an armour layer has a negligible influence on the wave run-up height. For Iribarren numbers between 3.5 till 4.0 a rough impermeable layer has influence on the wave run-up height. For surging waves the reduction of the wave run-up is entirely caused by energy dissipation in the pores of the armour layer.

In the Volume Exchange model the reduction factor \( c_r \) was based on the reduction of the surface wave run-up due to inflow of water into the core during the run-up period. So, the reduction factor \( c_r \) is a ratio between the run-up on an impermeable core and a permeable core. In this study it turned out that the surface wave run-up was not reduced for the cases with a permeable core. However, a reduction was found for the wave run-up on the core between an impermeable and a permeable core.

Results of the computations made with the Volume Exchange model were compared with measured values of the run-up reduction factor. A large difference was visible between the model results and the measured values. Most probably this was caused by an overestimation of the external wave run-up volume. A reduction factor to include this overestimation into the model was derived. This adjusted Volume Exchange model is used to determine a formula for the permeability coefficient. This has led to the conclusion that the permeability coefficient is dependent on the Iribarren number and the structural configurations of the breakwater.

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Feasibility study on the use of a floating breakwater to protect a new artificial beach in Balchik, Bulgaria

The coast of Bulgaria is subject to erosion. Because of this fact, around the town of Balchik, which is situated on the Black Sea coast, almost no sandy beaches are present. Last years there have been vast tourist developments in and around Balchik. Because of these developments, the province demands solutions to adapt coastal protection structures to become more attractive regarding recreation. In this study, a small pilot project on the creation of an artificial beach will be described. One possible source of nourishment sand is to dredge it from the local bottom. However, this sand is too fine to form a stable beach without a breakwater in front of it for protection.

In this study is investigated whether it is technically feasible to use a floating breakwater to protect the new proposed beach in Balchik. In order to do this, the following approach is followed. A description of the current situation as well as boundary conditions regarding wind, waves, water level, bathymetry and sediment properties is given. Next, the maximum allowed wave height to form a stable beach is determined by means of sediment transport calculations in cross-shore and longshore direction and several possible nourishment sand sizes are considered. In order to lower the incoming waves (boundary conditions) to the maximum allowed wave conditions, a floating breakwater with a certain transmission coefficient is necessary. An investigation on possible types of floating breakwaters is made and the possibilities to produce the floating breakwater are described. From the types of breakwaters found, the most suitable type is selected. The last step is to determine the required dimensions and offshore distance of the floating breakwater in order to achieve the required transmission coefficient. If the required dimensions stay within reasonable limits, it can be concluded that it is technically feasible to use a floating breakwater as beach protection.

It is chosen to use concrete caissons to create the floating breakwater, because of the fact that in the vicinity of the project location a company is located which can produce floating concrete structures. Regarding beach nourishment materials, the equilibrium beach profiles with mean grain diameters 0.1, 0.2 and 1.0 mm are considered. It is chosen to further elaborate the case of the locally available sand with a mean grain diameter of 0.1 mm, because for this sand a floating breakwater is necessary in order to stabilize the nourishment. The other two sediment sizes may form a stable beach without a breakwater in place.

In order to determine the required dimensions of the floating breakwater, a distance of 200 m between the floating breakwater and the coastline is chosen. With the aid of a literature study on floating breakwater dimensions it is found that for this particular location and governing wave conditions, the draft of the floating breakwater is the governing parameter which determines the transmission coefficient. The breadth of the structure is determined by stability requirements. In this design, it is assumed that the breakwater is fixed in space, which is, regarding the main outline of the design, a reasonable assumption.

The result of the study is a preliminary design of a beach nourishment with a volume of 91,000 m$^3$ which is protected by a 240 m long floating breakwater consisting of three elements. The final conclusion of this study is that it is technically feasible to use a floating breakwater as beach protection measure.
Design of berth n.12 in the port of Ventspils, Latvia

Introduction

Ventspils Free Port Authority has commissioned the design of the new berth capable of hosting post-Panamax vessels and having a retaining height of 18.5m. Furthermore, in proximity of the quay wall two existing sewage pipes are positioned, which need to be combined into one single conduit with a global diameter of 900 mm. The pipeline needs to intersect and cross the quay wall line. In addition, perpendicular to the quay wall’s line is positioned the already existing movable Bridge on the River Venta, at a distance of ca. 30 from one edge of the berth.

Objectives

The objectives of the final project are to develop a suitable design of the berth, considering the poor soil conditions, which characterize the construction site. Following the interpretation of the furnished CPT in fact, a multi criteria analysis is performed, which analyzes different type of structures, excluding the least convenient ones. A further objective of the thesis is to evaluate and to design the sewage pipe intersection possibilities. Given therefore the quay wall’s and pipeline’s design the interaction between the conduit and the quay wall is studied. The so found results are than taken into account in the pipe’s design procedure. Least but not last, the loads applied directly to the quay wall and to the area behind the berth, cause deformation of the soil surrounding the quay. These deformations and loads will affect the nearby Bridge’s foundation. Final objective of the thesis is in fact to determine the interaction between the berth and the foundation of the Bridge.

Analysis

Given the boundary conditions of the site and the CPT, the soil stratigraphy is obtained, together with all soil parameters. Following the MCA analysis, the most suitable structure is composed of a quay wall with a deep relieving floor, a front steel Combi-wall and a rear double row of concrete bearing piles. The foundation elements are designed after an analysis of all the possible loads acting on the quay wall. Particularity of the project is to be found in the fact that a movable crane is adopted, which requires a detailed analysis of the crane load distribution on the quay wall. The quay wall’s anchor is composed of an 8.5 m high anchor wall connected to the quay wall through horizontal anchor rods. The quay wall’s global dimensions are obtained from structural and operational considerations. The quay wall’s global stability is checked by performing a Plaxis 2D analysis. Given the above quay wall design, an estimation of the construction costs is performed. As far as it concerns the pipeline design, the adopted solution is a steel conduit, which intersects and crosses the quay wall line, below the level of the designed sheet-piles at a depth of -32 m Baltic Sea Level. The interaction effects between the conduit and the berth’s foundation are studied by employing Plaxis FEM program. Because of the complexity of the problem, the effects of the quay wall’s deformation on the Bridge’s foundation are determined by employing a Plaxis 3D analysis.

Conclusions and suggestions

Given the extremely poor soil conditions of the site and given the required retaining height of the quay wall, the total construction cost of the quay wall amounts to 28.000 euros per running meter excluding the costs of the pipeline. The interaction between the quay wall and the pipeline is limited and so are the effects of the quay wall deformation on the Bridge’s foundation.

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Mooring facility ‘Cruiseport The Hague’

There is a growing cruise market. To accommodate the growth of cruise shipping in North-West Europe, the developers Consortium ‘Cruiseport The Hague’ wants to construct an outer harbour at Scheveningen; to this day, the harbour of Scheveningen is not able to receive today’s large cruise ships.

Obviously, a cruise mooring facility has to be constructed in the outer port; however, this structure has to provide more than just the mooring of cruise vessels alone. A multifunctional structure was designed. The functions, besides providing mooring to cruise ships are an underground parking garage and substructure as a foundation for the cruise terminal and office towers (a ten level building).

The objective of my graduation project was to design the substitute of the mooring facility with related construction method. Construction method alternatives for the mooring facility are developed by a global feasibility study. This study, in combination with a multi-criteria analysis shows that the caisson construction method is selected for construction of the mooring facility. The caisson method is investigated in further detail to conclude whether it is possible to design and construct a very large (area of about 50,000 m²) joint free caisson structure as a mooring facility. A global design has been prepared for all the construction stages of the caisson mooring facility (from the construction to the removal of the temporary construction pit).

The technical feasibility of the mega caisson is evaluated using a hand calculation and a finite element model, ESA PT. Based on these models, it can be concluded that the use of a very large caisson structure as mooring facility is technically feasible. Furthermore, the study shows that, when it comes to the financial feasibility, the cofferdam method leads to the lowest construction costs.

The report describes the design for a caisson structure, able to resist the forces working on it throughout its lifecycle.


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Space intensification EMO-peninsula

The space in the Port of Rotterdam is getting scarce due to the growth of the port. This is the reason why the port authority shows the ambition to intensify the space in the port.

The EMO-peninsula on the first Maasvlakte is one of the areas in the port where there is a lack of space. There are three companies who are based on the peninsula. These are: EMO (dry bulk terminal), Electrabel (new coal/biomass power plant) and Gasunie (small LNG-storage).

The lack of space on the peninsula is caused by:
- enlargement of a port basin
- the new coal/biomass power plant
- the expected growth of EMO

A capacity analysis shows that the EMO-peninsula is indeed short of space. The focus, of the intensification of space, is laid on the dry bulk storage of EMO and the handling and storage of biomass on the peninsula. All the alternatives to increase space capacity are generated by a brainstorm.

The alternative keerwand (see picture) is elected as the best solution for the dry bulk storage problem of EMO. For the handling and storage of biomass, the best alternatives are the same as the current ideas. That is why only the alternative keerwand is developed and looked at in this study.

**Alternative keerwand**

The alternative keerwand contains of a retaining wall on both sides of the storage to enlarge the volume of the storage. Moreover, the volume will also be increased by adjusting the machine that is used for stacking and reclaiming the dry bulk, this machine is called the kombi. This will lead to more storage volume on top of the storage.

The alternative shows benefits on different levels. These are:
- gain in space
- financial positive
- technically feasible
- environmental attractive

The keerwand alternative results in a gain of space of 15.3%. The investment and the operational costs are relatively low. The construction of the retaining wall and the transformation of the kombi are technically feasible. Because of the relation between the surface and the volume of the storage is small, dust will be reduced to a minimum.

A disadvantage of the alternative is the freedom of movement of shovels and dumpers. They have to drive around the construction to reach their destination. In comparison to many other alternatives to increase storage capacity in the port, this study proves that space intensification (keerwand) is really interesting for a dry bulk terminal. It is even more attractive than expanding or move the terminal to a new location.

Especially the financial benefits are very positive. The investment and operational cost are considerably low. The most important argument against this alternative is the limited freedom of movement.

**Space intensification EMO-schiereiland**

The main conclusion of this study is that space intensification on the EMO-peninsula is feasible and interesting. By the use of space intensification there is no necessity for companies to expand on another location outside of the peninsula on the first Maasvlakte.

The study "Space intensification EMO-peninsula" contributes to the ambition of the port authority of Rotterdam to intensify the space in the port.
Modelling the equalizing process of rockfill dumps with a plough

A way to equalize granular rockfill dumps at a sea or river bed is the use of a plough. A plough can be modeled as a set of straight blades in sequence. Several cutting models for dry and saturated sand are present in the literature. In cutting coarse material, the increase in pore water pressures caused by dilatancy of the grain structure play a minor role. This results in a different shape of the layer cut than for traditional cutting methods in fine soils. The layer cut has a limited surface slope resulting in grains rolling down under the angle of repose. Failure of the grain structure in coarse material depends mainly on the gravitational, shear and inertial forces between grains. This master thesis gives an analytical model for cutting rockfill larger than medium coarse sand with straight cutting blades (Chapter 4.2). A description is given of the important processes involved in equalizing with a plough and the different stages of filling. The analytical model is realized by use of models made by S.Miedema for cutting saturated sand and models for cutting dry sand by Hettiaratchi, and Reece (1966). The analytical model is verified by performing a physical scale model. The scale model is used to attempt to simulate the process in a discrete element computer model EDEM.

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Morphodynamic analysis of the Ecobeach project

Ecobeach is a new method to combat coastal erosion. The method was discovered by a contractor in Denmark. The project was brought to the Netherlands by BAM as part of the WINN project of Rijkswaterstaat and Deltares. In cooperation with Rijkswaterstaat, BAM set up a test project with Ecobeach in 2006, consisting of a length of three kilometers on the beach near Egmond aan Zee.

**Het Ecobeach project**
Bij de Ecobeach methode wordt gebruik gemaakt van verticale drainagebuizen in het strand. De drainagebuizen worden om de 10 meter dwars op de kust en om de 100 meter langs de kust ongeveer 25 centimeter onder het inter-getijde strand aangebracht. Het principe achter Ecobeach is dat door passieve drainage van het grondwater in het strand een klein effect rondom deze buizen op zal schalen naar een groter effect op het hele inter-getijde strand. Onderzoek naar vele hypothesen over de werkingsmechanismen van Ecobeach heeft nog geen uitsluiting gegeven over de werking van het systeem. Er is ook nog geen duidelijk beeld van het systeem in zijn geheel. Daarom wordt in deze thesis met behulp van de JARKUS data onderzoek gedaan naar de mogelijke invloed van het Ecobeach systeem op de morfologie van de Nederlandse kust.

**Onderzoeksoptzet**
Om de effecten van Ecobeach op de morfologie te onderzoeken is allereerst een geschikt referentiegebied nodig. Het referentiegebied is onderzocht op de lange en korte termijn morfologische ontwikkeling. De lange termijn houdt rekening met hydodynamische condities, lange termijn ontwikkelingen van de banken voor de kust, staat van het strand en staat van de duinen. Voor de korte termijn is een onderzoek gedaan naar de correlatie tussen de banken en het strand gedurende de Ecobeach test (van 2006 tot 2010). Een tweede onderzoek is gedaan naar de invloed van suppleties net voor en gedurende de Ecobeach test periode. Het meest geschikte referentiegebied op de Nederlandse kust is gevonden in een drie kilometer groot gebied net ten zuiden van het Ecobeach test vak.

Zowel het Ecobeach test vak als het referentiegebied zijn echter ernstig verstoord door suppleties. Omdat geen kwantitatieve gegevens over de verstoring veroorzaakt door suppleties voorhanden is, is de aannemer gedaan dat alle gebieden in gelijke mate verstoord zijn.

**Conclusie**
Zowel voor het strand als voor de duinen geldt dat de mogelijke invloeden van het Ecobeach project op de morfologie overschaduwd zijn door invloeden van menselijke ingrepen, bijvoorbeeld suppleties, en natuurlijke variatie (grootte 120 m³/m).

**Aanbevelingen**
De Nederlandse kust is ernstig verstoord door menselijke ingrepen. De verwachte invloeden van de Ecobeach test vallen binnen de natuurlijke variatie. De invloeden van suppleties zijn bovendien in dezelfde orde als de verwachte invloed van Ecobeach. Een volgend onderzoek naar de Ecobeach methode kan beter worden opgesteld op een minder verstoorde kust. Zo’n kust is in Nederland niet voorhanden. Voor verder onderzoek met de huidige data is het nodig om meer kwantitatieve informatie over de invloed van suppleties en de natuurlijke veranderingen van de kust te hebben. Een laboratoriumproef of nieuwe veldproef naar de werkingsmechanismen van Ecobeach is de beste volgende stap voor onderzoek naar de Ecobeach methode.

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Probabilistic design of settling basins for environmental compliance

Settling basins for environmental compliance
The environmental impacts caused by suspended sediments are an important issue in the environmental impact assessment (EIA) of dredging and reclamation projects. This thesis is restricted to provide insight into the emission of suspended sediment particles due to the release of return water. This water is used to pump dredged material to the disposal area after which the excess water is released. Settling basins can be used to remove fines particles from the return water. The remaining concentration of suspended particles (outflow concentration) is hard to predict due to varying circumstances (e.g. wind, discharge and inflow concentration) and uncertainties in the settling process (e.g. agglomeration of clay particles). A probabilistic approach is a powerful method to incorporate these uncertainties.

New developed model
A probabilistic approach requires an efficient model that takes into account the relevant physical processes in a simplified way. A model is developed to simulate the transport of suspended sediment in the two dimensional vertical plane. Besides the turbulent mixing, processes as flocculation (agglomeration of clay particles) and secondary flow are included. This enables the model to provide realistic predictions of the concentration of suspended sediment in the vertical plane. The model is compared with measurement data and existing solutions which gives promising results.

Probabilistic analysis
A probabilistic analysis of a case study provides insight into the main sources of uncertainty in the outflow concentration. Wind has a significant impact on the outflow concentration due to turbulent mixing and secondary flows. Furthermore, processes related to the clay particles (minimal settling velocity and flocculation) are very decisive. These parameters are proposed as calibration parameters. There appears to be an optimal basin depth. When the basin is deeper than this optimal basin depth, the positive effect of the longer residence time is eliminated by the larger turbulent mixing that is caused by the increased depth.

Probabilistic design of settling basins
By expressing the environmental risk of the contractor in a financial risk (fine or downtime), it is possible to determine an economic optimal design of a settling basin. This economic optimum is determined for both the basin depth and the discharge (the latter can be considered as the choice of equipment). The optimal choice of equipment is between the minimal production costs at an acceptable risk. For this risk, time effects and the time period over which the risk can be spread, play an important role. Finally, the profitability of wind protection for settling basins is investigated. This appears to be beneficial for the case study.

Future use of the model
The availability of a probabilistic model for determining the outflow concentration of settling basins offers interesting possibilities for a probabilistic analysis of environmental impacts of dredging and reclamation projects. This is because not only emissions are quantified but also insight is provided into the uncertainties and the sources of these uncertainties. This also enables the determination of an economically optimal design of a settling basin and provides insight in the associated financial risks.

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In opdracht van het Recreatieschap Westfriesland werd een onderzoek gestart naar het verzandingsprobleem in de vluchthaven Wijdenes. De vluchthaven kampte jarenlang met verzandingsproblemen en er zijn diverse onderzoeken en aanpassingen uitgevoerd, maar het probleem is nog steeds niet verholpen. Door de verscherpte wetgeving in 2008, zijn de kosten voor het behandelen van baggerspecie toegenomen. Hierdoor is het financieel niet meer rendabel voor de havenbeheerder om de haven op diepte te houden.

Bij een bezoek ter plaatse bleek dat de zuidelijke golfbreker verzakt was. De opbouw van de golfbreker bestaat uit een geotube, een kunststoffilter en breukstenen. Door de verzakking van de golfbreker vindt nu golfoverslag met sediment plaats dat zorgt voor verzanding achter de zuidelijke golfbreker. Golfoverslag vindt meestal plaats in de zomer, omdat de waterstand in onze situatie de maatgevende factor is. Naast golfoverslag is de golfbreker ook sedimentdoorlatend geworden bij windopzet. Dit gebeurt wanneer het waterpeil de bovenkant van de geotube heeft bereikt.

Ook de vorm van de zuidelijke golfbreker zorgt voor verzandingsproblemen. De golfbreker staat bijna haaks op de kustlijn en zorgt ervoor dat het water achter de golfbreker kalmer wordt. Door het kalmere water kan het sediment bezinken en vervolgens naar de haven worden verplaatst.

Als laatste is de noordelijke golfbreker te kort, hierdoor kan sediment uit het noorden de golfbreker passeren. Omdat de zuidelijke golfbreker langer is dan de noordelijke golfbreker, wordt het sediment opgevangen door de zuidelijke golfbreker en vindt er verzanding plaats in de vluchthaven.

Om verzanding van de vluchthaven te beperken, zijn drie alternatieven uitgewerkt. Het verzakte golfbreker herstellen; de vorm van de zuidelijke golfbreker aanpassen en als laatst worden beide golfbrekers aangepast. Een kostenanalyse zou uitgevoerd moeten worden voor de diverse alternatieven, om de financiële haalbaarheid vast te stellen. Met behulp van een Multi-Criteria Evaluatie ontstaat er een overzicht van de sterke en zwakke punten van elk alternatief. Het vaststellen van de toekomstvisie van de vluchthaven is bepalend voor de keuze van de alternatieven.

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Comparison of quay wall designs in concrete, steel, wood and composites with regard to the CO$_2$-emission and the Life Cycle Analysis

This thesis focuses on quay wall structures in the Port of Rotterdam. A quay wall is a soil retaining structure where ships can moore and transfer goods. Over the centuries the developments in quay wall structures have been tremendous, due to increasing ship dimensions, loads and crane designs. Next to that climate change is a hot topic nowadays. The building sector is one of the sectors which have a large impact on the environment. Constructing durable and sustainable throughout the entire life cycle is becoming more and more important. CO$_2$-emission is a widely excepted parameter to estimate sustainability. Besides CO$_2$ many other environmental effects, so called impact categories, have an impact on air, water and soil, which can be shown with help of a Life Cycle Analysis (LCA).

In this thesis the impact on the environment of a quay wall constructed in four different materials is analyzed. These materials are: concrete, steel, wood and composites.

To make a good comparison, the designs must be based on the same requirements and boundary conditions. For this purpose the quay wall of the Euromax Terminal is used. This quay wall is situated in the Maasvlakte 1 area.

Several types of quay wall structures have been studied and their main dimensions have been determined. This resulted in a retaining wall in combination with a concrete L-shaped relieving structure. The stability of the structure is guaranteed by a combination of mv-piles and vibro-piles. In this design the retaining wall is constructed in the four different materials: concrete diaphragm wall, steel combi wall, wooden wall of Azobé elements and a Fiber Reinforced Polymer sandwich panel.

Next a cost estimation of the four designs has been made.

Finally the CO$_2$-emission of each structure is determined. This Carbon Footprint has been calculated with two different emission databases. Furthermore the emissions of several other environmental effects, so called impact categories, have been determined. They represent emissions due to pollution to air, water and soil, depletion and land use. Using monetization as a weighing factor, the so called "shadow prices" of each structure can be calculated. These costs represent the costs for the preventive measures that must be taken to reduce the emissions to a sustainable level.

From this it can be concluded that the steel retaining wall results in the lowest shadow costs, closely followed by concrete. The shadow costs for wood are slightly higher and for the FRP wall they are much higher. Furthermore it is recommended to investigate the influence of the end-of-life scenarios on the LCA outcomes, which could not be taken into account in this thesis. It is questionable if the concrete and steel structures than still show the best results.
Providing current forecasts for the 2012 Olympic Sailing Competition

This project focuses on studying and modelling the flow in the sailing area of the 2012 Olympic Sailing Competition, located partly in Portland Harbour and partly in Weymouth Bay, in order to provide accurate and reliable current forecasts for the Dutch Olympic Sailing Team.

From literature it follows that the main flow in the area is the tidal flow. Wind- and wave-induced currents may have a significant influence on the flow as well. Since the available current data is considered outdated, sailed current measurements have been performed to obtain reliable current data.

To provide for current forecasts, the two-dimensional depth-averaged numerical flow model FINEL2D, which has the finite element method (FEM) as numerical basis, has been used. FINEL2D adopts the discontinuous Galerkin method to solve the shallow water equations, complemented by a Riemann solver according to Roe to account for the fluxes trough the element boundaries. The TPXO model has been used to enforce boundary conditions on the model. A Nikuradse roughness of 0.035 m has led to model results which deviate least from the measured current. To overcome the phase shift that is still visible, the roughness around Portland Bill and the Shambles Bank has been increased to 0.25 m.

By investigating the influence of wind and waves on the flow, it appeared that the wave-induced current in the area of interest is negligible. Wind does however have a significant influence on the flow. Since it is difficult to obtain accurate and reliable wind predictions, accounting for the wind in the current forecasts is difficult.

In conclusion it can be stated that the flow in the sailing area of the 2012 Olympic Sailing Competition can be modelled well by means of the two-dimensional depth-averaged numerical flow model FINEL2D. The model results correspond well to the during the survey measured flow velocities and flow directions.
The Effects of The Ike Dike barriers on Galveston Bay

*A 2D numerical modeling study on hydrodynamics and the implications for the water quality and morphology of Galveston Bay*

In 2008 Hurricane Ike flooded large parts of the barrier islands in front of the Galveston Bay near Houston, Texas. The storm surge also entered the bay through the inlets causing great damage along the bay and the port of Houston. Because of the high probability that a hurricane would strike again the "Ike Dike" was developed. The concept consists of heightening and extending the floodwall on Galveston Island and Bolivar Peninsula. Barriers will be placed at the San Luis Pass and Bolivar Roads inlet whereas the Rollover Pass might be closed completely. The Bolivar Roads barrier will be a combination between a floodgate and a lifting gate structure.

During non-storm conditions, when the gates are open, the flow area through the inlets are expected to reduce up to 40-60% due to the barriers. The reduction of flow area can cause a decrease of the tidal prism and tidal range. Also current velocities are expected to increase near the barriers and decrease in the main bay. The residence time of fresh water in the bay is expected to increase and the salinity to decrease. The reduction of the tidal prism, tidal range and current speeds can cause a redistribution of the sediment from marshes and flats to the channels within the bay. The blocking of sediment from the Mexican Gulf by the barriers can further enhance this. Changes of the hydrodynamics, water quality and morphology in the bay could potentially result in loss of habitat and disturb the ecology.

A 2D hydrodynamic model has been created in order to investigate the impact of the barriers on the tidal prism, tidal range and circulation in the bay. The morphology and water quality of the bay are investigated qualitatively using literature, reference projects and the outcomes of the 2D hydrodynamic model.

It is concluded that a 40-60% decrease of the flow area at the Bolivar Roads entrance affects the hydrodynamics and could have implications for the morphology and water quality of the Galveston Bay. To mitigate or prevent these effects the design could be altered such that the flow area is reduced by less 20%, because the impacts of such a barrier are relatively small. Another mitigating solution could be to build compartment dams to preserve the tidal range.
Relatie tussen unity check en faalkans

De Maas kent een aantal waterbouwkundige kunstwerken die het einde van hun ontwerp levensduur van 50 tot 100 jaar naderen. Het is daardoor van belang te bepalen wat de huidige conditie van de kunstwerken is om de betrouwbaarheid van de Maascorridor te waarborgen. Om de huidige conditie van de kunstwerken te bepalen, dienen de constructieve elementen conform de voorschriften getoetst te worden. De uitkomst van de toetsing van een element geeft aan of het element wel of niet voldoet aan de voorschriften. Het resultaat zegt niks over de betrouwbaarheid van een element.

Om de betrouwbaarheid van de Maascorridor te kunnen bepalen moet begonnen worden met het bepalen van de betrouwbaarheid van de elementen. De betrouwbaarheid van een element kan uitgedrukt worden in de faalkans van een element. Het toetsen van elementen conform de normen geeft een unity check weer die iets zegt over de verhouding tussen de opneembare en optredende belasting. Het bepalen van de faalkans van een element wordt gedaan door middel van een probabilistische analyse. Het uitvoeren van een probabilistische analyse voor elk element vergt veel tijd, die niet altijd beschikbaar is. Om die tijd te besparen kan gebruik worden gemaakt van de in de normen voorgeschreven faalkans (uitgedrukt in de betrouwbaarheidsindex) voor elementen die aan de unity check voldoen, waarbij de grote van de unity check niet van belang is. Het nadeel van het toepassen van deze faalkans is dat het ten koste gaat van de nauwkeurigheid, dat uiteindelijk gevolgen heeft voor de nauwkeurigheid van de betrouwbaarheid van de corridor.

Het doel van het onderzoek is: Het komen tot een algemene relatie tussen de “Unity Check” van onderdelen van natte kunstwerken en de faalkansen, dat uiteindelijk voor elk onderdeel toegepast kan worden, om zo tot een nauwkeurige faalkans voor de corridor te komen die op een snelle manier toegepast kan worden.

Om uiteindelijk tot het doel te komen is het van belang te onderzoeken hoe de relatie opgebouwd kan worden en waar het van afhankelijk is. In dit onderzoek wordt uiteindelijk gewerkt vanuit de basis van de relatie naar de relatie voor een aantal case studies.

Voor het modelleren van de case studies moeten de kansverdelingen met bijbehorende verdelingsparameters voor de stochastische variabelen bepaald worden. De sterkte van materiaal en afwijkingen in de dimensies zijn variabelen waarvoor al onderzoek is gedaan, maar belastingen zijn erg situatie afhankelijk, waardoor hiervoor in dit onderzoek extra aandacht aan besteed is.

In dit onderzoek zijn voor twee stuwen in de Maas een aantal stalen en op druk belaste betonnen elementen als case studies genomen. Voor deze elementen zijn voor zover mogelijk een niveau II analyse en Monte Carlo simulaties toegepast. De uitkomsten van de probabilistische berekeningen (uitgedrukt in betrouwbaarheidsindices) zijn vergeleken met de unity checks van de elementen. De resultaten zijn gecategoriseerd om uiteindelijk de betrouwbaarheidsindex voor de unity check te kunnen bepalen. Zo kan op een snellere methode dan een volledig probabilistische aanpak en nauwkeurigere methode dan voorgeschreven in de normen, de faalkans van een element bepaald worden.

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Invloed van zandeigenschappen op het piping proces

Een van de faalmechanismen van een dijk is piping. Een waterstandsverschil tussen de twee zijden van een dijk zorgt ervoor dat er een grondwaterstroming optreedt in de zandlaag onder de (klei)dijk. Deze grondwaterstroming kan zand transporteren van onder de dijk vandaan naar het uittreepunt van het grondwater. De formule van Sellmeijer is wiskundig afgeleid op basis van de continuïteitsvergelijking, Poiseuille stroming en het evenwicht van korrels volgens White. De invloed van $D_{70}$ op het kritieke gradiënt is lineair in de Sellmeijer formule. Omdat grof zand in het algemeen meer doorlatend is dan fijn zand, is de netto invloed van korrelgrootte op het kritiek verval in het algemeen minder dan lineair, maar nog wel positief. De Wit heeft experimenteel onderzoek gedaan en heeft gevonden dat grof zand een hogere kritieke gradiënt heeft dan fijn zand. In het kader van Sterkte en Belastingen Waterkeringen (SBW), zijn proeven uitgevoerd. De invloed van $D_{70}$ op de kritieke gradiënt is minder dan is voorspeld op basis van het Sellmeijer model.

1. Probleem definitie en doelstelling van het onderzoek
Het doel van deze thesis is de invloed van de korrelgrootte en andere zand eigenschappen op het kritiek verval te onderzoeken, en een verklaring te vinden voor het verschil dat gevonden is tussen de SBW resultaten en de Sellmeijer formule.

2. Aanpak en resultaten van de studie van de variabelen
Een studie naar de invloed van variabelen op het kritiek verval is uitgevoerd. Een multi variate analyse (MVA) is succesvol uitgevoerd op SBW. De resultaten van de MVA bevestigen de resultaten gevonden door (López de la Cruz, 2009). De invloed van $D_{70}$ op het kritiek verval is minder dan is voorspeld op basis van het Sellmeijer model. Voor fijne zanden komt de Sellmeijer formule redelijk goed overeen met de experimenten, voor grof zand geeft de Sellmeijer formule een onveilige predictie. Gebaseerd op de MVA op SBW is een aangepaste Sellmeijer formule geformuleerd door Sellmeijer (Sellmeijer 2010a). De MVA was ook geprobeerd op de data van de Wit, maar was niet succesvol. De data van de Wit is ingevoerd in de aangepaste Sellmeijer formule, en de uitkomst kwam niet overeen, mogelijk omdat de data van de Wit mogelijk niet gecorrigeerd is voor de filterweerstand van de proefopstelling, of omdat de range van variabelen in de dataset van de Wit niet hetzelfde is als in de dataset van SBW.

3. Aanpak en resultaten van het onderzochte erosie mechanisme
In het Sellmeijer model wordt het evenwicht van de korrels beschreven volgens het model van White, die individuele korrel erosie aanneemt. Het is onderzocht of dit correct is. Een proefopstelling is gebouwd om het erosie proces experimenteel te onderzoeken. De korrels worden losgemaakt uit de korrelmatrix met enkele honderden tegelijk, met een laag dikte van ongeveer 7 korrels. Het transport van zand vond plaats in massatransport, in golven, slurry flow genaamd. Het is niet zeker of het waargenomen erosie proces van de korrels uit de zandmatrix maatgevend is voor het bepalen van de kritieke gradiënt. Het moet verder onderzocht worden of het waargenomen erosie mechanisme maatgevend is voor bepalen van de kritieke gradiënt.

Het is waarschijnlijk dat het waargenomen loskomen van korrels ook aanwezig is in geval van een echte dijk. De implicatie van de gevonden resultaten is dat het Sellmeijer model mogelijk het loskomen van de korrels en het piping proces niet correct beschrijft. Meer onderzoek is nodig om te valideren dat het waargenomen erosie proces maatgevend is voor het bepalen van de kritieke gradiënt.

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The morphological effects of Sediment diversions on the Lower Mississippi River

The wetlands in the Mississippi delta (USA) are drastically subsiding and eroding. Many projects and researches are ongoing to determine how this "drowning effect" of the delta can be stopped. One of the solutions that could be feasible is implementing sediment diversions in the levees of the Lower Mississippi River in order to divert sediment into the delta.

This thesis addresses the morphological effects of river diversions on the Lower Mississippi River. The main objective is to analyze and optimize trade-offs between delta building and river navigability.

For this purpose a 2DH numerical model with Delf3D has been created; the model simulates the hydro- and morphodynamic behavior. The river reach which has been studied is the final 110 km of the river from Point a la Hache at River Kilometer 78 (RK 78) down to the mouth of the river (RK -30), below Head of Passes. The hydrodynamic model has been calibrated and verified with flow and stage data from daily observations on the river. With the available sediment data a calibration has been carried out of the morphological behavior in the river. The model has been used to simulate several scenarios to get insight in the problems in the delta.

From analysis of the model results the river bed in the study area can be divided into three categories. Upstream of RK 4 the bed is subject to erosion, around RK 4 the bed is practically in equilibrium and downstream of RK 4 the bed is subject to sedimentation. The reach downstream of RK 4 is the dredging reach; after analyzing the long-term simulation of 20 years it is not expected that the dredging quantities will decrease in the future. Closing off West Bay diversion has a positive effect on the dredging quantities.

The best diversion site for this study area is found in the inner bend of the river upstream of Empire (RK 47) at RK 53. This site is most efficient and diverts the largest quantities of sand through the diversion.

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Stroming van beton in diepwanden

During the construction of a station of the north south line in Amsterdam a leak, caused by a deposit in the diaphragm wall, lead to severe damage to adjacent buildings.

The following investigation let to no clear explanation of the presence of the deposit. Yet it revealed a lack of a clear understanding of the mechanisms involved. This prompted an investigation in to these mechanisms.

As a part to this investigation the flow pattern of concrete has been investigated. A numerical model has been used. In the model a constant stream of concrete was introduced in a layer of concrete submerged underneath a bentonite suspension.

From the simulation it became clear that the reinforcement plays an important role in the formation of deposits. The research revealed that whether or not a deposit will form depends on how the concrete flows through the reinforcement structure. Two flows compete to fill the space between the reinforcement and the wall. The filling of the panel will be mostly vertical. The concrete has to flow through the space between the reinforcement bars to fill the area between the wall and the reinforcement. This adds resistance to the flow. The level in the centre of the panel will therefore rise faster than at the edges. To keep up a horizontal flow will occur from the top layer of concrete to the edges. If the vertical flow stays behind to strongly the horizontal flow can enclose the bentonite suspension from the top. This results in a deposit.

From the simulations we can conclude that the density of the bentonite suspension has no significant part is in the formation of deposits. Yet the yield stress of both the bentonite suspension and concrete have a great impact in the formation of deposits.

When the spacing of the reinforcement is cut in half something remarkable occurs. In the simulation with the full spacing a deposit is formed, while when the spacing is cut in half the deposit does not form. This occurs because the horizontal flow instead of covering the bentonite suspension it will squeeze the bentonite suspension upwards.

With the spacing back to the full distance but irregular. The simulation shows an alternating pattern of the horizontal flow covering and squeezing. Resulting in some deposits. We see deposits forming not at the decreased distance but at the increased distance. This is because the decreased space hinders the vertical flow while the increased distance helps the horizontal flow.
3.1

Civil engineering theses

Hydraulic Engineering
– COMEM Domain

Coastal and Marine Engineering and Management
Modeling the Evolution of the Wax Lake Delta in Atchafalaya Bay, Louisiana

In this study, a process-based, depth-averaged Delft3D hydrodynamic and morphologic model of the Wax Lake Delta in Atchafalaya Bay, Louisiana was developed to simulate a five year period of delta development. The purpose of this modeling effort was to test the ability of process-based modeling tools to successfully simulate typical delta-building processes and the resulting morphologic and stratigraphic characteristics of the delta. Recent developments in conceptual modeling of mouth bar formation and full delta development have confirmed the capability of process-based models to simulate the processes necessary for delta growth and the resulting long-term, geologic scale morphologic and stratigraphic features. In this attempt to model the actual development of a prototype delta, the applicability of physics-based modeling to delta evolution simulation will be further validated.

Morphology qualitatively reproduced typical river-dominant delta growth through the establishment of new depositional lobes while maintaining approximate radial symmetry. The successive stacking of coarsening upwards sequences observed in Wax Lake Delta mouth bar deposits was evident in the stratigraphy of modeled incipient jet deposits, a result of the varying discharge regime. Though incipient jet deposits developed in the model at the distal ends of distributary channels, the prograding bars did not aggrade sufficiently to induce flow bifurcation and the development of a mature mouth bar depositional lobe. The overall coarsening-upwards, though sand dominant stratigraphic sequence of typical friction-dominant river mouth deposits is reproduced.

The Wax Lake Delta is clearly river-dominant according to traditional classification schemes; however, the deposition of fine sediments is influenced by basin processes that resuspend and export significant quantities from Atchafalaya Bay. The processes contributing to the coarse sediment depositional features that dominate the Wax Lake Delta are qualitatively simulated under purely riverine forcings, but the fine sediment dynamics cannot be accurately simulated in the present, process-limited model.

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The appraisal of climate adaptation measures and coastal management strategies for Durban, South Africa

Research done by the IPCC working groups and other organizations has sparked global concern over the possible impacts of climate change and corresponding sea level rise upon coastal communities. In reaction, global studies were done (Nicholls et al., 2008, Hanson et al., 2011) to assess the vulnerability of coastal regions. However, most of these publications did not address the development of climate adaptation designs to protect the coastline. In this study it is demonstrated how a localized coastal vulnerability assessment could guide the development of conceptual designs in an African context.

The overall aim of this thesis is the appraisal of climate adaptation measures and coastal management strategies for Durban, South Africa. The main focus is on an illustrative case study, for a coastal section along Durban’s central beaches. The case study is an example of how the vulnerability to coastal hazards could be assessed, for different SLR scenarios, to provide guidance for developing conceptual coastal protection designs.

The March 2007 storm event (estimated to have a one in 50 year return period) indicated that significant damage can be sustained from coastal hazards in Durban at the current conditions. A one in 100 year storm is shown to already affect the operations of critical infrastructure in current conditions such as the beach road in the vulnerability assessment. The vulnerability increases significantly for future SLR scenarios.

Softer, sediment based protection solutions were preferred for the case study due to the environmental, recreational and touristic requirements of the beachfront. Protection solutions developed for the two SLR scenarios give an idea of the footprint of different options and how easily the can be adapted to higher water levels.

The vulnerability assessment and proposed protection solutions could be used as a basic tool for budgeting and long term spatial planning as it gives indicative costs and an idea about the areas that could potentially be at risk to coastal hazards.

Developing a generic vulnerability assessment methodology could be beneficial for local municipalities. Completing similar vulnerability assessment studies (or more detailed studies) at other vulnerable coastal locations is a recommended starting point for the climate adaptation process and to inform global vulnerability and adaptation studies. Local governments are recommended to gather local data, assess vulnerability, propose a strategy to deal with future SLR scenarios and develop protection solutions for critical areas.

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Impact of access of channels geometry on wave penetration in harbours

Access channels (entrance channels) to ports are a relevant part of port facilities, and they have a strong influence on the port operations as well. However, little information is available about their analysis and design regarding the wave interaction with access channels. This study is focused on the interaction of waves with entrance channels regarding wave propagation. This report has three parts: i) a qualitatively assessment of diffraction effects carried out with SWAN; ii) a comparison between SWAN (phase averaged wave model) and SWASH (phase resolving model) results, regarding refraction and diffraction effects; and ii) a systematic analysis of the results in SWAN on several wave conditions and a few access channel geometries (slopes).

SWASH is used to test SWAN capabilities in an environment where significant refraction and diffraction is expected. The results of the comparison are analyzed and recommendations for future comparison are presented.

The systematic analysis of conditions provides information about performance of SWAN and its ability to correctly represent physical phenomena particularly regarding refraction and diffraction. Additionally, recommendations for wave propagation analysis for entrance channels are presented. Finally, based on the results, engineering recommendations and considerations are presented regarding operations of ports and the design of related structures such as breakwaters.

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Reef systems have been estimated to exist along approximately 80% of the world’s coastlines with living coral reefs, relic limestone platforms and submerged rock formations being the most common types observed. The processes of wave breaking on a reef crest and the setup on a reef and flow over and within a lagoon, have been the primary focus of research to date, while wave transformation shoreward of the reef crest and surf zone have also been studied. The propagation of low frequency waves has been shown to have a large influence on flow, sediment transport and morphology. Furthermore, it has been demonstrated that these waves may possess periods that, if closely correlated with the reef width and depth, may enter a standing wave type form and possibly resonate.

**Aim**

The aim of this study was to determine the indicators of low frequency resonance in field, laboratory or numerical model data, and to identify the influence of different geometric parameters on the generation of low frequency wave resonance on a fringing reef.

**Methods**

The indicators were tested by the use of the numerical model XBeach. The model was calibrated with high-resolution field data obtained at the Ningaloo Reef (Western Australia). The tested indicators were then applied to the Ningaloo Reef field data to determine if a resonance signal could be identified at the site. Finally, a geometric parameter sensitivity analysis was conducted with an idealised reef profile based upon the Ningaloo Reef. The wave boundary of the model was forced with a JONSWAP-type spectrum that characterised the peak of a storm at the site. The influence of different geometric parameters (in both non-frictional and frictional cases) was investigated and compared to an analytical model.

**Results**

For two time-series that are spatially lagged across a reef, three indicators need to be satisfied to demonstrate the presence of resonance. They are: the surface elevation variance across the basin must be coherent, a phase relationship associated with the mode of resonance considered must exist, and an amplification of the wave between two points considered at the frequency of resonance must occur. The results of the indicator tests showed strong agreement with a simple basin analytical model that was adapted to include the effect of a lagoon. Strong amplification (resonant) peaks were observed for the first two standing waveforms. The frequency of these peaks was affected by the setup on a reef while the amplitude was affected by the influence of friction. It was shown that for frictional values consistent with Ningaloo Reef, the amplification peaks ‘flatten’ to magnitudes similar to the progressive waves in the spectrum. The geometric sensitivity analysis indicated that the resonant frequency was more sensitive to the reef and lagoon length than the reef and lagoon depth. The amplification was greatest for the zero and firstmode of resonance. However this amplification was dampened with the introduction of friction. It was determined that resonance is not likely to occur on reef systems with the geometry, frictional characteristics and wave forcing similar to the studied section of Ningaloo Reef. Resonance may occur for reef systems with shorter reef and lagoon widths, lower frequency forcing and/or less frictional dissipation. The latter may occur for reefs that have a different roughness to Ningaloo Reef as well as for reef systems that are damaged or dying in which coral assemblages degrade into coral rubble.
Civil engineering theses

Geo Engineering
Experimenteel modelleren van horizontale belastingen op grote diameter monopaal fundaties in zand

De laatste jaren zijn verschillende offshore windmolenparken voltooid. De windmolen van deze parken worden veelal gefundeerd op holle stalen buispalen, ook wel monopalen genaamd, met een diameter van 4–5 m en worden ontworpen aan de hand van standaarden (API, DNV, GL) die de zogeheten p-y methode hanteren voor laterale belastingen. Echter, deze p-y methode is niet gevalideerd voor palen van deze afmeting. Verder zijn veldproeven en modelpaal proeven met correct geschaalde grondspanning en laterale belastingen schaars.

Het effect van een diameter toename op de laterale grondweerstand van 2.2 m en 4.4 m diameter monopalen met een constant lengte/diameter ratio in droog zand is onderzocht. Verplaatsingsgestuurde statische en krachtgestuurde enkelzijdig cyclische modelpaal proeven zijn uitgevoerd gebruik makend van de Technische Universiteit Delft geotechnische centrifuge.

De resultaten laten zien dat de kleinere 2.2 m diameter paal een lagere secant en tangent stijfheid heeft vergeleken met de 4.4 m diameter paal. In alle proeven is de tangent stijfheid ongeveer 50% hoger dan de secant stijfheid en leidt een toename van belastingsexcentriciteit tot een toename van de grond-paal stijfheid. Verder is gevonden dat bij een constant lengte/diameter ratio van de paal, gelijke relatieve dichtheid van de grond en ongewijzigde belastingsexcentriciteit een paaldiameter toename leidt tot een significante toename van de laterale capaciteit voor statisch belaste modelpalen. Ook de secant en tangent stijfheid nemen aanzienlijk toe bij paaldiameter toename.

De accumulatie van horizontale paalverplaatsing als functie van het aantal opgelegde enkelzijdige belastingen is onderzocht voor 500 cycli. Een toename van aantal belastingen leidt tot een toename van de de paal verplaatsing, terwijl het increment van de verplaatsing afneemt. Een aanzienlijk groter aantal belastingwisselingen is aanbevolen, bijvoorbeeld 100000.

De resultaten van de statische modelpaal proeven zijn vergeleken met een veel gebruikte ontwerprichtlijn, namelijk de p-y methode. Gebruik van de, onder andere, door de API voorgeschreven standaardwaarden voor de hoek van inwendige wrijving en relatieve dichtheid van de grond leidt tot een aanzienlijke overschatting van de initiële grond-paal stijfheid. Wanneer daarentegen een spanningsafhankelijke secant stijfheid $E_{50}$, welke afkomstig is van triaxiaal samendrukkingsproeven, wordt gebruikt, wordt een betere overeenkomst tussen p-y methode en experimentele resultaten gevonden voor paal verplaatsingen <0,1D. Echter, de p-y methode omschrijft de last-verplaatsingsresultaten voor een paalverplaatsing van 0,05D met ongeveer 25% voor de 4.4 m diameter paal.

Vervolg onderzoek met belasting condities die de offshore condities beter representeren en een hogere relatieve dichtheid van het grondpakket worden aanbevolen. Verder wordt aanbevolen de huidige experimentele configuratie, met name regulering van de belasting, te verbeteren en vervolg modelpaal proeven te doen op verzadigde grond en in een grote bak.

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Piled embankment with Geosynthetic Reinforcement

Numerical Analysis of Scale Model Tests

In the last few years, the CUR committee 159B has been working on the new Dutch Design Guideline for the design of piled embankments. To validate the guideline several field tests have been performed. From the field measurements is concluded that the design method is very conservative. Improving the design guideline will reduce the construction costs. To understand the physical behaviour of the piled embankment and to validate the theory, experimental scale tests have been performed. During these tests the load distribution, deformation and strains were measured. The results of the scale tests are analysed and published. To improve the understanding of the phenomenon arching and where possible, to confirm the observed load distributions and displacements, numerical analysis of the scale tests have been performed and reported in this thesis.

The numerical analysis of the scale test is performed with Plaxis 3D Tunnel version 2.4 (Plaxis). The geometry of the Plaxis model is one quarter of the geometry of the scale test. This reduces the amount of elements and therefore the calculation time. In the scale test circular piles are applied. Circular geometry cannot be modelled in Plaxis, therefore the circular pile is mathematically converted to a square pile. The sand and granular material are modelled with Mohr Coulomb (MC) model and Hardening Soil (HS) model. The scale test is driven by applying top load and by drainage of the foam cushion. The top load is modelled as the measured equally distributed load on the embankment. To model the drainage of the foam cushion, the measured water pressure is assigned to the subsoil clusters in Plaxis by a water pressure head.

From the Plaxis results can be concluded that arching is immediately found after the first drainage of the foam cushion. Increasing the top load and drainage of the foam cushion in Plaxis results in an increase of loads transferred to the pile by arching and GR, thus results in improvement of arching. The by Plaxis calculated tensile forces in the GR are concentrated in ‘tensile strips’ that lie on top and between adjacent piles. The largest displacement of the GR is found at the middle of four piles. The results of the Plaxis calculations are compared to the scale test results. The total load on the pile and water pressure in the foam cushion found with Plaxis are corresponding with the scale test results. During the first part of the test, the load distribution shows similar results as the measured load distribution. During the second part of the test the load transferred to the pile by arching is overestimated and the load transferred to the pile by the GR is underestimated. The displacement of the geosynthetic reinforcement calculated with Plaxis is underestimated compared to the scale test results. In general the results of the HS model are better than the MC model.

By varying a number of parameters in the model, possible causes for the underestimated displacement are investigated. This research concludes that the stiffness of the foam cushion and the water pressure in the foam cushion does not have influence on the GR displacement. The vertical effective stresses are concentrated on and directly next to the pile and are relatively small between the piles. The internal friction angle does have a large influence on the geosynthetic reinforcement displacement, because when the internal friction angle is decreased, the arch decreases and the settlements increase. However, the measured geosynthetic reinforcement displacement from the scale test is still not found in the numerical results calculated in Plaxis.

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Grondvervormingen ten gevolge van het maken van bouwputten

Dit afstudeeronderzoek richt zich op het grondvervormingsgedrag naast aan te leggen bouwputten. Vooral bij diepe bouwputten in stedelijke omgeving is het onduidelijk hoe en waar het vervormingsgedrag, afhankelijk van de Nederlandse specifieke omstandigheden zoals de grondopbouw, belendingen en funderingen, tot stand komt.

Onderzoeken in bestaande literatuur, ten aanzien van grondvervormingsprofielen van het grondmassief naast aan te leggen bouwputten, geven een (veelal empirisch) weergave van het grondvervormingspatroon. Deze onderzoeken zijn voornamelijk gericht op ‘green field’ situaties (zie figuur 1a). Maar er is bijvoorbeeld bij de op dit moment aan te leggen NoordZuidlijn in Amsterdam helemaal geen sprake van ‘green field’ situaties (zie figuur 1b).

**Hoofdvraag:**
Is de omgeving van invloed op het grondvervormingsgedrag (zowel horizontale als verticale grondvervormingen van het grondmassief) naast aan te leggen bouwputten?

**Conclusies:**
Maaiveldmetingen bij station Rokin laten zien dat belendingen wel degelijk van invloed zijn op het grondvervormingsgedrag naast aan te leggen bouwputten (zie figuur 3). Deformatiepatronen in ‘green field’ situaties geven dus een ander gronddeformatiespatroon dan in stedelijke gebieden zoals bij station Rokin. Helaas is het lastig om deze conclusie te verifiëren met andere aanwezige ondergrondse meetinstrumenten zoals automatische extenso- en inclinometers. Deze monitoringsinstrumenten hebben veel minder informatie geleverd dan op voorhand was voorzien.

Tijdens dit onderzoek is gestuit op onverwachte bevindingen in het grondvervormingsprofiel in de nabijheid van de bouwactiviteit voorboren die uitgevoerd is bij station Vijzelgracht en station Rokin. Tijdens deze bouwactiviteit worden ondergrondse obstakels ter plaatse van het diepwandtracé verwijderd en vervangen door Softmix. Vanwege de tijdens het voorboren opgetreden zeer onverwachte en nog nooit eerder geconstateerde relatief grote deformaties zijn de bevindingen dan ook in dit onderzoek gepresenteerd.
Toepassing spanningspadmethode op een horizontaal gronddruk vraagstuk

Indien een kademuur gerealiseerd moet worden kan gekozen worden voor constructie ‘in den natte’ of ‘in den droge’. Als er in het voorontwerp nog geen keuze is gemaakt voor constructie type, moet rekening gehouden worden met beide types. Meestal worden ontwerpen in de voorontwerpfase doorgerekend met het verenmodel of een met een traditionele methode van vergelijkbare strekking. Uit indicatieve berekening voor een project uit praktijk van Gemeentewerken Rotterdam bleek dat voor beide hierboven genoemde bouwmethoden gelijke resultaten volgen. Na een gedetailleerdere berekening aan de hand van het eindige elementen programma Plaxis werd een aanzienlijk verschil gevonden. Hieruit volgde een zwaarder ontwerp met een duurdere constructie.

In dit onderzoek is eerst aangetoond dat bij gelijke parameters in MSheet voor beide bouwmethoden gelijke resultaten worden gevonden en verschillen worden gevonden bij een modellering met behulp van de eindige elementen methode in Plaxis. Parameters voor Plaxis zijn in de eerste instantie bepaald aan de hand van conventionele triaxiaalproeven. Vervolgens zijn de spanningspaden voor verschillende punten in de geometrie opgelegd aan een monster in een triaxiaalcel. Hieruit volgden resultaten voor de rekken aan de hand het opgelegde spanningspad. Om het gebruikte rekenmodel en Plaxis te valideren zijn deze proeven gesimuleerd. Geconcludeerd kan worden dat het Hardening-Soil Small Strain model binnen de rekken die optreden in de gebruikte geometrie een goede weergave geeft van het grondgedrag. Door de resultaten van de spanningspadproeven was het mogelijk om de parameters voor Plaxis te verfijnen en tot een nauwkeuriger berekeningresultaat te komen. Door dat er in het begin van het onderzoek al veel grondonderzoek beschikbaar was waren de parameters in de eerste instantie al redelijk nauwkeurig bepaald, van een duidelijke aanpassing van alle parameters was geen sprake.

De beddingsconstante is berekend aan de hand van de resultaten uit de eindige elementen berekening. Deze beddingsconstante leidt in MSheet tot een goede benadering van de gevonden resultaten in Plaxis. Geprobeerd is dit te extrapoleren naar een algemene aanbeveling voor het modelleren van dergelijke situaties. Aangezien dit alleen aan de hand van de in dit onderzoek vastgestelde randvoorwaarden gedaan is, kan nader onderzoek uitkomst bieden om hierin duidelijkheid te verschaffen.

Om het onderzoek te beperken zijn enkele aspecten vereenvoudigd of niet beschouwd. Zo is uitgegaan van een uniforme grondopbouw bestaande uit zand. Ook zijn alleen vrijstaande damwanden beschouwd. Het is een waardevolle aanvulling op de praktische toepassing van de aanbevelingen die volgen uit dit onderzoek als bijvoorbeeld verankerde damwanden en typische Rotterdamse grondprofielen worden beschouwd.

Kort samengevat kunnen uit dit onderzoek de volgende conclusies getrokken worden:
1. Door berekeningen is aangetoond dat er een significant verschil is tussen ontraven voor een grondkerende constructie of aanvullen er achter. Het aanvullen van een vrijstaande damwand veroorzaakt een ca. 20% groter buigend moment en ca. 50% grotere vervormingen aan de bovenzijde van de damwand.
2. Uit de spanningspad proeven blijkt dat anders grondgedrag gevonden kan worden in geval van een ontlast spanningspad dan in van een belast spanningspad.
3. Ieder spanningspad leidt tot een unieke stijfheid, maar de sterkte van het materiaal blijft gelijk.
4. Uit simulatie van de spanningspadproeven met het Hardening-Soil Small Strain model blijkt dat het model goed presteert tussen axiale rekken van 0% en ca. 3%.

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Negative Skin Friction; Design challenges in Singapore

Reason for the research is are discussions between Delta Marine Consultants Singapore Pte. Ltd. and an ‘accredited checker’, an independent engineer, who checks the design and has to approve it. The design will not be build, without approval by this engineer. The discussion exists due to the wide interpretation range of the Singapore Standard (CP4). This research is to interpret the Singapore Standard, compare it to available literature and other standards and the objective was to get to recommendations in regard to the design of piles subjected to negative skin friction in Singapore.

Negative skin friction is the name of a phenomenon where the soil undergoes a relative downward movement compared to the pile shaft. Two main aspects play a role; settlement of the soil and movement of the pile. Negative skin friction is an interaction process between the pile and the soil. The interaction process is characterized by the relative movement between pile and soil. The soil moving downward past the pile will cause a drag load. The pile moving downward past the soil will cause positive skin friction and end bearing i.e. bearing capacity. The depth where the upward and downward forces are equal is the depth where the relative movement is zero and is called the neutral plane. Note that the upward and downward forces are functions of the depth of the neutral plane and vice versa until an equilibrium state is reached.

The overall factor of safety approach as prescribed in the CP4 is compared to the partial factor approach as prescribed in the Eurocode 7 and the British annex (EC7). Based on the accepted assumptions that creep only occurs in very soft and organic soils and that the neutral plane lies below the Marine Clay, a design according to the EC7 leaded to a more economic design than a design meeting the CP4 requirements.

It is important to state that geotechnical failure cannot occur due to negative skin friction. Geotechnical failure means that the pile moves downward past the soil, thus negative skin friction is out of the question. This makes negative skin friction a settlement problem. The final settlement when the equilibrium state is reached, should be acceptable for the supported structure. Especially the lack of attention for the settlements when negative skin friction is considered, is remarkable in the CP4. It is recommended to use literature and other standards as guidelines when designing with negative skin friction in Singapore. This will lead to more economic designs.

A more economical design does in principle not lead to a safer design. Further investigation is needed to establish a new equilibrium between an economical and safe design. Key factors in further investigations should be the availability of proper measurement data in the form of long term (static) tests and special attention to the installation process of the instrumented pile.

Finite element calculations have been performed to back-calculate a statnamic load test in order to validate soil parameters. Unfortunately the dynamic behavior of clay during a statnamic load test is not governed by the finite element calculation packages thus back-calculation turned out to be unsatisfactory. Although creep is hardly taken along in the design in Singapore, it turned out that, especially for offshore piles, this may not be neglected. Even more so, from interaction calculations it followed that the neutral plane lies below the soft marine layers, contrary to what is generally assumed.

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Civil engineering theses

Watermanagement
A Decision-Support System based on Real Time Control and Data Assimilation

The integration of forecasting and decision-making in real-time Decision-Support Systems (DSS) provides a powerful tool to operators of water resources systems for evaluating the future control of hydraulic structures. Decisions may be supported by presenting information about predicted disturbances, e.g. inflows into the water system, enabling the operator to try out future trajectories of structure control, or suggesting an optimum control based on predictive controllers. The aim of the MSc project is the transfer and extension of real-time DSS knowledge and techniques to a typical Dutch canal system such as Twentekanalen, using simulation tools in development at research institute Deltares.

The main research objective is to assess the potential of DSS in this context and to investigate and verify a robust concept for applying Model Predictive Control on canal systems, taking into account missing or wrong data by applying Data Assimilation techniques.

The main system characteristics and relevant processes of the Twentekanalen system are the following:
1. 3 Canals connected by locks in which the water level needs to be controlled.
2. The water level is chiefly governed by the operation of locks, which need to turn in order for ships to pass, discharging a large quantity of water each time in comparison to other water flows in the system.
   - The water level is regulated by pumps and discharge structures at the locks
   - Other water flows that occur in the system are lateral inflow and outflow.

At the start of the research a set of tools was available at Deltares. FEWS, a data management system, and RTC Tools, a reservoir routing model in development which was later extended with Data Assimilation capabilities. Near the end of the research a detailed model of the system in Sobek, a 1D and 2D water flow model, became available. A model framework has been designed to assess the potential of applying MPC and DA in a DSS for such a system. The incremental design and verification of this model framework has been the core of this research. The novel research is the addition of Data Assimilation techniques to Model Predictive Control.

In order to show the added value of DA and verify its implementation, a verification approach is needed to address the other components in the framework as well. The first method taken to achieve this was to setup the MPC for Twentekanalen and integrate it into FEWS in hindcast mode, assuming a perfect forecast. When the data set was made available it became clear that it contained large water balance errors. Adding DA showed improvements in the forecast, but while using realistic values for the DA, the forecasts were still far from accurate. Considering the low quality of the data set it was decided to expand the scope of the research and replace the data set by an accurate hydraulic model that became available near the end of this research. This model still uses measurements from the Twentekanalen system as input, but with internal controllers to regulate the pump and spill structures the water balance is maintained. With an extra expansion to inject known errors in the system, a thorough investigation of the effects of Data Assimilation and Model Predictive Control can be executed. First results from this expanded approach show promising results, but because of practical implementation issues of conflicting software modules, the full results will not be available within this research.

Conclusions: From a theoretical point of view DA has a lot of potential. State updating solves an important issue of real time control; keeping the model state as close as possible to the real system state. Model training by parameter updating can be a good way to increase model forecasting performance. Online Parameter Updating can be very effective in systems were a high correlation occurs between measurements and unmeasured processes. These elements will make the model more robust, it can adapt to changing conditions. This also provides the model developer with interesting feedback on the workings of the modeled water system.

From a practical point of view DA has shown improvements in the performance of the DSS as designed within this thesis project. But because of the large errors in the measurements it is difficult to translate these improvements to the effects in other systems. Implementation of the designed model framework will give a more satisfactory answer to that question. Recommendations have been made for improvements of the RTC Tools module, the development of prediction modules for the Twentekanalen system and further research using the developed framework with the models, scripts and programs written for this research. Most importantly getting predictions and real-time measurements on lock turning in the Twentekanalen system, and increasing the flexibility of model design in RTC Tools.

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Integrated water management from the treasurer’s perspective

Introduction
In this thesis, the concept of water budgeting is discussed. This concept is based on a comparison between water resources and financial resources. It aims to approach water resources management problems more like a treasurer would. Water resources can be distributed in such a way as to optimise the chance of achieving a desired goal. Depending on what the most important goal of the water manager is, different ‘water budgets’ are possible. The concept of water budgeting is: to distribute the available water resources in such a way as to optimally achieve a certain objective.

Research objectives
The following research objective is formulated: "To evaluate the usefulness of the water budgeting concept for integrated water resources management." The concept of water budgeting focuses on determining the objectives for the water system. On the basis of these objectives the water is distributed in such a way as to optimise the achievement of these goals. Model Predictive Control (MPC) is considered a potential tool for the water budgeting concept. MPC is able to translate the desired goals, in the form of penalties on undesired states, into the operational water management. MPC can translate the desired goals into the proper ‘water budgets’ (water distribution). The use of MPC as a water budgeting tool results in the following sub research objective: "To evaluate the effectiveness of Model Predictive Control as a tool for water budgeting."

Research approach
The concept of water budgeting is applied to the South-Western Delta, in The Netherlands, in order to test its usefulness. Different goals are set for the area, and these different goals result in different operational water management strategies. The three goals, that were set for the area were: ecology, shipping and fresh water availability. The ecology goal is to have as much interaction between the North Sea and the rivers. The shipping goal is to have optimal conditions for navigation by ships. This results in some minimum and maximum water levels in the area. The fresh water goal aims to keep the salinity in the area low, by preventing salt water from entering.

Results
In the case used, it was not possible to control the Maeslantkering. This resulted in limited control over the water bodies connected to the Nieuwe Waterweg. In the internal model water salinity was not included. This made it very hard to control salinity. Penalties for the controller were developed that were assumed to influence salinity. These penalties were however not sufficient to prevent salinities to become too high in certain areas. This shows that the controller needs to be able to directly predict what the salinities will be, in order to control salinity.

Conclusions
The application of Model Predictive Control to a water system of this size and without a very clear (single) objective is relatively new. During the research it became clear that: it is very important to be able to control all the (large) in and outflow structures, and that it is important to included the parameter that needs to be controlled in the internal model. The application of Model Predictive Control, as a tool for water budgeting, has proven to be limited. The most important limitation of using Model Predictive Control is: the reduced transparency of the decision making process. It is difficult to trace back why the controller ‘chooses’ certain control actions. This reduces the predictability of the operational water management.

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Subsurface abstraction in the Amsterdam Watersupply Dunes

Towards a better extraction in the Amsterdam Watersupply dunes?
Nowadays Waternet uses an artificial infiltration and abstraction system in the Amsterdam Watersupply dunes (AWD) which meets 70% of the total drinking water demand of Amsterdam and surrounding. The artificial system consists of infiltration ponds, drains and open abstraction canals. The three most important motives for transition towards subsurface abstraction, which is proved by research and conversations with involved colleagues, are better disinfection, decreasing capacity of the existing drains and chances to increase the ecological values of the AWD.

Preconditions
The open abstraction canals have a lot of functions which impedes integration of a subsurface abstraction. Besides abstraction, the canals also provide transport towards the Oranjekom (collection pond), control of ground water levels in- and outside the AWD, storage and flexibility. The precondition is that none of these functions can suffer from transition towards subsurface abstraction. It is expected that the drains, which are used to abstract water, will not operate properly any more in about twenty years. The costs of replacement of the drains is estimated to be about 20 million euro. The most important conditions for subsurface abstraction are to maintain a residence time of the water of minimal 60 days in the subsurface and to maintain the current capacity of 70 million m$^3$/year. Also attention is payed to keep away brakish water from the abstraction system, storage during intake stops and the flexibility of the new system.

Phreatic abstraction
Several options for subsurface abstraction in the phreatic abstraction are researched. With all options the groundwater is, before flowing into the abstraction canals, captured by new phreatic wells or drains. Several spatial integrations are tested to see whether they meet the conditions. Integration of subsurface abstraction with wells or drains is not easy because the existing system is designed to have a residence time of 60 days. Therefore a lot of options did not meet the criteria of on the one hand residence time or on the other hand capacity. If phreatic abstraction would be realized re-wetting can occur. An indication of the costs is about 90 million euro, including replacement of the existing drains.

Deep infiltration and abstraction
With subsurface abstraction in the deep aquifer are, next to new deep extraction wells, also new infiltration wells necessary. A 2D cross-section model of the deep aquifer makes clear that in all scenario’s brakish water will rise towards the abstraction wells. Measurements to keep away the brakish water were modeled and proved to be effective. A cost indication of this new system is 105 million euro. It will refrain the salt water and increases residence time of the infiltrated water in the subsurface. It is also more flexible in coping with fluctuation of the drinking water demand. Furthermore the bridging of an intake stop becomes more easy. Due to the separation of water production in the deep aquifer and ecology at the top aquifer this system provides the opportunity to allow natural water level variations in the phreatic aquifer, large-scale re-wetting and grazing. Replacement of the drains is not necessary.

Conclusion
Subsurface abstraction can both be realized in the deep or phreatic aquifer. Both options prevent re-contamination of the open canals and give a lot of opportunity for ecology and recreation. Both the costs and the advantages seem to be greater with deep infiltration and abstraction compared to abstraction in the phreatic aquifer.
Groundwater dynamics landslides in varved clays

Introduction
Numerous landslides have occurred within the Trièves Plateau in the French Alps in the last century. The Trièves Plateau is characterized by the outcrop of varved clays and buried under a colluvium layer. Varved clays are sediments with alternating laminae of silt and clay and are highly anisotropic. It is known that the infiltration of precipitation, enhanced by vertical fissures, is the most important triggering mechanism for landslides in varved clays. However, knowledge of the hydrological mechanisms is limited and the groundwater dynamics are difficult to quantify. A better understanding is needed for the prediction of future displacements. This research aims to characterize the groundwater dynamics in landslides in varved clays.

Situation
The groundwater dynamics of landslides in varved clays can be summarized as follows: Precipitation infiltrates into the colluvium and directly influences the perched groundwater level in this layer. Outflow from the colluvium enters the vertical fissures. From these fissures the water infiltrates horizontally into the silt layers in the varved clays. Water leaves the system as discharge from the fissures.

Model
A hydrological model is developed to simulate the groundwater dynamics. In this model the varved clays and colluvium are seen as two subsystems which are connected by the fissures. The finite difference method is used to calculate the head in the varved clays and colluvium. The silt layers in the varved clays are modeled as separate confined layers with saturated and unsaturated flow. The colluvium is modeled as an unconfined aquifer. The head in the fissures acts as a boundary condition for both subsystems and is calculated by means of a water balance.

Calibration
The model is calibrated to data of different landslides in the Trièves. Information about the local circumstances at the measurement locations is limited, but comparing model simulations and measurements indicates that the model gives a good representation of the actual hydrological mechanisms.

Analysis
Analysis of the model results gives more insight into the most important factors influencing the groundwater dynamics. The fissure width and outflow from the fissures largely influence the magnitude of the head in the fissures and clays. The extent to which the pressure propagation in the clays is delayed and damped is strongly influenced by the hydraulic conductivity and specific storage of the silt layers. Also the depth of the fissures and distance between the fissures influence the fluctuations of the head.

Results 1959-2004
The model is run for the years 1959 until 2004 to study the long-term groundwater dynamics. The results indicate that the heads are largest during the first months of the year. In general, also the activity of the landslides is largest during this part of the year. The influences of wet and dry years seem to be larger for systems with large fissure distance and depth than for systems with small fissure distance and depth.

Recommendations
It is recommended to perform additional measurements of the water levels in the fissures and the pore water pressures in the varved clays in order to further verify the correctness of the model. Measurements of the width and depth of the fissures and the distance between the fissures are required to improve the accuracy of the model simulations. It is also recommended to include the effects of snowmelt in the model and to evaluate the equation used to calculate the outflow from the fissures. Furthermore it would be interesting to examine the effects of entrapped air in unsaturated silt layers. A next step could be to combine the model results with slope stability or displacement calculations.

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5.

Civil engineering theses

Transport & Planning
Micro dynamisch verkeersmanagement

De huidige maatregelen ter verbetering van de verkeersdoorstroming betreffen voornamelijk generieke maatregelen die voor alle voertuigen gelden. Dankzij technologische ontwikkelingen, betere (voorspellings)modellen en ontwikkelingen op het gebied van telecommunicatie ontstaan mogelijkheden om verkeersstroomanalyses direct te verwerken en informatie ter verbetering van de verkeersstroom naar unieke voertuigen te versturen. Hierdoor ontstaat een nieuwe toepassing waarbij de beschikbare infrastructuur beter benut wordt door het geven van individuele aanwijzingen aan automobilisten, namelijk micro dynamisch verkeersmanagement (MDVM).

Het doel van MDVM is om de doorstroming en stabiliteit op het hoofdwegennet te verbeteren door het geven van individuele aanwijzingen. Met behulp van Fosim zijn twee verschillende verkeerssituaties gecreëerd en is er gekeken naar de effecten van de aanwijzingen onderzocht. De eerste situatie betreft het eerder anticiperen op langzame voertuigen stroomafwaarts. Zodra twee voertuigen gedetecteerd worden die langzamer rijden dan 60 km/u, worden de voertuigen binnen 500 meter stroomopwaarts een aanwijzing gegeven om het gaspedaal los te laten en passief te remmen. Hierdoor wordt het snelheidsverschil kleiner en neemt de verstoring in de verkeersstroom af.

De tweede verkeerssituatie die gecreëerd is, heeft betrekking op voertuigen die tijdens het invoegen belemmerd worden door een platoon op de rechterrijstrook. Invoegende voertuigen worden gedwongen om hun snelheid te verlagen, het platoon te laten passeren en vervolgens met een lage snelheid in te voegen. Door een voertuig in het platoon de aanwijzing te geven zijn de vertragingen tijdelijk te vergroten, ontstaat meer ruimte voor invoegende voertuigen en kunnen zij met hogere snelheid invoegen.

Simulaties tonen aan dat de aanwijzingen om eerder te anticiperen op langzame voertuigen niet tot een significant verschil leiden in de doorstroming en de totale verlies tijd. Het verlies, als gevolg van het eerder afremmen, wordt niet voldoende gecompenseerd door de minder verstoorde verkeersstroom. De afname van de snelheidsverschillen leidt echter wel tot een aanzienlijke verbetering van de stabiliteit. Het aantal schokgolven neemt met bijna 60 procent af en de gemiddelde lengte daalt met 40 procent.

De aanwijzingen ter bevordering van het invoegen leiden wel tot een aanzienlijke verbetering van de doorstroming. Het ontstaan van de file wordt gemiddeld met bijna 7 minuten uitgesteld en de file is aanzienlijk korter. De totale verlies tijd neemt met ruim 50 procent af en er is dan ook sprake van een significant afname. Daarnaast neemt het aantal schokgolven met bijna 50 procent af en de gemiddelde lengte daalt met bijna 25 procent.

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Het aanleggen van turborotondes is de beste manier om ervoor te zorgen dat een kruispunt veiliger wordt. Turborotondes hebben namelijk weinig conflictpunten en een lage snelheid op de rotonde. Het liefst wordt dus zo lang mogelijk gebruik gemaakt van een turborotonde om de bouw van een kruispunt met verkeerslichten zo lang mogelijk uit te stellen. Het toepassen van verkeerslichten op turborotondes is een mogelijkheid om bij hoge intensiteiten nog steeds gebruik te maken van een turborotonde.

Uit een eerste analyse blijkt dat het toepassen van verkeerslichten op turborotondes tot verbetering kan leiden van de verkeersafwikkeling. In dit onderzoek is daarom onderzocht wat het effect is van een RotondeDoseerInstallatie (RDI) op verschillende typen turborotondes. Uit dit onderzoek blijkt dat door het toepassen van een RDI de totale capaciteit tot 10% kan worden verhoogd en tegelijkertijd de verliestijden tot 50% kunnen afnemen. Hierbij gaat het om een winst van 10 tot 30 verliesuren per uur, waarmee de relatief geringe investering snel kan worden terugverdiend.

Een RDI is een tweekleurig verkeerslicht dat geplaatst wordt op de hoofdstram. De RDI is een doseerinstallatie, met het doel om de hoofdstram te clusteren, zodat het verkeer vanaf de zijstram makkelijker de rotonde op kan rijden. Door het toepassen van een RDI blijkt dat de stroom die kort wordt tegengehouden door de RDI, tegen de verwachting in, ook een lagere verliestijd heeft. Door de toepassing van een RDI kunnen dus alle richtingen profiteren van een lagere verliestijd. De optimale instelling en plaatsing van deze lichten is tot stand gekomen met een reeks VISSIM simulaties. Hierbij is de werking van de RDI getest op zowel de turborotonde als de spiraalrotonde.

Beide rotondes zijn getest met verschillende belastingen, inclusief vrachtverkeer, waarin telkens een vaste verhouding tussen de verschillende stromen en richtingen is aangehouden. Bij de turborotonde blijkt de RDI voor alle belastingen effectief. Bij de spiraalrotonde blijkt dat het effect groter wordt naarmate de hoofdstram dominanter wordt.

De resultaten van dit onderzoek moeten leiden tot een praktijkonderzoek, zodat de resultaten uit dit onderzoek kunnen worden bevestigd. Daarna is het belangrijk dat de keuzemodellen die nu worden gebruikt voor het kiezen van kruispuntvormen worden aangepast. Hierdoor kan vaker voor een rotonde met RDI worden gekozen in plaats van een grootschalig kruispunt. Immers profiteren alle richtingen bij de toepassing van een RDI.

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Line design of the future

For a transport company like NS (Dutch railways) it is of utmost importance to provide the best services where travel demand is the highest. It is the challenge of the designer to provide this service, considering constraints such as budget, infrastructure, equipment and personnel. This study presents a method to generate lines optimized to the travel demand and therefore the travelers’ needs. As a starting point all influences of politics and historical decisions are omitted. The research focuses on three main research questions:

1. In some areas there is a potential lack of travel demand, as a consequence of poor services. How big is the potential travel demand for transport, independent of the existing services?
2. What is the best set of lines to service this potential travel demand?
3. What lessons can be learned from this? Where do we find the similarities and differences with the current services?

The potential travel demand is mapped with two methods. The first method assumes a virtual service of 6 direct trains per hour between each pair of stations. The potential travel demand is calculated using a demand elasticity model, comparing this virtual service with the existing services. It turns out that especially in the region of Amsterdam and between Twente and the region Arnhem-Nijmegen, a large relative growth is possible. In absolute terms, the largest growth is possible in the Randstad area. The second method uses travel forecasts from the Dutch National Modelling system (LMS). In this case, a feasible train-share in the total travel demand is estimated by comparing all travel relations with currently well-connected relations. Again it appears that especially in the Randstad area a large growth is possible. This growth manifests itself often between cities and their suburbs.

Subsequently, a genetic algorithm was used to generate an optimal set of lines for medium to large distance travel. A genetic algorithm starts with a random set of solutions and then searches an optimum, using the principles of evolution. Each solution is evaluated using a set of criteria. Solutions that are evaluated best have the biggest chance of survival. These solutions are mutated and combined, in the hope that better solutions are found. A new solution is not per definition better than its ancestors, so a new round of evaluation starts with the new generation, until no further progression is observed or a time limit has passed. To guarantee that an optimal solution doesn’t get lost in the process of evolution, the best solutions survive without mutations. The model provides a proof of concept: although the problem is very complex, it is possible to develop a line network, based on the travel demand. Different variants were developed, yet the differences in results were not substantial. In fact, the similarities are more interesting, since the different variants show the same patterns. Some promising results are now included in the investigations for future timetables.

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Redesign of the bus station Groningen assisted by a new simulation tool for bus stations

The spatial configuration of the current bus station of Groningen consists of a fishbone with fourteen platforms for the regional busses and directly behind the fishbone an island platform for the city busses. The feeder roads of the bus station are congested during the peak hours. Busses cannot reach the bus station in time. At the bus station passengers and busses make use of the same limited amount of space. This leads to very dangerous situations for the passengers. Not only the safety of the passengers is endangered, also the bus flow on the bus station is hindered by the large amount of passengers. Besides the bus passengers there are also a large amount of pedestrians en cyclists between the train station and the city centre that tribute to the chaos at the bus station of Groningen. In the near future a tramline will be constructed from the train station to the city centre. This tramline will partly be constructed at the location of the current bus station.

A bus station consists of very complex traffic streams. To help analyze this complex situation and evaluate new design a simulation tool is needed. Currently there is no simulation tool available that can handle the complex bus movements at bus stations and at the same time deals with all the other traffic movements within the area. For the purpose of evaluating the functionality of different designs a simulation tool is developed which combines the functionalities of VISSIM and Simbus. For four different designs the average travel time for every Origin Destination is determined with this simulation tool. The results of the simulation combined with other design characteristics leads to a preferred design. In the preferred design the fishbone is stretched at the expense of the island platform and a crossover is created for the main pedestrian route between the station and the city centre. These measurements decrease the weighted average travel time by 20% in comparison to the design where the bus station stays more or less the same.

The simulation also shows that the different assigning tactics (static, semi-dynamic of dynamic) of busses to the boarding platforms have no influence on the travel time of the busses on the bus station.

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Futures of Rotterdam South

Sustainable mobility based on scenario planning

Rotterdam South, a city part of the municipality of Rotterdam, is confronted with major socioeconomic problems. With this, the accessibility of job opportunities, facilities and shops is under pressure. For the future of the entire city and its inhabitants, it is essential that this situation will be addressed.

Next to the socioeconomic problems, the various transport networks are currently not able to handle the traffic demand in a sustainable manner. First of all, the bicycle network does not suffice: the river, railway lines, motorways and urban roads form major barriers in this network. Next to that, the public transport network has many flaws, especially for trips over 15 kilometers. The network for car traffic in the city part is too much designed for through traffic. All of this results in a high car dependency, which cannot be judge as sustainable in urban areas.

This study first of all shows what possibilities exist to deal with the socioeconomic problems of Rotterdam South. To explore these possibilities, four scenario’s for the future have been developed, based on the two most important uncertainties for the development of this city part: the level of segregation and the scale of developments. This resulted in four different possible futures of Rotterdam South.

Based on these four scenario’s four strategies has been developed how the municipality of Rotterdam should invest in the mobility system in order to support these possible developments in a sustainable manner. The main focus of these strategies lies on improving the bicycle network and the public transport network.

Between the four different strategies large differences are recognizable, both for the shape of the network as for the appropriate transport means. The differences are especially large for the desired public transport network, but also the different strategies for the bicycle network differ a lot. However, a good coordination between the network for slow traffic and the network for public transport is crucial in every strategy.

How one should invest in the mobility system turns out to be strongly linked to the approach of the socioeconomic problems in Rotterdam South. The currently policy of the municipality, which mainly focuses on large-scale development, doesn’t seem sufficient. For a more effective approach, more attention is needed for small-scale developments and the resulting displacement pattern.
De overgang van 80 km/uur naar 50 km/uur op de grens bebouwde kom

De gevolgen van vormgeving op het snelheidsgedrag

Onderzoek
Het onderzoek naar de overgang op de grens bebouwde kom bestond uit drie onderdelen. Een literatuuronderzoek naar de relaties tussen vormgevingskenmerken, snelheid en ongevalkans. Een zestal snelheidsmetingen naar het daadwerkelijk snelheidsgedrag over de overgang. En een enquête onder experts naar de verwachte invloed van vormgevingskenmerken, de oorzaken van de verscheidenheid in vormgeving en mogelijke oplossingen hiervoor.

De verscheidenheid in uitvoering van de vormgeving is voor het onderzoek onderverdeeld naar drie categorieën voor de omgeving (het wegbeeld), een niet-ondersteunende, een ondersteunende en een versterkende omgeving. En naar drie categorieën voor de vormgeving (ontwerp infrastructuur), een afwezige barrière, een visuele barrière en een fysieke barrière.

Resultaten
Uit de verschillende methodes bleek dat de resultaten van de enquête en de snelheidsmetingen sterk overeenkwamen, een sterke invloed van fysieke barrières op het snelheidsgedrag en geen aantoonbare invloed van visuele kenmerken. Op basis van het literatuuronderzoek werd voor zowel fysieke als visuele kenmerken een invloed op het snelheidsgedrag verwacht. Alleen bij toepassing van fysieke barrières wordt het gewenste verkeersgedrag afgedwongen, dit is echter van korte duur. De resultaten suggereren dat een druppel barrière (fig. 2) het gewenste gedrag langer afdwingt, maar een definitieve uitspraak vereist verder onderzoek.

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Separation of Freeway Traffic Flows by Dynamic Lane Assignment

This thesis deals with separation of freeway traffic using dynamic lane assignment, based on one's destination; either or not to the next downstream exit. At freeway exits a high amount of lane changes lead to capacity reduction. Furthermore, when the flow to the exit exceeds the exit capacity (like at an IKEA on Sundays) a queue will form that spills back to the freeway. In case no measures are taken, congestion spreads out over all freeway lanes. Traffic flow theory shows that separating exiting traffic from through-going traffic can prevent this total roadway blockage in case increasing the exit capacity is not possible. Compared with existing measures, this study explores chances and drawbacks of dynamic flow separation on one roadway. Here dynamic means variable in time and space, so no physical or static separation is used. The goal of this type of separation is to improve outflows for through-going traffic near oversaturated off-ramps.

Therefore two traffic controllers have been designed in this study. Through-going vehicles are guided away from the rightmost lane while exiting vehicles are guided to the rightmost lane. The dynamic aspect is that the length of this separation measure is based on the location of the tail of the queue. Both controllers switch on when the vehicle speeds drop below a threshold value at a specified location. In the first control strategy (a feedback controller) the length of the dynamic separation upstream of the exit is determined by a fixed offset distance upstream of the measured tail. In the second control strategy (a feed forward controller) the location of the tail is predicted using shockwave estimation. The separation length is now determined by the shockwave speed and direction.

Both controllers have been tested in an adapted version of FOSIM for different flow/capacity ratios by altering controller parameters like intervention location and (initial) offsets. The simple feedback controller mostly improves the outflow for through-going traffic. The advanced feed forward controller works as well, but the control behavior is very unstable due to measurement errors of many variables. The benefit in outflow can grow to 30% with a well specified intervention location, offsets around 1000 m and compliances from 80%. The results show a more uniform traffic situation near the exit, reduction of congestion spillback and no total roadway congestion after implementing a controller. A clear separation in flows can be seen resulting in higher speeds on the leftmost lane. The results are suboptimal however, because the speeds and flows on the lane adjacent to the exit queue are low. This is due to the legal and safety aspects related to the maximum speed difference between non-physically separated lanes.

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Committee: Prof.dr.ir. S.P. Hoogendoorn (TU Delft), Dr.ir. A. Hegyi (TU Delft), Dr.ir. H. Taale (Rijkswaterstaat), R.H. Kraaijeveld, MSc (Rijkswaterstaat), Dr. A.A. Nuñez Vicencio (TU Delft), Ir. P.B.L. Wiggenraad (TU Delft)

For further information please contact the section Transport & Planning, 015 278 9341
Email: transport.planning@citg.tudelft.nl
Regional effects on road safety of the RijnlandRoute

Research
The province of South-Holland has advanced plans to create a connection on the southern side of Leiden between the A4, the A44 and the coast at Katwijk. This connection is called RijnlandRoute. The purpose of the RijnlandRoute is to increase the road-traffic capacity of the east-west corridor, improve the livability in the area and facilitate spatial-economic developments.

Traffic engineering aspects and environmental effects are considered mainly when variants for the RijnlandRoute were developed. Road safety on the other hand, is hardly taken into account in this process. This can be seen in reports about the RijnlandRoute that have been written so far. Unlike the other studies, this report focuses mainly on the evolution of road safety in the region around Leiden.

The evolution of road safety has been compared for three different variants, which come from the Milieueffectrapportage (environmental impact assessment): a reference alternative, Zoeken naar Balans phased and Zoeken naar Balans unphased.

By using road lengths, intensities and crash figures is investigated whether there are differences in risk figures and in the amount of accidents between the variants in both the entire region around Leiden and parts of the network.

Subsequently, a fictional safest variant has been developed, in which design of the roads is adjusted to the requirements of the Dutch road safety vision Sustainable Safety and some roads are downgraded.

This gives insight in the possibilities to reduce the number of accidents by adjusting the road design and the network structure.

Results
The results show that only little difference is found between the three main variants. Further research shows that the number of accidents in the urban area decreases due to a decrease in the number of kilometers driven. Outside the urban area we see the exact opposite. Due to the RijnlandRoute, more accidents will happen on east-west oriented roads. However, this increase is compensated by a decrease on other roads in the research area.

Creating the safest variant, it became clear that downgrading roads doesn’t increase the road safety, but applying Sustainable Safety measures can result in a 25% decrease of the number of accidents.

Mvandijk.png
Around the metro - Research intro the potencies of the metro stops in Rotterdam

Subject
Rotterdam has a well developed metro system, widely used and seemingly embedded in the spatial structure of the town. Yet the share of the car is relatively high. The existing metro lines provide opportunities to make Rotterdam a more attractive city, by stimulating the use of this sustainable transport mode. The study explores the chances to enhance the use of the metro system through the improvement of the physical layout of the areas around the metro stops. This is an interesting approach, because it deals with better utilizing the valuable investments, done in the past.

Method
The thesis starts with an inventory of measures to improve ridership. This leads to a set of eight general guidelines referring to the spatial structure and the physical layout of the areas around and within the metro stops. These guidelines were then used by way of a quick scan, to assess the quality of all the metro stops in Rotterdam. The quick scan is partly qualitative, partly quantitative. The assessment was completed by experts’ views.

Main observations
The quantitative part indicates that the amount of urban programme around stations is small in many cases. Together with the opportunity to reach destinations with the metro, urban programme is fundamental to create high ridership. Data about on Rotterdam provide empirical evidence for this assumption. Especially urban functions that generate a lot of metro passengers (like schools and hospitals), are in many cases too far from metro stations (more than 200 meters). About half of these stations could handle at least double the size of the urban programme, with the most dense areas in the region as a reference. Furthermore, the number of bike and car parking places should be much higher, so their capacity is more than sufficient and potential passengers will be attracted.

The qualitative part of the quick scan shows that the quality of the station areas is generally low, while the (potential) metro customer is generally sensitive to any lack of quality issues. This means the overall quality should be high. Four qualitative guidelines are distinguished: liveliness (by having a diverse area), sufficient and attractive routes for slow traffic, the metro station as a central, recognizable object in the direct surrounding, with buildings oriented to the station and the last point, a comfortable station itself. The main conclusion is that hardly any metro stop in Rotterdam functions as it might be - ridership rise strongly if the spatial arrangements and the lay out of the stations areas are improved. Though, certain station areas form a good example for the other stations, like Wilhelminaplein and Blijdorp. These areas in general invite people to use the metro, they meet all the eight aforementioned guidelines.

Importance of measures
Increasing the amount of urban programme around stations and increasing the number of car and bike parking places will separately and in a direct way lead to more passengers. Improving the quality of the areas is not only wishful to lure new passengers, it also avoids losing current metro travels. In general, more focus should be on attracting potential public transport passengers, with the awareness that they are sensitive to any shortcomings.

Advice
The involvement of experts at the municipality of Rotterdam shows that there is general knowledge about well-designing metro areas. The guidelines provide concrete points of attention for designers. Investments should be divided over several stations; the quality of the whole system should be raised. It is wise to search for necessary improvements. Sometimes these can be quick wins (for example painting the station, improving walking paths). In other cases the whole area should get an upgrade, with more urban programme as an absolute precondition to create a public transport-friendly area.

For further information please contact the section Transport & Planning, 015 278 9341
Email: transport.planning@citg.tudelft.nl
Last year’s Theses
Master’s Theses February 2011

**Civil engineering theses**

**Structural Engineering**

- Living Tree Buildings
  
  *Student: Anne Nuijten*
  
  Application of Ultra High Strength Concrete in LNG Terminals
  
  *Student: Michel Kortenaar*

- Mechanical behavior of bridge bearings of concrete bridges
  
  *Student: M. de Boer*

- Winter damage of porous asphalt
  
  *Student: S.A. Mohan*

- Snap through of large shield driven tunnels
  
  *Student: T.G. van der Waart van Gulik*

- Traffic induced bearing loads and movements of a steel plate-girder bridge
  
  *Student: V. Bos*

- The optimization of tripod substructure and its application to two different topsides
  
  *Student: Wenchao Wang*

- Human Induced Lateral Vibration of Bridges
  
  *Student: D. Karagiannis*

**Building Engineering**

- Covering A28 highway at Amersfoort
  
  *Student: S.L. Huneker*

- The elevated metro structure in concrete, UHPC and composite
  
  *Student: R.J.A. Kenter*

- The sustainable refurbishment of bk city
  
  *Student: M.K. Prodromou*

- A timber bearing structure for ‘Concept House’
  
  *Student: A.D. van Wijngaarden*

**Hydraulic Engineering**

- Integral Design of Work Channels and Basins
  
  *Student: T, IJsebeart*

- Dredging history of the river Waal and expected future dredging works
  
  *Student: J.S. Bardeel*

- Numerical modeling of wave run-up on a dike
  
  *Student: I.C. van den Bosch*

- Analysis of costs in new terminals investments
  
  *Student: C. van Buuren*

- Shell factors for piles subjected to horizontal soil displacements
  
  *Student: Erik den Arend*

- A comprehensive assessment of Multilayered Safety in flood risk management
  
  *Student: Frouke Hoss*

- The Gevelco quay wall
  
  *Student: D. Grotegoed*

- “Feasibility study of a Climate Dike”
  
  *Student: Larissa Smolders*

- Flood defence town centre Dordrecht
  
  *Student: M. Hinborch*

- Long-term morphological modelling of the mouth of the Columbia River
  
  *Student: Emiel Moerman*

- Dynamic behaviour of tunnel elements during the immersion process
  
  *Student: G.W. Nagel*

- Stimulering provinciale binnenvaart door verkeersmanagement en aanpak knelpunten
  
  *Student: C. van der Hoog*

- Gaining new insights regarding traffic congestion, by explicitly considering the variability in traffic
  
  *Student: O.M. Miete*

- Modelling nearshore currents driven by waves and set-up gradients
  
  *Student: P. van de Linde*

- Morphological Impact of Coastal Structures
  
  *Student: R. van der Hoeven*

- Post-trenching with a trailing suction hopper dredger
  
  *Student: K. van de Leur*
Port Design
Student: R.A.R. Heuts

Numerical modelling of turbidity currents in submarine channels
Student: Anne Ritsema

Geo Engineering
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Student: J. Ruigrok

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Validation of SMOS satellite data over Ghana and Burkina Faso
Student: A. Poelstra

Onderzoek naar verbrakking Polder Westzaan
Student: I. Gozuberk

Analyzing the effects of large-scale green roof implementation in Singapore
Student: J. van Spengen

Clogging of permeable pavements in semi-arid areas
Student: M. Amirjani

Observing tidal slack in the Scheldt estuary
Student: M. Lievens

Low cost disdrometer
Student: S.A.P. de Jong

Swale filter drain system:
The inflow – discharge relation.
Student: E. A. Donkers

Conditioning of aggressive water
Student: J.C.J. Gude

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Gaining new insights regarding traffic congestion, by explicitly considering the variability in traffic
Student: O.M. Miete

Accelerating the introduction of electric bicycles
Student: Jeroen Loijen
Master’s Theses October 2010

Civil engineering theses

**Structural Engineering**

- Structural Failure in the Netherlands  
  *Student: W.F. Boot*

- Special Nodes in Ultra High Performance Concrete  
  *Student: Hasan Han*

- Corrosion of steel reinforcement in 12 years old concrete: Inspection, evaluation and electrochemical repair of corrosion  
  *Student: J. Pacheco Farias*

- Design of walls with linear elastic finite element methods  
  *Student: M. Romans*

- V-shaped pylon concept  
  *Student: J. van Weerdenburg*

- The feasibility of full 3D modeling of concrete viaducts  
  *Student: N.W. Kostense*

- Autogenous and drying shrinkage  
  *Student: Jan van Capellen*

- Phenomenological modeling of ice induced vibrations of flexible offshore structures  
  *Student: H. Hendrikse*

- The effect of the introduction of the eurocode on the safety level of existing platebridges  
  *Student: Frank Schotman*

**Hydraulic Engineering**

- "Layout design for greenfield port Filyos"  
  *Student: L.B. Donders*

- Undesired reshaping of exposed core material  
  *Student: P.H.M. Mulders*

- Experimental research on spatial distribution of overtopping  
  *Student: A. Lioutas*

- Sharp bend flow  
  *Student: A. van Sabben*

- Analysis of the Carbon Footprint of coastal protection systems  
  *Student: A.L. Labrjure*

- An analysis of vessel behaviour based on AIS data  
  *Student: Thijs de Boer*

- Tidal influence on sediment transport and bed level in the river Merwede  
  *Student: A.L. de Jongste (MSc Hydraulic Engineering)*

- Aeolian transport on beach based on field measurement on the Dutch coast  
  *Student: Marion Coquet (Coastal engineering)*

- "The influence of core permeability on armor layer stability"  
  *Student: H.D. Jumelet*

- Behaviour of segment joints in immersed tunnels under seismic loading  
  *Student: Ruben van Oorsouw*

- Numerical modeling of sediment transport over hydraulic structures  
  *Student: Vincent Vuik*

- Cross-shore morphological response on Chaland Headland due to Hurricanes Gustav and Ike  
  *Student: Marion Coquet (Coastal engineering)*
Student: S.N. Kuiper
Cobble Sea Defence: Hydraulic Interface Stability of Sand underlying a Single Filter Layer
Student: Arthur Zoon

Model a dynamic equilibrium of yearly averaged salinity in the Pontchartrain Basin
Student: S. van den Heuvel

Failure of rubble mound breakwater’s armor layer
Student: unknown

Behaviour of nourishments in quasi 3-dimensional graded sediment models
Student: unknown

Pilot Sand Groynes Delfland Coast
Student: unknown

Dong Lam Cement Factory
Student: W.A. (Wouter) Broersen

Probabilistisch diepteontwerp voor binnengebied haven Rotterdam
Student: Y. Abdelouarit

New Profile for the Amsterdam-Rhinecanal
Student: L. Lievense

Master plan Porto Romano Bay, Albania
Student: M.K. Kersten

Geo Engineering

Bentonite cavities in diaphragm walls
Student: A.J. Lubach

The adaptation of the method URUP for the Netherlands
Student: A.J. Beijer

Process and stability of slow moving landslides
Student: Eva Johanna Sloof

Modelling horizontal soil deformations
Student: C.W.J. te Boekhorst

Transport & Planning

Dynamic Speed Limits: Extension and Application
Student: Ilse Schelling
Master’s Theses July 2010

Civil engineering theses

**Structural Engineering**
Simulation of steel-concrete bond-slip with sequentially linear analysis using interface elements
*Student: S.W.H. Ensink*

(Environmental) costs in the Dutch civil concrete industry
*Student: M.R. de Moel*

Sequentially Linear Analysis of Shear Critical Reinforced Concrete Beams
*Student: A.T. Slobbe*

Third tier on the Amsterdam ArenA
*Student: J.F.Y. Smeets*

Proposal New City Bridge, Nijmegen
*Student: S. Weusthof*

**Building Engineering**
Seismic Risk Mitigation in Greece
*Student: Dimitris Detsis*

Reinforcing glass with glass: Application of transparent reinforcement in structural glass beams
*Student: C.C.K. Leung*

Usage of lifts for the evacuation of high-rise projects
*Student: R.H.J. Noordermeer*

“The differences in risks between EPIC and Traditional projects”
*Student: O. Rienks*

Structural design of ‘The Wave’
*Student: S.A. Sligman*

**Hydraulic & Geo Engineering**
Boussinesq-type wave modelling in port applications
*Student: Joas Boeyinga*

Morphodynamic modelling of the Galgeplaat
*Student: I.L.L. Das*

Master plan coastal haven, “Nikas”, Kuwait
*Student: J.C.S. Geerlings*

Controlling extreme waterlevels on Lake IJssel
*Student: Rindert de Jong*

The evolution of sandbars along the Colorado River downstream of the Glen Canyon Dam
*Student: L. Kemp*

Rüttel-Injectiepalen: Ontwerp, proef, monitoring en modellering
*Student: I. van Kempen*

Wave impact on grass covered outer slopes
*Student: B.C. Mous*

Experimental research on the effects of a surface screen on a mobile bed
*Student: Siem Troost*

Hydrodynamic pressures on large lock structures
*Student: M. Versluis*

Salt based dam design in a hyper saline environment
*Student: Carina Wierda*

Ontwerp voor de toekomstige Merwedekering
*Student: T. Wijdenes*

**Watermanagement**
The potency of applied control theory on the river Linge
*Student: J.W. Bronkhorst*

A fast method to assess biological stability during drinking water distribution
*Student: T.J. van Delft*

Performance comparison of LP vs. MP mercury vapour lamps
*Student: Josanne Derks*

Calibrating a Hydrological Model on Vegetation Data: Application on Drylands
*Student: Ing. J.A. Flapper*

Herstellen van de wincapaciteit van de Amsterdamse Waterleiding Duinen
*Student: M.M. Houdé*
The influence of hydraulics and spatial differences on the daily practice within an irrigation system A case study in Arequipa, Perú
*Student: E.E. Koopman*

Prediction of temperature distribution in a Drinking Water Network
*Student: L. Magda*

Nood op de Boezem
*Student: J.W. Nelissen*

Staying ahead of the flood; The influence of higher resolution flood simulation models on the accuracy and visualisation of information.
*Student: O.K. Pleumeekers*

### Transport & Planning

Reconnecting Rotterdam Port
*Student: Aart de Koning*

Development of an assessment framework to weigh conventional and unconventional interchange designs based upon literature research and micro-simulation
*Student: Arjan van der Palen*

Coordinated signal control for urban networks by using MFD
*Student: Maarten Strating*

Microscopic interaction behavior between individual pedestrians
*Student: Dirk Versluis*

Accident modelling of road intersections in The Hague
*Student: P.H. Voorburg*

Sustainable mobility at urban development
*Student: Yvonne van Zon*

### Theses Offshore Engineering

The design of an offshore floating lifting vessel specialized in installing wind turbines
*Student: Yannick Van Hoof*

Selection of limiting Sea States for Offshore Wind Turbine Installation
*Student: Jaap Pieters*
Master’s Theses March 2010

Civil Engineering Theses

Structural Engineering

Self-healing in ECC materials with high content of different micro-fibres and micro-particles
Student: S. Antonopoulou

Immersion of underpasses underneath highways
Student: Jordi van Groesen

Dry High Performance Fiber Cables for Civil Engineering Structures
Student: Detlev Keijdener

Recalculation of a post-tensioned solid concrete slab bridge (1963)
Student: J. Kooiman
Effect of cope holes in the crossbeam of orthotropic steel bridge decks
Student: P.P.M. van Pol

Overlay of orthotropic steel deck bridges with prefabricated concrete elements
Student: P.L. Quist

Lateral-torsional buckling of coped beams with single sided angles as end connections
Student: Dipl.Ing. F.I. Romo-Leroux Idrovo, MSc BA

Structural Dynamic Analysis of a VAWT
Student: J. Truijens

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

Self healing in ECC materials with low content of different micro-fibres and micro-particles
Student: E. Tziviloglou

Nonlinear Finite Element Modeling of Cylindrical Diaphragm Wall
Student: Christina Vlachioti

Optimization of Solar Energy Usage for Dwellings with a Solar Thermal System
Student: B.J.C.M. Hendriks

Swimming pool "De Vosse"
Student: Alex Langeveld

Wind-induced sound on buildings and structures
Student: J.C.F. Ploemen

Precast concrete cores in high-rise buildings
Student: K.V. Tolsma

Hydraulic & Geo Engineering

Uncertainty analysis of the mud infill prediction of the Olokola LNG approach channel
Student: Suze Ann Bakker

Lateral behavior of large diameter offshore monopile foundations for wind turbines
Student: Leon Bekken

Pre-stressed diaphragm walls
Student: L. Francke

Dune erosion along curved coastlines
Student: Bas Hoonhout

Spatial distribution of wave overtopping
Student: D.C.P. van Kester

WAD een beweging
Student: W. Knaack

Piled and reinforced embankments: Comparing scale model tests and theory
Student: Herman-Jaap Lodder

Connecting Maasvlakte 1 & 2
Student: P.M. (Pieter) Nordbeck

Modelling of Installation Effect of Driven Piles by Hypoplasticity
Student: Pham Huy Dung

The influence of an Ecobeach PEM on beach development
Student: Jelle-Jan Pieterse

Foundations in Almere: The bearing capacity of precast concrete piles in Almere

Building Engineering

Progressive Collapse Indicator
Student: S.J. (Simon) Bolle

The influence of an Ecobeach PEM on beach development
Student: Jelle-Jan Pieterse

Foundations in Almere: The bearing capacity of precast concrete piles in Almere
Student: Marco Spikker  
Binnenvaart Service Centrum op Maasvlakte 2, een haalbaarheidsstudie  
Student: Robert Zuideeest

Watermanagement

Future use of Aquifer Thermal Energy Storage below the historic centre of Amsterdam  
Student: Ruben Johannes Caljé

Closing the water balance of lake Lauwersmeer  
Student: K.P. Hilgersom

From rainfall to runoff: Hydrological processes resulting in threshold behaviour and low rainwater contribution in rapid subsurface flow.  
Student: Ruben Rothuizen

Transport & Planning

Validation Microsimulation Models for Rail Traffic  
Student: Marten Agricola

E-mission. Ontwikkeling van een Decision Support tool voor verkeersemissies bij bedrijven  
Student: Jorrit Konings

Allochtonen onderweg  
Student: Rik Verhoeven

Return of water in the city  
Student: Jan de Vries

Theses Offshore Engineering

Outline design of a semi-submersible wind turbine installation vessel  
Student: Andreas Croes

Technical feasibility of offshore wind turbine installation with a spudpile vessel  
Student: Jasper van der Dussen

Reducing Seafastening Time for Jacket Removal Projects in the North Sea  
Student: Jan Pieter Duvekot

Integrated Design Methodology for a Monopile Support Structure for Offshore Wind Turbines using Numerical Optimization  
Student: Paul Godfroy  
Feasibility of tripod support structure for Offshore Wind Turbine in deeper waters  
Student: Atikunde Lawal

An alternative solution for joining and installing tendons of a tension leg platform  
Student: Reinier op ten Noort

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

Improve Set-down Operations during Removal Activities in the North Sea  
Student: Tom Piscaer

Torsion in offshore wind turbines and the effect of torsion on a jacket support structure  
Student: Maxim Segeren

Friction forces in pigging: a predictive model  
Student: M. Tillemans

Validation of Hydrodynamic Load on Stinger of Pipelaying 0vessel Solitaire  
Student: Tong Bai

Pieter Schelte - Jacket Lift System: Dynamic Analysis of the Initial Lifting Phase  
Student: Florian Wasser

Optimizing Heerema’s pipe supply process for future pipelay projects  
Student: Remco van der Wielien

The added mass effect in centrifugal pumps  
Student: J.M. van Wijk
# Research groups and professors within the faculty of Civil Engineering and Geosciences

## Design and Construction

**Construction Mechanics Research Group**
- Construction mechanics: Prof. J.G. Rots 83799
- Dynamics: Prof. A.C.W.M. Vrouwenvelder 84782
- Numerical mechanics: Prof. L.J. Sluys 82728

**Materials Science and Sustainable Construction Research Group**
- Acting chairman: Prof. K. van Breugel 84954

**Road and Rail Construction Research Group**
- Road Construction: Prof. A.A.A. Molenaar 84812
- Rail Construction: Prof. A.A.A. Molenaar 84812

**Building and Civil Engineering Structures Research Group**
- General Construction Design: Prof. L.A.G. Wagemans 84752
- Concrete structures: Prof. J.C. Walraven 85452
- Concrete modelling & materials: Prof. Ir. A.Q.C. van der Horst 87014
- Building physics and installations: Prof. J.J.M. Cauberg 83387
- Timber structures: Prof. dr. ir. J.W. van de Kuilen 82322
- Steel structures: Prof. J. Wardenier 82315
- Steel structures: Prof. F.S.K. Bijlaard 84581
- Steel construction of buildings: Prof. J.W.B. Stark 82303
- Utility buildings: Prof. J.N.J.A. Vamberský 85488

**Product Design Research Group**
- Methodical Design: Prof. H.A.J. de Ridder 84921

## Hydraulic Engineering

**Fluid Mechanics Research Group**
- Fluid Mechanics: Prof. dr. ir. W.S.J. Uijttewaal 81371
- Environmental hydro informatics: Prof. A.E. Mynett
- Sediment Dynamics: Prof. Dr. Ir. J.C. Winterwerp 84582
- Physical Oceanography: Prof. Dr. J.D. Pietrzak 89455

**Hydraulic and Offshore Engineering Research Group**
- Probabilistic design and
  - Hydraulic Structures: Prof. J.K. Vrijling 85278
  - Coastal Engineering: Prof. M.J.F. Stive 84285
  - Ports and Inland Waterways: Prof. Ir. T.Vellinga 85075
  - River morphology & River Engineering: Prof. H.J. de Vriend 81541
  - Offshore Engineering: Prof. J. Meek 84777
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<tr>
<th>Specialisation</th>
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<td><strong>Water Management</strong></td>
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<td>Prof. C.P.J.W. van Kruijsdijk</td>
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<td>Reservoir Systems &amp; Control</td>
<td>Prof. J.D. Jansen</td>
<td>87838</td>
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<td>Prof. F.B.J. Barends</td>
<td>85423</td>
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<td>Prof. J. Bruining</td>
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