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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

Last year's Theses

Master's Theses October 2010
Master's Theses July 2010
Master's Theses March 2010
Master's Theses October 2009
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 Quelerij
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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The book's layout
The summaries of the various theses are published per Master's programme and specialisation:

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

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

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

A Master's programme spans several different departments, each of which corresponds to a specialisation within the programme in question. At the end of this book is a comprehensive list of specialisations, which includes the names of their respective professors.
1.

Civil engineering theses

*Structural Engineering*
Living Tree Buildings

A tree does what no building does, namely repairing the weak spots in the construction. This self-optimalization process can be used in the structural engineering field. The focus of this graduation project is to explore in what way living tree structures can be used as load bearing system for buildings and what the load bearing capacity of such a structure is.

Using living trees as load bearing structures has several potentially positive aspects. Trees repair weak spots in the construction, they make optimal use of the strength and durability qualities of the wood, trees have a beneficial influence on our health, they create a balance in the CO₂ level and are the ultimate C2C load bearing structures. Buildings in which living trees act as part of the load bearing system can be divided into treehouses and living tree buildings of which the last are a relative new development. Treehouses are residences at a certain height from ground level which are attached to a tree or build around a tree. Living tree buildings on the other hand are structures where the trees are an integral part of the structure. The positive aspects of building with living trees are used best within the living tree buildings. Trees respond to external loads and damages in the tree by producing extra wood, called reaction wood, in order to minimize the stresses in the structure. Trees can grow together with other trees or non-living material when it helps to reduce the stresses. Trees can grow together into axial welds and cross welds or can be made into grafts by man. Most broad-leaved trees are suitable for living tree structures because they are able to grow together. Needled-leaved trees contain resins which make it difficult to grow together. When two different types of trees are combined they prefer to have a bark which falls off in the same direction and have the same growth speed and size.

In order to bring the concept of living tree buildings to the next level, solutions have to be found for possible technical and non-technical drawbacks. Technical points of attention are the longer construction time, the need for a flexible or growing façade and the uncertainty about the safety of the structure. A longer construction time is a technical point of attention on which the focus lays. Some solutions to reduce this construction time have not been tested yet. The focus in the research done for this graduation project will be on one of these, namely the comparison of connection methods. Non-technical points of attention are the acceptance by the user or stakeholders involved and trees which contain toxic substances. These points of attention are also taken into account in this research, but in a less dominant role, while the focus is on the technical aspects of building with living trees.

The design assignment for the Living Tree Pavilion was to design a building which is a research object for the TU Delft to test the load bearing capacity of the structure, in particular of the connections, as well as to design a building that inspires people and shows the possibilities of living tree structures as load bearing structure. The Living Tree Pavilion is a pavilion of which the load bearing structure exists of living trees. It is an open dome-shaped building with a diameter of six meters and contains at four meters height a platform on which people can walk. The design of the Living Tree Pavilion fulfills the stated demands and wishes in a more than satisfactory way.

After 10 years the structural elements are expected to be able to carry the loads. Grafts are expected to transfer tension forces, a moment or a shear force better than an axial weld, due to the larger area of common rings. In the connections a larger surface is needed to take up the tension stresses perpendicular to the grain due than to take up the compression stresses perpendicular to the grain. Whether the structure will indeed be able to carry the loads after 10 years, depends on the accuracy of the assumptions. Most assumptions made increase the safety margin, except for the assumed growth speed of the trees. Further research into the assumptions and research data of the Living Tree Pavilion itself can help to determine more accurately the time the structure needs to carry the loads. Taking into account the large safety margins in this calculation, the amount of years might be reduced.

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Ultra High Strength Concrete (UHSC) is a relatively new material formed mainly by reducing the water-binder ratio and an improved packing density. In comparison with Ordinary Concrete (OC) this alteration leads to different or increased material properties, such as very high compressive strength, increased tensile strength, improved Young's Modulus, low maintenance and improved liquid tightness.

These improvements led to further explorations on its structural applications, but were mainly focused on bridges. This thesis covers the application of UHSC in LNG terminals, storage tanks for Liquefied Natural Gas (LNG). A traditional LNG terminal consists of an OC outer tank and a steel inner tank to store LNG.

In this thesis the interest was to present an economic and technical feasible LNG terminal design using both an UHSC inner and outer tank, for a good comparison a reference project was used, and also to address critical loadcases for this UHSC design. An important code that covers LNG terminal design extensively is British Standard 7777. Two downsides of this code are that only steel inner tanks are covered and this code was written without taking UHSC into account. Furthermore, this code is very conservative and therefore not applicable when an UHSC is used.

The Eurocode, a structural code active in the European countries, does not describe material properties of UHSC. Therefore, in this thesis the French code, Association Française de Génie Civil, on UHSC is used for design parameters.

Storage of LNG demands for liquid tight tanks. Therefore, crack width control in the Serviceability Limit State (SLS) is of great importance. To ensure a non brittle failure and reduce crack width of UHSC, fibers are added. Uncertainty with respect to effective fibers is taken up by reduction factors. The combination of fibers and rebars in LNG terminals lead to more structural safety. In this thesis two different crack width models are used that are both based on the combination of rebars and fibers (Leutbecher, T. and Fehling, E.; Crack Width Control for Combined Reinforcement of Rebars and Fibres exemplified by Ultra-High-Performance Concrete, 2008 and Yuguang, Y., Walraven, J.C. and Den Uijl, J.A., Combined effect of fibers and steel rebars in high performance concrete, 6 heron 54 2009).

LNG terminals are subjected to complex combinations of loadcases that can be split up into loads acting on the inner tank and loads acting on the outer tank. Conventional loadcases were used for both inner and outer tank, earthquake loading on the inner tank and PRV loading on the outer tank were not considered. Finite Element Models (FEM) were used to model these complex load combinations. The use of UHSC gave better results with respect to SLS and ULS calculations especially for the combination of rebars and fiber reinforced UHSC.

With a simplified calculation of Life Cycle Costs (LCC) the economics of practical use is shown. Without further optimizations a LCCA showed that the application of UHSC leads to an economic beneficial solution in comparison to a traditional design. At the end of this thesis, recommendations for a safe design are made which can form a basis for new research on properties of UHPC in cryogenic circumstances.

Application of Ultra High Strength Concrete in LNG Terminals

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New and current materials for bridge bearings are subjected to tests, according to the European Standards (NEN-EN 1337). With these tests the materials are not subjected to forces, displacements and rotations that are similar to those in practice. In order to give a critical opinion about the tests, it is necessary to obtain more knowledge about the variable load and movement history of bridge bearings of a concrete bridge, the ‘Dintelhavenbrug’.

The load and movement history of bridge bearings of the ‘Dintelhavenbrug’ are analyzed by means of a finite element model. In this model the loads caused by traffic and temperature are considered. The traffic loads follow from a fatigue load model with 12 types of trucks, based on the European Standard for traffic loads (NEN-EN 1991-2) and measurements of traffic on the bridge near ‘Moerdijk’.

The temperature loads follow from the European Standards (NEN-EN 1991-1-5). For both types of (static) loadings the forces, displacements, rotations and slide paths, which occur during the lifetime of the different bridge bearings, are determined for each bearing.

These results are compared with the values which are presented in the tests of NEN-EN 1337 Part 2: Sliding elements and NEN-EN 1337 Part 5: Pot bearings. From the comparison of the tests and the model results and an extensive analysis of the model it can be concluded that:

- the relation between the values of the slide path in the tests and the time are not clear (it could be 1 year or 10 to 25 year, the lifetime of a bearing)
- a large number of values which are determined with the aid of the finite element model of the ‘Dintelhavenbrug’ match in terms of magnitude with the values in the tests
- for the speed of displacements further research will be required
- for the real development of the horizontal forces on bearings and related with that, the contact surface of the guides of a bearing, further research will be required
- distances between trucks and the numbers of trucks at the same time on the bridge will have a big influence on the slide path of a bridge bearing

For further research it is recommended to:

- do measurements on bridge bearings of the ‘Dintelhavenbrug’
- perform dynamic analyses in order to determine the dynamic amplification factor
- perform dynamic analyses in order to model friction in bridge bearing in a more realistic way
- do traffic simulations in order to get more information about the distances between trucks and the number of trucks present on the bridge at the same time

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With an increasing population in the Netherlands, people started to live relatively close to the primary road network. This led to major noise hindrance issues. As a solution it was decided to apply porous asphalt surfaces on the primary road network. These types of surface layers have a relatively open structure compared to traditionally applied dense asphalt mixtures. Application of porous surfaces brings along their first major advantage: noise reduction. A second major advantage of porous asphalt layers is an increased safety during rainfall. Due to its open structure water is stored and moved horizontally within the layer which reduces splash and spray effects and thus increases the visibility of drivers during rainfall. On the other hand, the major disadvantage of porous asphalt layers is durability. The decisive factor for the relative short lifetime of porous asphalt is the loss of aggregates from the surface, also known as ravelling. This type of distress leads to a rough surface and decreases the material’s noise reduction potential. Furtheron the loosened particles cause damage to cars. In the winter ravelling develops at a much higher speed. This results in totally damaged sections as was noticed during the winter of 2009/2010 in the Netherlands.

In this research a recently developed Lifetime Optimization Tool (LOT) for porous asphalt was used to find out why different sections of the primary road network showed this type of excessive damage. Therefore LOT required information about the load, geometry and the response of these failed porous asphalt sections. In this research eight different sections were studied. The required input for LOT was determined directly from these eight sections. The results showed that in the winter the main cause for this increase in damage is caused by the reduced relaxation potential of the mortar of the mixture. Further on the calculated performance of the eight different sections was compared with the observed performance during the winter of 2009/2010 and it was shown that they were in good agreement with each other. From this it was concluded that the Lifetime Optimization Tool is capable of explaining winter damage of porous asphalt concrete.

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Structural Engineering

1 Structural Engineering

Snap through of large shield driven tunnels

Until the 1990’s the commonly used Dutch tunnelling methods were the cut and cover methods and the immersed tunnels. Tunnelling in soft ground conditions with a high water table (like in the Netherlands) generally employs a shield with excavation wheel as standard practice for the purpose of providing a safe working environment for the tunnellers, and for achieving more effective and efficient tunnel excavation. The entire tunnelling operation is done by a Tunnel Bore Machine. In 1964 Schulze and Duddeck described ring behaviour of shield driven tunnels by a collection of graphs. The method assumes that the tunnel remains circular and equilibrium of forces is guaranteed at all time. The failure criterion is based on the bending moment capacity. Blom showed that a shield driven tunnel will not collapse after formation of a plastic hinge. Finally, the tunnel becomes unstable as a result of large deformations. This is a very explosive and dangerous failure mechanism which is called snap through (figure). The current design method is only valid if reaching the bending moment capacity is decisive. Since snap through probably becomes more critical in case of large tunnel diameters, the question remains: “Are shield driven tunnels with large diameters more sensitive to snap through than smaller ones?”

To answer this question a physical and geometrical non-linear model was used to analyse different segmented rings surrounded by soil. This model takes into account soil loading, soil support, cracking of segments, yielding of reinforcement and deformations of segments and longitudinal joints. To increase bending moments and trigger snap through, the ovalisation loading is increased by small steps. This was done to find out which mechanism is decisive.

The situation concerning snap through is worse than Blom [4] predicted. The safety factor $\gamma$ is close to one for all diameters, instead of $\gamma = 3$ as Blom predicted for the Botlek Railway Tunnel. If $\gamma = 1$, it means that snap through and reaching the bending moment capacity occur at the same time. Therefore, a closer look at practical design methods is needed. It turned out that a linear elastic calculation always provides safe results. When non-linear longitudinal joints were added, it is more likely that the analysis provides unsafe results for tunnel diameters larger than 8 meter. Hence, shield driven tunnels with large diameters are more sensitive to snap through than smaller ones. A larger possibility exists that snap through takes place without any plastic hinge. Secondly, snap through is also influenced by the segmental thickness. The safety factor $\gamma$ is determined for many cases. Again a closer look at practical design methods is needed, since the reserve capacity is close to the critical point for snap through ($\gamma = 1$) or even smaller. It turned out that a linear elastic calculation provides safe results if $d_{seg} > D/40$. When non-linear longitudinal joints were included, the analysis only provides safe results for the interval $1/38 < d_{seg}/D < 1/22$. If the segmental thickness over the internal diameter ratio does not fulfil these requirements, the corresponding analysis could provide unsafe results. Additionally, it was possible to determine the optimal segmental thickness. This research part confirms the correctness of the empirical design rule to determine the segmental thickness in relation to the radius. Materials are used most efficient if $d_{seg} \approx D/22$. Despite the wrong results, one can conclude that a linear elastic calculation provides safest results. More awareness of reality is required for everyone who takes into account non-linear longitudinal joints. Since it is not unthinkable that snap through is the decisive failure mechanism, it is very dangerous if one realises that practical methods to analyse a shield driven tunnel will not notice this failure mechanism. The tunnel design is probably based on the wrong criterion.

It takes a lot of time to determine the real load bearing capacity by using the advanced model mentioned above. Therefore, a simple model to analyse snap through is developed (see figure). The model provides qualitative knowledge about the character of snap through and the load bearing capacity influenced by the soil, the segments, the longitudinal joints and the radius. The model is able to indicate quantitative whether or not the tunnel is stable. After calibrating the simple model it was possible to develop a practical procedure to predict the right snap through inducement and corresponding load bearing capacity in no time.

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Traffic induced bearing loads and movements of a steel plate-girder bridge

Bearings are structural devices that principally transmit vertical forces from a bridge’s superstructure to its substructure and allow the superstructure to rotate locally about 1 or several axes. Additionally, they either transfer horizontal forces or allow local horizontal translations of the superstructure with little resistance. The combination of such movements and contact stresses causes wear of some bearing components as PTFE-sheets, internal seals and guides. Because of this, bearings have to be replaced or renovated many times in a bridge’s life, which is rather expensive and hence not desired by governments, for example. Nowadays, wear sensitive components are tested for durability or in order to determine the coefficient of friction after a certain sliding distance (EN 1337). These tests prescribe very little variation in the test parameters (contact stress, sliding distance and movement velocity) which is exactly what wear is related to. Also the correctness of the total sliding distances in these tests is questioned. A research into actual values for these parameters probably results in extended service lives for bearings.

This thesis reports the results of an investigation into bearing loads and movements of a steel plate-girder bridge (main span 162m, 2 side spans of 93.5m) in the Netherlands (Hagestein A27). The behaviour is examined in a static analysis in which frictional resistance in the bearings itself is disregarded. Subsequently, a linear dynamic analysis (disregarding friction as well) was performed in order to analyse possible dynamic amplifications. Although a nonlinear analysis of the bridge, including friction, appeared to be too complicated (with MIDAS Civil 2010) at the moment, possible reductions due to friction are estimated and taken into account.

The results show that the support displacements and vertical reactions can perfectly be analysed statically. The resultant effect of dynamic amplification and expected frictional resistance seems to be negligible. The input parameters for the long-term friction test type B (EN 1337-2) correspond to the results of an average lorry on the bridge. The input parameters for the durability test for internal seals (EN 1337-5) correspond to the heaviest (considered) lorry only. The accumulated displacements in both tests are much smaller than those found in the analysis (e.g. 80km/year translation instead of 10km in total). Although it has been found that the longitudinal translations and rotations about the lateral axis are considerably reduced when examining actual traffic rather than single lorries, still the current test values are exceeded largely. The current constant contact pressure in the tests appears to be realistic for intermediate supports (due to the large dead load reaction) but conservative for the end supports. Horizontal reactions are predominantly influenced by frictional resistance of the movable supports. Because friction is not included in the finite element calculation, these reactions cannot be considered as reliable.

The influence of friction on horizontal reactions and support movements has to be studied further. A traffic simulation is needed in order to obtain the actual development of longitudinal translations and rotations about the lateral axis of the bridge. Also measuring actual support displacements is recommended in order to verify the validity of the static approach. Furthermore, a finite element model of a bearing itself, subjected to a displacement history, may lead to useful information about the actual movements and stresses of bearing components inside the bearing.

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The optimization of tripod substructure and its application to two different topsides

Offshore energy is emerging as a serious contender to onshore energy for its large-scale property, cost-effectiveness and cleanliness. In the development and expansion of offshore energy, the most critical aspect is the substructure, in which a jacket is a normal substructure type in shallow water. However, tripod as a new type will be paid more and more attention to due to its light weight, less welding and easier fabrication. This study, supervised by TU Delft and IV-Groep, is an attempt to find out an optimization and concept design of a tripod substructure.

Two objectives are included in this study:

- The first objective is to find the values of the base radius and the main node height of the layout to achieve a relative optimization of the total mass. The total weight of a tripod substructure is very important, which will decide the type of lift on/off ship and the final cost of fabrication. The structure layout is analyzed by three aspects, including angle restriction, splash zone and previous study results, which will give us a relative optimization structure layout dimension.
- The second objective is to find out the governing load condition and the governing design condition. Normally, the offshore structure is working in static, dynamic, fatigue and boat impact condition, where wind, wave, current, boat impact and dead weight load the structure together. Which design condition is the most important and which load should be paid much attention to is the field of interest in this study.

- The governing design condition is fatigue and the governing design load is the wave load.
- The main node, which is very sensitive to dynamic fatigue, is the critical joint in the tripod substructure.
- The dynamic effect cannot be ignored in the fatigue analysis even when its natural period is less than 3 s.
- There is a simple inverse relation between the minimal fatigue life and the natural period.
- The base radius is equal to 20 m and the main node height is around 25 m above the seabed to achieve a relative optimization of the total mass.

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Human Induced Lateral Vibration of Bridges
*Modelling and Design Perspectives*

The advance in technology and progress in computational methods have allowed in recent years for more advanced designs of structures. The recent past has seen the construction of footbridges with challenging designs characterised by longer spans and a more efficient use of materials. These slender designs imply that the structures possess less mass and less damping than conventional footbridges as well as natural frequencies that lie closer to the excitation frequencies by pedestrians. Dynamic loads have therefore become more relevant in design with pedestrian induced vibrations often determining the considerations for the serviceability limit state.

The serviceability criteria a footbridge must fulfill can have a great impact on its design. In order to comply with these criteria it is often necessary to adopt control measures. Such measures imply important design considerations regarding the preservation of space and the additional structural weight. Current building codes do not model the pedestrian induced forces accurately enough and are not able to predict the occurrence of human – structure interaction. Therefore it is important to develop a design tool that is based on an interactive model that can predict the response of the footbridge due to pedestrian loading and assess the risk of the occurrence of human – structure interaction.

The main aim of the thesis was to study and further develop a pedestrian-bridge interaction model that has the potential to form the basis for a design tool. That is a model that will be able to predict the bridge’s response and be applicable on any footbridge where different load cases will be able to be considered. A secondary aim was to investigate the possibility of introducing frequency dependent parameters and extend the model to include loading in the vertical direction that will be dependent on the adjustment of the pedestrians to the lateral response of the bridge.

Up to the time or writing the thesis a number of mathematical models had been proposed for the description of the phenomenon of lateral synchronous excitation. One common thing among these models was that they had all stayed within the theoretic realm and no attempt had been made to consistently check their validity and implement them in a numerical procedure with the final goal of creating a useful design tool. The first step of this study was therefore the critical analysis of these models with the aim of identifying one that would be suitable for forming the base of a design tool with general applicability.

After the identification of a suitable model this was adjusted in such a way as to ensure its general applicability to any footbridge and subsequently calibrated on basis of experimental data. Experiments were used that involved pedestrians walking on moving platforms which described the manner with which the pedestrians adjust their walking characteristics depending on the movement of the deck. These experiments were obtained from literature. The experimental data also included synchronisation ratios and pedestrian induced forces for different deck accelerations and frequencies.

The following step was the testing of the adjusted calibrated model on existing footbridges. This was done through comparison of simulated responses of the bridges with measured responses that were available in literature.

The study ended with a description of a suggested workflow to be used during the design of a footbridge supported by the model, a proposal for future experiments to gain further understanding of the underlying mechanisms in the phenomenon of lateral synchronous excitation and finally recommendations for future development of the model.

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Civil engineering theses

*Building Engineering*
Covering A28 highway at Amersfoort

Integrating a highway in its surroundings

The A28 highway in Amersfoort is causing a great nuisance to the residents of the Verdiweg and the surrounding area. The growth in air pollution and traffic noise due to increasing traffic numbers hinders the development of the east side of the city, as well as the expansion of the highway to resolve the existing congestion problem. Along the east side of the highway a nature and recreation area called De Schammer will be realised. The research investigates the social and economic feasibility of (locally) covering the highway to resolve the nuisance in the area and to strengthen the coherence between Amersfoort and De Schammer. To improve economic feasibility and coherence, the aim is to focus on the multiple use of space above the covered highway.

The project site has many limitations. The highway crosses two waterways, the Barneveldse Beek and the Valleikanaal, and has a high density of exits to the local road network. Also, given the importance of the A28 in the Dutch and European road network, the A28 must remain open for the transportation of dangerous goods. The waterways hinder a partially sunken highway and the presence of dangerous transports eliminates the integration of existing exits under the cover structure due to safety concerns. Interrupting the cover structure at these barriers is not an option, as this will greatly reduce the effectiveness in reducing air pollution and traffic noise. This will also create visual clutter in the road environment. To allow a longer section to be covered, the exits to the local road network need to be adjusted. The exit Leusden will be terminated and the local road network will be improved to redirect the traffic flow through the exit Leusden-Zuid.

A cover structure for a highway at ground level can be realised as a light or a heavy structure. To overcome the physical barrier of the highway the cover structure needs to be at least partly realised as a heavy structure, to allow crossing over the highway. This results in a tunnel structure, which can be at ground level or (partly) below. When the top side of the cover structure is given a second function, multiple use of space is achieved, thus further integrating the highway into its surrounding environment. Several options for the multiple use of space above the covered highway are examined and the development of real estate on top of the cover structure is a real option. This can be achieved by building across the covered highway, with the foundations on both sides, as often applied, or by building on the actual cover structure by means of an integrated transfer structure in the roof of the cover structure. By applying certain preconditions, a transfer structure is designed on which three-storey buildings within the set limitations can be realised, thus allowing the development of residential housing on top of the cover structure. For higher and bigger buildings a separate transfer structure needs to be integrated within the actual building.

Realising a heavy cover structure for the highway, which will cross the Valleikanaal underneath, best meets the objectives. The presence of the expanded highway in the environment is minimized and the nuisance resolved, allowing a largely free development at ground level. The feasibility of a covered A28 depends primarily on the economic value attributed by the concerned authorities to the social benefits created by the realisation of the cover structure.

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The elevated metro structure in concrete, UHPC and composite

In some large cities, the infrastructure is elevated high above the ground. An elevated metro system has the advantage that its construction is cheaper compared to an underground metro system. The construction time is relatively limited and the physical barrier is small. The large elevation has a positive influence on the visual hindrance of an elevated metro system as it creates a more open and lighter space below the structure.

In the future, Rotterdam wants to extend its existing metro system. An elevated metro system high above the city is one of the possible concepts. The engineering office of Rotterdam Public Works is interested in this concept and moreover in whether there can be gained profit on the elevated metro structure by applying Ultra High Performance Concrete (UHPC) or Fibre Reinforced Polymer (FRP) instead of conventional concrete. The objective is to determine the dimensions and normative structural verifications of the elevated metro structure when this is made of conventional concrete, UHPC or FRP and to compare these designs with each other.

For the designs of the elevated metro structure made of conventional concrete, UHPC or FRP the focus is on the lightest railway girder and not on the minimum depth of the girder. The suitable elevation and span of the elevated metro structure are respectively 15 and 45 metres. The best concept for the concrete and UHPC railway girder is the precast segmental box girder with external prestressing tendons.

The optimal concrete box girder has 6 prestressing tendons and a dead load of 102.02 kN/m. This optimal design is found by means of an optimisation process where the behaviour of the box girder is examined by changing several parameters. The normative structural verification of the optimal concrete box girder is fatigue of the concrete. By closer examination, it turns out that fatigue of the concrete is not normative when studied in more detail. As a consequence the verification of the ultimate resistance moment at t=0 is normative.

The optimal UHPC box girder has also 6 prestressing tendons and a dead load of 69.4 kN/m. The normative structural verification of the optimal UHPC box girder is the ultimate resistance moment of the box girder at t=0.

The design of the railway girder made of FRP is a sandwich girder and is based on a bridge concept. The normative structural verifications of the FRP sandwich girder are deflection of the girder and buckling of the core triangles. The dead load of the FRP sandwich girder is 34.48 kN/m. The difference in dead load between the three designed railway girders is quite large. The application of a lighter railway girder does however not result in a large reduction of the number of piles. This is due to the small weight contribution of the railway girder to the total vertical load at the piles and the large contribution of the bending moments at the foundation to the pile forces. The normative structural verification of the columns is stiffness of the viaduct. Applying UHPC or FRP instead of conventional concrete for the railway girder thus has a small impact on the substructure.

The direct construction costs for the elevated metro structure with a concrete box girder are about €450,000 per span of 45 metres. When the unit price of UHPC is lower than €450/m³, the UHPC box girder becomes a serious competitor of the conventional concrete box girder from a financial point of view. For the FRP railway girder holds that FRP is currently far too expensive to compete with the (UHP) concrete box girder.

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The sustainable refurbishment of bk city

Introduction
Climate change - and particularly its long term-implications - has become the greatest challenge that scientists and politicians have to face. The building sector worldwide and, more specifically, the existing building stock, have been identified as major contributors to both global energy consumption and environmental damage.

Problem definition
This study aims at investigating the most appropriate measures for the refurbishment of the Architecture building of TU Delft (BK City) that, currently, lacks sufficient energy conservation measures and is characterized by its obsolete fabric and outdated building services systems. Moreover, the final proposals take into account the historical value of the building, along with its most essential features.

Research & results
The first part of the study is a theoretical approach to the problem that starts by defining the content of the terms ‘sustainability’, ‘refurbishment’ and ‘historic buildings’. Next, a framework of the ‘sustainable refurbishment of historic buildings’ in terms of legal, ethical and procedural aspects, is outlined, as well as the range of possible refurbishment measures that can be applied within this framework. After having analyzed the extent and severity of the problem with specific reference to Europe, this section ends by highlighting the potential of refurbishment and by providing a brief summary of the current status of well-known refurbishment policies in four European countries.

The second part of the study is an investigation of the case-study building. Necessary information concerning the context of BK City is presented, ranging from climatic and geographical data, to specific information on the building, its history and its performance in terms of building physics. Here, the distinguishing features of the building are identified, as well as the permissible interventions. With regards to building physics, it is pointed out that the weaknesses of the building are, mainly, the out-dated exterior envelope and mechanical equipment, which result in a poor indoor climate, despite the excessively high energy consumption. The information in this section is essential for the development of the refurbishment strategies.

Before elaborating on the refurbishment alternatives, an investigation is carried out to cluster all possible measures in 8 categories and cite relevant showcases and good practice examples of previously refurbished buildings. The most appropriate of these measures form the three proposed refurbishment Strategies of this Thesis, that range from basic interventions, such as cavity wall insulation, to more sophisticated solutions, as is the use of fuel cells. Advantages and disadvantages, application guidelines and market availability for each measure are provided.

The objective of the last section is to evaluate the impact of a selection of the aforementioned measures. For this purpose, a model is provided that allows the static calculation of the heating and cooling demands that will keep the indoor climate of the building at comfort levels. The results of these calculations are further analyzed and discussed.

Conclusions
The conclusions suggest that the existing building is wasteful in its use of energy resources and, thus, huge possibilities lie in its refurbishment, even if only moderate measures are applied.

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A timber bearing structure for ‘Concept House’

Background and cause of research
The ‘Concept house prototype project’ is a new building system for apartments of maximum 4 storeys, which development is coordinated by the research group ‘concept house’ of the faculty of architecture from Delft University of technology. Aim of the project is to create an industrial building system for apartments which are sustainable, flexible and cost effective. The bearing structure of the apartments needs to be worked out further. Characteristic are a large floor span of 7,5m, high sound insulation requirements and no use of façades for stability purposes.

With existing timber bearing structures it's impossible to fulfil all boundary conditions. But they're important to accomplish: To relieve prefab housing from the image of container housing a free façade form is very important. And the standard sound insulation between stacked apartments often causes complaints of occupants.

Objectives and research content
This research focus on the solving of important bottlenecks which hinder a timber bearing structure. Finally a complete bearing structure is designed but as far as connections concerns only those in connection with bottlenecks are worked out. Point by point the research looks as follows.

• Development of a new stability system
• Realization of a well performing, slender floor
• Providing insight into the environmental score of a timber bearing structure

First existing timber bearing structures are studied. Via design stages in which the level of detailing becomes every time higher there is worked then towards a design which fits in the new building system.

Results and conclusions:
The final design has some characteristics which can be categorized with the earlier mentioned research points.

• Development of a new stability system
  A thin massive plate is introduced besides the sanitary cell as a stabilizing plate. There's no acoustical contact between this plate and the floor above it due to a beam on top of this plate.

• Realization of a well performing, slender floor
  With a total thickness of 514mm the requirement of 500mm is slightly exceeded. The vibration behaviour almost comply with the building regulations (euro code) but according to new research the floor stiffness must be made 2,5 times higher to ensure no vibration discomfort.

• Providing insight into the environmental score of a timber bearing structure
  The environmental score of distinct total bearing structures are compared by their energy and material use. But the calculated values should be treated as an indication only.

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Civil engineering theses

*Hydraulic Engineering*
Integral Design of Work Channels and Basins

During the execution of reclamation projects by Boskalis, often a temporary work channel and basin are required. This work channel is used by the dredging equipment to reach the project site as close as possible. The project site is often located in very shallow water which makes an approach channel necessary. The basin is used to transport the dredged material ashore and to make a turn. Often, these work channels are only used during the execution of the project and are only used by trailing suction hopper dredgers (TSHD’s). That specific situation is considered in this thesis. Nowadays, the design of a work channel is based on the guidelines regarding approach channels for ports. This often leads to an over- or underestimation of the channel dimensions, which could result in unnecessary high costs. More insight in the backgrounds of a TSHD in a work channel must lead to an optimization of the channel and basin layout and dimensions. The design rules on approach channels formulated in the most commonly used guidelines are all based on the interaction between ship, environment and channel. Wind and currents give the ship a certain drift angle while sailing and therefore influences the required channel width. The channel depth is mainly determined by the amount of squat. Bank effects and, in case of two-way traffic in the channel, the interaction forces between two ships must also be taken into account. Nowadays, the most currently used guidelines are given by the nautical institutions PIANC, USACE, Japan Institute of Navigation, Spanish Port Authority and the Canadian Coast Guard (CCG). A comparison between the guidelines is made based on a case study. The largest differences between the guidelines are found in the channel width. Compared to the eventually constructed width, the guidelines by USACE and Japan show an underestimation, the guidelines by PIANC and CCG give a slight overestimation and the Spanish guideline gives a large overestimation. A large problem of the empirical methods is that they do not give a continuous result for increasing environmental conditions. Also these methods are often widely interpretable. The under- or overestimation seen in all guidelines can be assigned to the fact that these guidelines are developed for the design of an approach channel to a port which has to last for a long time, not for a temporary work channel. Five projects executed in the past by Boskalis are analyzed to gain insight in the currently used design procedure of a work channel. It is clear that nowadays the PIANC guidelines are used and that the engineers at Boskalis interpret the guideline in such a way that the minimum channel dimensions are reached. This results in low estimated costs during the tender phase, but also leads to the fact that often the channel does not satisfy the requirements of the TSHD’s during the construction phase. Adjustments to the channel are then inevitable. Based on the experiences from executed projects, interviews with captains and available theories, a new design-tool is set up especially for the design of a work channel and basin for a TSHD. The design method is based on the PIANC but only the influences that are important for a TSHD in a work channel are taken into account. Also the empirical character of the PIANC method is not used in the new design-tool. For the given input values, the design tool computes the dimensions of a one-way and a two-way crosssection and the dimensions of the basin. An assessment of the design tool is made based on a case study. The design of a work channel is calculated by the design tool and several runs are made with the fast-time simulation software SHIPMA. The results concluded that the design-tool gives a slight overestimation. This can be seen as a safety margin to take some of the assumption in the design tool into account. The design tool computes the dimensions of a one-way channel and a two-way channel. The choice between the two channels can be made according to an analysis of costs. When choosing for a two-way channel, the benefits of using two TSHD’s must weigh up to the extra production costs and the extra costs of a larger channel. The choice depends largely on the used TSHD(’s) and the nature of the project.

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Dredging history of the river Waal and expected future dredging works

Rijkswaterstaat is responsible for maintaining the fairway of the river Waal for navigation for more than a hundred years. In the past problem areas, which cause hindrance for navigation and block the fairway, were prevented with structural measures. Dredging was used as a last resort. In 2005 the desired fairway depth was increased from BRV -2.5m to BRV -2.8m which changed the role of dredging in the maintenance of the fairway. The dredging of the fairway is now executed through a performance-based contract. Today dredging is seen more as a permanent measure and is constantly used to maintain the fairway.

In the last hundred years an increasing number of measurements have been executed on the river Waal and have been stored in databases. This data is currently hardly used for the day-to-day maintenance of the river system. This research aims at gaining more insight in the dredging efforts needed to maintain the fairway using the available data from Rijkswaterstaat. Former dredging contracts as well as the currently used performance-based contract were studied in order to get a better understanding of the efforts needed to maintain the fairway for navigation.

It was tried to deduce a relation, between the discharge hydrograph and the efforts that are needed to maintain the fairway, in order to obtain an indication of expected future changes to the river system. Currently the program Spatial Planning Key Decision (SPKD) 'Room for the River' is running. This program is developed to increase the discharge capacity of the Dutch rivers to allow for higher discharges at current water levels avoiding the need to raise the flood banks. In this research one possible measure of the program Room for the River is studied, namely changing the current river groynes. Two possible options for changing the river groynes are studied. The first option is lowering the currently used river groynes and the second is the Island groyne which was designed by Royal Haskoning.

Besides changing the current river groynes climate change is also expected to have its effect on the river system. It is expected that climate change causes an increase in the winter discharges and a decrease in the summer discharges.

The relation found describes the volumes of sediment in the fairway above BRV 2003 -2.8m, which is closely related to the necessary dredging efforts, using the discharge hydrograph. When the currently used river groynes are altered this will lead to a change in this relation which makes the relation found unusable to predict the consequences of changing the river groynes to the necessary dredging efforts. Image_bardoel.jpeg

The relation found can be used to predict the consequences of climate change to the necessary dredging efforts because in this case only the discharge is expected to change. The expected influence of climate change on the discharge is still under discussion which is why multiple scenarios are used in this study. Climate change causes an increase in the winter discharges which in turn cause an increase in the occurring shallow areas, especially just after the winter season when the water levels decrease. The shallow areas cause problem areas for navigation. Besides an increase in shallow areas climate change also causes a change in the BRV level. The BRV level is determined by the lowest discharges. Because all the lowest discharges occur in the summer discharge season and the summer discharges are expected to decrease so will the BRV level. Together both effects will cause a major increase in the necessary dredging efforts which will be required in the future if the current dredging strategy and criteria will remain the same.

This research indicates that a new (dredging) strategy is needed in the future to maintain the fairway of the river Waal under the influences of the changes caused by climate change.
Numerical modeling of wave run-up on a dike
*Simulations with the VOF-model ComFLOW*

Wave fields in the close vicinity of a coastal structure can be very complex, this is especially the case during extreme storm conditions and for complex geometries. There is a growing interest for numerical simulation tools capable of predicting in detail the complex hydrodynamic loads due to waves and currents and its effect at structures. In this context the model ComFLOW will be used in this thesis to study wave run-up on dikes. The code is a (3D) hydrodynamic flow model based on the incompressible Navier-Stokes equations. The evolution of the free water surface is described by the Volume-of-Fluid method (VOF). The model is capable of calculating velocities, pressures and water levels in a detailed level, while geometries are easily adjustable.

The objective of this study is to analyze numerical simulation of wave run-up and other relevant wave-structure interaction processes on smooth and impermeable coastal structures with perpendicular wave attack and to investigate whether the Volume of Fluid (VOF) model ComFLOW is able to accurately represent these processes with 2DV simulations. A related aim is to determine whether the model is robust and which model settings are preferred.

To investigate whether the numerical model different mathematical aspects properly solves for relevant processes, simulation results are compared with analytical solutions known from literature. Three test cases are considered: the dam break test with a horizontal bed and with an upward sloping bed and test of Carrier and Greenspan of a standing wave on a sloping beach. General performance of the model for the analytical solutions is well. The study of the analytical solutions led to the following observation: numerical diffusion leads to a decrease of run-up and run-down heights.

An analysis of the different wave-structure interaction processes is performed, by studying not only wave run-up, but also wave run-down, reflection and visual inspection of the type of wave breaking. Simulations are performed with regular waves, three different slopes are used (of 1:3, 1:4 and 1:6). In combination with seven different wave conditions, this gives a wide range of breaker parameters. The results are compared with data from experimental model tests of Schuttrumpf and Bruun and Gunbak.

The results with respect to wave run-up are convincing, having very good resemblance with data of physical experiments. The results concerning wave run-down are less convincing. The relative wave run-down is overestimated compared to experimental data, especially in the region of breaking waves. The calculated reflection coefficients show good resemblance with data from physical experiments.

Overall it can be stated that the model is well able to accurately represent different wave-interaction processes including wave run-up and the model proved to be robust for this type of simulations.

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Analysis of costs in new terminals investments

This thesis studies cost estimation and investment decisions under cost uncertainty of large construction projects. The combination of these two topics intends to satisfy the Master’s theses of Civil Engineering at the Delft University of Technology and Quantitative Finance (Econometrics) at the Erasmus University Rotterdam. The first part relates to the Delft University of Technology, the second to the Erasmus University Rotterdam. Both parts are interrelated but can be read separately.

Part A develops a model for APM Terminals to estimate costs of new terminals investments. Present-day estimates of APM Terminals insufficiently incorporate risk. Therefore, the study formulates and analyses six (new) estimation models. Differences in the model include the use of error distribution function or the incorporation of interdependency. The analysis subjects the models to various constraints and selects the most appropriate model for APM Terminals. The selected model requires little input information, uses normally distributed error distributions and accounts for shocks. Moreover, the study points out shocks are of great importance in the estimation of costs. Shocks increase expected costs and mainly determine cost uncertainty. The change of estimation model and occurrence of shocks implies that APM Terminals changes its estimation process. The new approach requires an estimate of both expected cost and uncertainty to estimate construction costs.

Part B studies investments of projects subjected to cost uncertainty. Prior to construction investors have an idea of the value but not of the costs. Academic research assumes that cost uncertainty is composed of technical and input uncertainty (Pindyck (1993)). Technical uncertainty covers the physical difficulty to complete the project and is only known after completion. Input uncertainty relates to the pricing uncertainty of the required commodities to complete the project and is known beforehand. This study adds shocks to uncertainty because of the significant contribution to uncertainty (Part A). The research argues that shocks are a special form of technical uncertainty. Shocks occur after investing and complicate physical completion. But where technical uncertainty can accelerate construction, shocks solely delay progress. The study uses option theory to examine investments subjected to the different types of uncertainty. The analysis defines optimal investments and shows shocks increase the aversion to invest.

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Shell factors for piles subjected to horizontal soil displacements

Piles subjected to horizontal soil displacements are a common phenomenon at constructions next to soil embankments, for example an abutment of a bridge. Shell factors play an important role in the analysis of these piles with 2-dimensional (2D) design methods. This study investigates if the limitations of a 2D method, in relation to the 3-dimensional reality, can be covered by shell factors. Starting points for this study were the conclusions from the recently published CUR-report 228: Ontwerprichtlijn door grond horizontaal belaste palen.

First, by a literature study and an analysis of current 2D-methods, the role of shell factors in these methods is investigated. It appears that shell factors are being used in different ways, to take care of different 2D limitations, depending on the method. In current design practice, this difference in function of the shell factor is often not taken care of.

Second, a PLAXIS 2D finite element model is made to calculate shell factors. With this model a parameterstudy is been executed, in which the influence of the following parameters on the value of the shell factor is been determined:

- Horizontal soil stress;
- Soil parameters: soil stiffness, cohesion and angle of internal friction;
- Pile diameter and pile shape;
- Size of the relative pile-soil displacement.

A single pile is being considered, and time-dependant factors (consolidation and creep) are being neglected. Finally, a calculation is made with a 2D method, with calculated shell factors. The results are validated on the measurements of a laboratory test.

From the study, it can be concluded that it is possible to make good predictions of bending moments in piles, with the use of correct shell factors. Because the study is executed with a 2D model, validation with a 3D finite element method is necessary. Further investigation of the time-dependant aspects, such as creep, is highly recommended.

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A comprehensive assessment of Multilayered Safety in flood risk management

MLS is seen as the next step in Dutch flood risk management. In the last decades the idea that only flood defenses can prevent floods gave way to the realization that prevention can also be implemented along other lines, e.g. giving the rivers more space. The next thought was that besides preventing floods it should be possible to reduce the loss due to flooding. Therefore, MLS is meant to introduce comprehensive flood risk management by implementing three layers, or put differently safety nets: 1. Prevention (dikes, space for rivers, etc.), 2. Spatial Solutions (flood-proofing houses, elevating houses, re-locating etc.), 3. Crisis Management (evacuation, warning, etc.).

Before this study, there was no academic interpretation of MLS and it had never been tested comprehensively. Consequently, a theoretical framework is being developed in this thesis to be able to model MLS. This is followed by a hypothetical case study and additional one for the City of Dordrecht to examine the actual effect of MLS on the flood risk and its cost-efficiency.

It was found that theoretically MLS is indeed an alternative to only Prevention. Furthermore, it introduces the option to better customize flood risk management to local circumstances. By doing so, flood risk management becomes more cost-efficient. As the cost-efficiency is found to be dependent on the initial safety level, it is concluded that in the Netherlands MLS only has the potential to supplement the existing flood protection. In areas with a heavy implementation of flood defenses like in Dordrecht, MLS is fit to complement flood risk management rather than replacing the prevailing Prevention approach. However, to do so (local) authorities need to be able to base their flood management policies on flood risk, e.g. by benchmarking a certain Individual Risk.

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The Gevelco quay wall

In this thesis, an investigation is described to the measured horizontal displacements of a quay wall in the Port of Rotterdam. This quay wall was built in 2003 to replace an existing jetty. A combined tubular wall was installed and some of the concrete jetty piles were reused as foundation piles for the relieving platform. Anchorage for the quay wall is provided by an eight meter high continuous anchor wall, 38 meter behind the quay wall made of steel sheet piles. The connection between the two walls consists of high strength steel pretsetressed strands.

Prior to describing the actual research in this report, measurements are considered that have been carried out over time on top of the quay wall. These measurements indicate that horizontal displacements increase nonlinearly in time. This trend was the reason for an investigation to all possible causes of the horizontal displacements of the combi wall. In this thesis, the research is discussed and possible causes of the measurements are revealed by considering one representative cross section of the largest part of the quay wall.

The main part of this thesis deals with the investigation for possible causes of the measurements and is elaborated by considering the different influences for the representative cross section.

Examples of effects that have been analysed are time dependent soil behaviour, anchor wall capacity, the influence of expected values in stead of a design philosophy, the influence of the position and magnitude of a surcharge load and accumulating effects of cyclic loading.

Finally, it is concluded that saving money in the design stage by applying an anchor wall, resulted in more deformations than expected and made them dependent on the position of loading. Additionally, it is concluded that applying a higher load than was agreed upon in the terms of reference, resulted in more deformations than expected as well.

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The public has become more and more aware of the influence of climate change on their own situation. This is even more obvious in Holland where a large part of the population lives below sea level. Because of this future threat, there is a growing need for improved water and flood prevention. From society, the government and scientific field, there is a growing feeling that the Climate Dike concept might offer different opportunities and improvements in many areas. The aim of this MSc. thesis is to gain insight into the basic principles and into the features of the Climate Dike, as well as the technical feasibility and implications for society.

The assessment criteria for dikes, and the water levels they are designed for, are adjusted every 5 years because of uncertainties and fluctuations in nature. Because there is a growing fear that climate change might threaten our way of life, the Delta Committee (2008) made some recommendations to improve the water safety. The most important recommendation was the suggested increase in water safety by a factor 10. At locations where more safety is required or wanted a so-called Delta Dike could be constructed. A multi-functional alternative for this Delta Dike is the Climate Dike. A Climate Dike is a broad term that describes a dike with a layout that provides a robust character that is hard to breach. In this way, the Climate Dike can offer a durable safety even when future climate differs from current forecasted scenarios. Next to its robust character, the Climate Dike also has a multi-functional character to be able to combine its water defence role with, for example, recreational, residential or infrastructural functions. The characteristic properties and its boundary conditions of such a Climate Dike are investigated and presented in this report.

To increase the safety levels of current dike designs, it is important to evaluate the method of calculation of past, current and future dike designs. The current trend in calculation methods shows that there is more and more interest in probabilistic design which can provide more accurate and tailored designs. Therefore in this report a probabilistic design method is used to determine the characteristic dimensions of a Climate Dike in relation to required safety levels.

Use is made of a Monte Carlo simulation combined with two failure mechanisms, namely Piping (Sellmeijer) and Overtopping to take into account both height and width of the dike. These two mechanisms are assumed to be critical for a river dike section, and therefore the case study performed required suitable cross sections where piping and overtopping are indeed the limiting mechanisms.

From the cases studies it can be concluded that the Climate Dike can already be constructed in case the present dike section is broadened with 10 to 20m and heightened 0.5 to 1m. With these reinforcements a safety level increase of a factor 10 to 100 can be obtained. To be able to state that a Climate Dike is 'hard to breach', it has been shown that a present dike slope of 1:3 can already be gradual enough, provided that the revetment layer is of sufficient quality. In this report however, an even more gradual slope of 1:10 is assumed that should guarantee the unbreachability of the dike and allows for commercial use of the dike.

However, the cost and benefit analysis showed that even though the Climate Dike can be designed such that it meets its technical requirements, it is very costly to construct a Climate Dike in the whole dike ring (to obtain the required safety level). It can be said that a Climate Dike is not the most efficient measure to increase the safety level of a dike section.

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Flood defence town centre Dordrecht

The flood defence in the historical town centre of Dordrecht is situated in the Voorstraat, which is a busy shopping street. The dike itself is too low at some places, but with a system of flood stop logs in the doors of buildings along the street some extra height can be reached. The reliability of the stop log system is doubted however, so plans for strengthening the flood defence are needed. One important issue for strengthening the flood defence is the climate change. Warming of the earth would lead to sea level rise and higher river discharges.

The rate of climate change is unsure however and various scenarios have been made which range from minor to major changes. The water level at Dordrecht is determined by both the sea level and river discharges, so climate change could have severe consequences for the safety against flooding of Dordrecht. When the advice of the Delta Committee is followed, the safety standards of the dike rings should be heightened and much higher water levels have to be expected. Also the plans for the Rijnmond-Drechtsteden area are important for the strategy of strengthening the flood defence in the town centre of Dordrecht. A system of barriers in this area could protect Dordrecht against flooding, but it is also possible that strengthening the flood defence in the town centre of Dordrecht is still needed.

Strengthening the flood defence in the Voorstraat is difficult. Therefore also a new flood defence through the part of the town centre which now lies outside the flood defence is considered. Various alignments are possible, of which a flood defence along the river, which protects the entire town centre against flooding, has been elaborated. This new flood defence will consist of an automatically floating barrier in the quays. Under normal circumstances this barrier is invisible and when the water level rises the barrier automatically floats up. At the Wolwevershaven buildings stand with the facades directly along the river. Here a boulevard through the river will be made, separated from the buildings. By integrating the floating barrier in the structure the boulevard can be kept low. Inside the flood defence there is place for a marina and a swimming area.

At five places in the alignment a harbour has to be crossed. For this purpose at four places a flood gate will be made, which under normal circumstances lies at the bottom, so it is not visible and ships can pass. When a flood is expected the gates are closed. At one place, at the largest harbour crossing, a multi-functional barrier will be made. This barrier consists of two gates which stand horizontally when retaining a flood. After the flood the gates are lifted and rotated to form a bridge and viewing platform over the harbour. Because of the floating barrier the largest part of the new flood defence will not be visible under normal circumstances, so it will have little impact on the historical town centre. Therefore it is a good and sustainable solution for protecting the entire town centre of Dordrecht against flooding for a long time.

Full text of the report is available via:
http://repository.tudelft.nl/view/ir/uuid%3Adfac8bb7-3c53-4bb9-8da6-267dc350d83f/

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Long-term morphological modelling of the mouth of the Columbia River

With the construction of a process-based long-term morphological model (Delft3D) for the Mouth of the Columbia River (MCR), a first approach is made in trying to simulate the long-term morphodynamics of the MCR. Focus is on simulating the observed morphological changes for the post-jetty period of 1926-1958. The model is supplied with a high-resolution schematisation of river discharge and wave conditions in combination with a representative tide. Seasonal variations of the forcing conditions and their joint probability of occurrence are accounted for. Morphological acceleration techniques allow the simulations to stay with acceptable computation times.

General patterns of erosion and sedimentation as a result of jetty construction as well as general bed level developments are represented by the model. Both the model and the observations show that jetty construction pre-dominantly pushed sediments from the inlet and the inner delta onto the outer delta. Differences in quantity and orientation are however present between the observations and the model. Despite the application of lower limit sediment transport calibration factors, a general overestimation of the morphological change is computed. Also, a wider and shallower inlet channel develops in the model. The interaction of the MCR with the adjacent coast is modelled to a limited extent only. Certain morphologically important physical processes may therefore still be missing in the model. The representation of forcing conditions responsible for morphological change at the MCR allows for optimization.

Even though model results in this study do not fully simulate the observed morphological changes of the MCR yet, an important first step has been taken in the goal of simulating the long-term morphological change of the complex coastal area of the MCR. The products of this study provide a valuable base for continuing research.

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Dynamic behaviour of tunnel elements during the immersion process

A study to the influence of swell waves and wind waves

Immersion of tunnels is an often used technique in rivers and canals. The transport of tunnel elements can be done under offshore conditions, but immersing the elements under these conditions is not common practice. The tunnel elements of the Busan-Geoje Fixed Link in South Korea were immersed in such a situation. During this process, several loads act on the element and the equipment, such as current and wave loads. Wave loads consist of relatively long waves (swell waves) and short waves (wind waves). The wave induced motions of the tunnel element are restricted during immersion due to serviceability limit state conditions.

In this study, the influence of swell and wind waves on the immersion configuration is analyzed. In order to solve this problem, equations of motion are composed and solved to analyze the dynamic behaviour. In the first step, the natural frequencies of the configuration are determined, and in the next step the total response is analyzed. The latter is given in response amplitude operators, that represent the ratio between motion of the tunnel element and height of the wave per frequency. One of the findings is that some natural frequencies of the configuration are close to the frequency of swell waves. Especially the frequency of the rotation of the tunnel element is close to the frequency of swell waves. The influence of wind waves on the forces in the immersion cables is negligible.

One of the findings in this study is that large motions of the element and high forces in the cables may be expected during resonance. This should be avoided by adjusting the immersion configuration, for example by decreasing the cross section of the floaters. This will result in larger natural periods.

The main conclusion is that the influence of swell waves on the forces in the cables is significantly larger than the influence of wind waves.

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De provincie Zuid-Holland wil de bereikbaarheid van de regio waarborgen en daarom het goederenvervoer over water stimuleren. Dit afstudeeronderzoek bevat een netwerkanalyse om de knelpunten bloot te leggen. Het aanbod van de infrastructuur heeft beperkingen. Vernauwingen, krappe bruggen, scherpe bochten en spitsuursluitingen zorgen er voor dat de gemiddelde reistijd van een schip laag is. Voor een betere benutting van de vaarweg dient ook de vraag naar vervoer over water te steigen. Naast korte en betrouwbare reistijden is het belangrijk dat bedrijven zich dicht bij de vaarweg vestigen en een losvoorziening hebben aan het water.

Qua oplossing voor een snellere en betrouwbaardere reistijd kunnen knelpunten opgelost worden door de vaarweg en bruggen te laten voldoen aan een bepaald profiel. Daarnaast hebben sommige gemeenten het plan om de industrielocaties te verplaatsen. Ook het opheffen van de spitsuursluiting zorgt voor een vlottere reistijd. Echter een spitsuursluiting is ingesteld om de wachttijd van kruisend verkeer te voorkomen. Voor de vaarweg van Rotterdam naar Den Haag is een model-studie gemaakt, waarbij diverse scenario’s zijn door-gerekend. De gemiddelde reistijd, afwijking van de reistijden en de wachttijden voor het kruisend wegverkeer vormen de belangrijkste uitvoer. Uit deze modelstudie bleek dat de beoogde reistijdverkorting (circa 10%) alleen gehaald kan worden als er gesleuteld wordt aan de spitsuursluiting.

Echter de wachttijden voor het kruisend verkeer neemt toe. Om de wachttijd te beperken dient voor enkele stroomwegen de spitsuursluiting gehandhaafd te blijven. Daarnaast dient men een maximale openingsduur van 5 minuten te hanteren. Echter door deze maatregelen moet men ook een aantal fysieke knelpunten, zoals vernauwingen en een scherpe bocht, oplossen om zo de gewenste reistijd te halen.

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Gaining new insights regarding traffic congestion, by explicitly considering the variability in traffic

In hydraulic engineering it is known that for the evaluation of the performance of a system, a probabilistic approach is preferable to a deterministic one. The essence of such a probabilistic approach is that random variability/uncertainty is explicitly taken into account. In this graduation project, this probabilistic way of looking at a system is applied to the traffic system, in the context of analyzing (ways to alleviate) traffic congestion. Basically, the mechanism behind traffic congestion can be described as a process of interaction between the traffic demand and supply on a road network. Both this traffic demand and supply show a significant level of temporal variability, which makes the resulting traffic conditions variable as well.

Traditionally, in evaluations of the effectiveness of proposed congestion relief measures this variability is taken into account only in a limited or simplified way, or even not at all. Often simply a kind of ‘representative’ situation is calculated. The main objective of this research project was to reveal what kind of new insights can be obtained if we actually do explicitly/systematically take into account the variable nature of daily motorway congestion.

After a comprehensive study into the sources of the variability in the traffic conditions, and the selection of appropriate performance indicators, a quantification model was developed. The main principle of this model is that a large number of traffic simulations are performed for varying traffic demand and supply values. Subsequently, the desired performance indicators are computed from the combined set of simulation results.

In order to explore the (potential) new insights obtained by explicitly considering the variability, the developed model was applied to a reasonably sized real-life motorway network. From the results it is clear that a ‘representative’ calculation (in which all demand and supply variables are taken at their ‘representative’ level, which for example could be the mean or median value) does not give a good impression of the performance of the traffic system. It underestimates the congestion in certain respects, and – obviously – does not provide information on the uncertainty in travel times (which is an important factor in the societal costs of traffic congestion).

The research has shown that if the variability in traffic is explicitly considered, new insights can be obtained into the relative importance of different (variable) influence factors. This was demonstrated by ‘deactivating’ these influence factors in the model (one at a time). The results of this demonstration indicate that the capacity variations due to the intrinsic randomness in human driving behavior play a central role in (peak period-related) congestion. Such information yields important insights into how traffic congestion can be remedied most effectively.

By considering the example of a rush-hour lane, the research has shown that new insights can also be obtained into the effectiveness of specific measures that are proposed to alleviate traffic congestion. It turned out that the ‘traditional’ way of evaluating may actually result in a significant underestimation of the benefits of a measure. The precise nature and extent of the additional/revised insights will be highly context and measure specific, however. Of course, these new insights are not necessarily all positive in nature. Some more negative aspects of a measure could be brought to light as well.

The above implies that in practice more systematic attention should be given to the variability in traffic, when evaluating the effectiveness of measures that are proposed to alleviate congestion. Because of the complexity involved, this would have to be done by using a model in which the different sources of variability are explicitly accounted for, such as (a further developed version of) the model developed in this project.

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Modelling nearshore currents driven by waves and set-up gradients

During the fall of 2003, an extensive measurement campaign called the "Nearshore Canyon Experiment" (NCEX) was set up along the coast of La Jolla, California. The project site covered an area in which two submarine canyons are located, respectively La Jolla and Scripps Submarine Canyon. Over 20 institutions collaborated on recording the hydrodynamics and morphological changes. The collective objective of these institutions was to gain more insight into nearshore processes. The canyons are responsible for substantial changes in wave energy distribution over an alongshore distance of a few hundred meters. The irregular wavefield (see Fig. I) that arises in the direct vicinity of the canyons results in a complex nearshore circulation (Fig. II) and morphological changes in the surfzone.

The following research objectives were proposed for this study: 1) "What is the relative contribution to the alongshore current of (i) alongshore water level gradients due to the alongshore variation of wave set-up and (ii) obliquely incident waves?" And 2) "Can the numerical model Delft3D reproduce the order of magnitude and direction of the nearshore currents?"

This master thesis describes the hydrodynamic circulation in the nearshore of the measurement campaign and the results of the numerical model Delft3D for two specific cases, respectively a day with wind sea and a day with swell waves. The incident waves drive currents and create wave set-up. Owing to the influence of the submarine canyons, alongshore gradients develop in the wavefield. It is concluded that the influence of the submarine canyons becomes more prominent in case of swell waves and therefore a larger alongshore set-up gradient arises. In both the observations and the model predictions an alongshore current develops strong enough to counteract the wave-driven flow.

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Morphological Impact of Coastal Structures

In many coastal engineering problems the application of coastal structures to resolve these problems seems to be a proper solution. In a lot of cases, however, the implementation of coastal structures does not lead to the expected situation.

Erosion management operations may have unwanted impacts on a coastal system. Decisions on the most appropriate management approach at a given site should be driven in part by the desire to minimise these impacts so as to preserve the natural characteristics of the coast. It is important to bear in mind that erosion of beach and dune areas is a natural and dynamical process and normally should not be regarded as a problem. Problems only arise when erosion threatens human activities or assets, or when the erosion is the result of human interference with coastal processes along an adjacent frontage.

A profound study of the actual processes causing the problem should always precede the design of the structure itself. This report intends to provide some clear guidelines to facilitate the design process of coastal structures by discussing several cases and relevant design aspects that seem to be obvious but could easily be overlooked. Especially the recognition of the mechanisms that cause the occurring problem takes a central part in the design process of coastal engineering measures and thus the main emphasis of this report is to awaken consciousness of the mechanisms involved.

The cases as discussed in this report are all examples of actual problems. Every solution has its impact on the morphological balance of the coastal zone; this report describes these impacts. It becomes clear after studying all cases that measures to resolve coastal engineering problems are very complicated and adverse effects can be expected in many cases. The main purpose of this report is to make decision-makers in coastal engineering matters aware of the complications that are involved.
Post-trenching with a trailing suction hopper dredger

It is common practice to protect subsea pipelines by embedding them into the soil. Trenches can be made before or after the pipelines have been laid. In the latter case, the excavation process is called post-trenching.

The essence of post-trenching, as handled in this thesis, is erosion of sand by a water-jet. The literature study focused on the processes of jets and erosion. A lot of research has been done in the field of water jets and useful information is widely available. Nevertheless the available information on the subject of impinging jets is rather limited and the validity remains questionable. Water jets used for post-trenching create high flow velocities for which the traditional erosion equations are not valid. Therefore use is made of a special set of equations for high speed erosion.

With the information provided by the literature study a description of jetting in sand was made. The known processes were arranged resulting in a set of equations. Following the rules for scaling the set of equations was converted into a properly scaled model.

Preliminary model tests were conducted to observe the jet-process and narrow down the possible jet angles. These preliminary tests were followed by scale model tests to determine the erosion depth for different nozzle angles, flow velocities etcetera.

A numerical model was developed to simulate jet-induced erosion. Since the erosion equations, making use of the average flow velocity, could not model the erosion behaviour of a jet, a turbulence term was introduced. The results of the simulations were compared with the model tests. Though the numerical erosion model showed promising results, it could not be validated due to a lack of data.

The most important conclusions are that soil can be eroded to the desired depth, a data-set has been created and much insight is gained with respect to the post-trenching process. Last but not least, a numerical model was made that can prove to be useful after better validation.
Port Design

Along the northern coast of Morocco order has been given for the construction of a large port in the Mediterranean Sea, at a designated project location 20 km. to the west of the city of Nador. On this green-field coastal stretch a new transshipment port will have to be developed for various types of cargo: a container terminal, a liquid bulk terminal and a dry bulk terminal. Besides the defined port’s throughput specifications, additional objectives are maximizing throughput for all of the terminals, providing a plan for in-phased port expansion, incorporating possibilities for independent development of the bulk port and the container port, taking into account up to 20% of cargo transport to the hinterland and including enough surface space within the design for a refinery and a free trade zone. Relevant data regarding the project (location) has been identified and analyzed: hydrodynamic data (wind, waves, currents, water levels) and environmental site data (topography, bathymetry, geology, hydrology and morphology). Besides this, a forecast has been formulated with the expected design vessels that will visit the new port. From this, cargo-vessel distributions and vessel-arrival distributions have been defined, resulting in the total amount of shipping traffic for every terminal. Subsequently, the design of the port masterplan can commence in which first of all the approach channel, port basins and manoeuvring and berth areas have been designed. As a next step the characteristics of the various terminals have been determined, under which the number of berths, quay length and surface areas. After using all port elements listed above jointly, several port masterplan layouts have been drawn up. From these port masterplan layouts, the most promising alternative has been selected after comparison by means of a Multi Criteria Analysis on various criteria under which nautical ease, safety, expansion possibilities and costs. Concluding to this, the selected port masterplan layout has been optimized. The resulting port layout has been assessed regarding the topic of in-port wave penetration. Limiting operational wave criteria have been defined and relevant wave processes have been evaluated with the wave simulation model DIFFRAC-2DH. It became clear that strong wave reflection could be expected due to monolithic breakwaters. In order to decrease this reflection (and thus the port’s downtime), new simulation runs were carried out with an improved breakwater configuration using low-reflectivity caissons. With these wave-dampening improvements included, the simulation model runs yielded very positive results. The wave study was concluded with an assessment on port oscillations as a result of earthquakes, tsunamis and meteorological forces.

After the performed wave study, the port breakwaters have been designed. For this, two typical cross-sections were selected: one rubble mound and one vertical composite breakwater. After including construction constraints (a large water depth, the use as berth and probability of earthquakes in the area) and wave dampening measures, the rubble mound breakwater was designed with an armour layer of 15m³ Accropodes II, and the vertical composite breakwater as a vertical slit caisson on a rubble mound foundation bed. The application of wave energy absorbing measures is a necessity in order to minimize the port’s downtime, and will have to be included in a final design. The designed port masterplan layout meets all stated specifications and requirements and its breakwaters are adequate in creating calm in-port berthing conditions resulting in high availabilities of the berths.
Numerical modelling of turbidity currents in submarine channels

Turbidity currents are gravity currents driven by sediment in suspension. They differ from other conservative density currents by the ability to exchange sediment with the bed, and thus have the capacity to become larger and faster as they progress downstream. Due to their magnitude, turbidity currents can form a potential danger for submarine pipeline and cables.

The maximum current velocity of turbidity current is an important parameter for a safety assessment of existing submarine pipelines, but also for future projects related to pipeline route decision and pipeline protection. Ocean floor bathymetry around an existing or proposed path of a pipeline can be used to detect areas, where it is more likely that turbidity currents occur. Numerical simulations in these areas can provide a range of current velocities at which turbidity currents might hit a pipeline.

Turbidity currents flow through submarine canyons and they are believed to be the main mechanism for submarine canyon incision. These canyons often show regularly spaced steps in the bed indicating a probable relation between the currents that generate them and the bed itself. Several researchers suggest that these steps are cyclic steps, i.e. steps which are bounded on both sides by a hydraulic jump.

Due to the capacity to destroy equipment, the episodic character of the currents and the hostile environment (at hundreds of meters water depth) in which they occur, most information on the flow behaviour of these currents is based on laboratory experiments and numerical modelling. Shell International Exploration and Production has a numerical code, which can simulate turbidity currents by solving the complete three-dimensional Reynolds Averaged Navier Stokes equations for bulk fluid mass and mass conservation for multiple grain size classes using a k-ε turbulence closure model.

The main objective of this thesis was to perform a numerical study to investigate the influence of regularly spaced steps, which were found in a submarine canyon in the vicinity of an existing pipeline, on the flow behaviour of turbidity currents and assess the possibility of the steps behaving as cyclic steps. The focus was on the estimation of the maximum current velocity of turbidity currents.

The numerical study revealed that cyclic step-like flow behaviour can occur in the submarine canyon provided that 1) the current thickness is much smaller than the wavelength of the bedforms, 2) the average slope of the canyon favors supercritical flow, 3) the bedforms have a pronounced step-like shape, i.e. a relatively short steep region and a relatively large region with a more gentle slope that forces the current to become subcritical and 4) the wavelength of the bedforms increases in the downstream direction to account for the increasing current thickness due to the entrainment of ambient water.

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Civil engineering theses

Geo Engineering
Laterally Loaded Piles, Models and Measurements

This thesis is a comparison between different geotechnical models which can be used to design single laterally loaded piles. The comparison is useful, because in the daily practice of geotechnical engineering many discussions arise on which model is most suitable in which situation. This is also mainly due to the differences in results between different models. Sharp designs can reduce cost massively. Of course, in literature several researches were already conducted in comparing different models. However, these comparisons were either theoretical comparisons, or comparisons between a single model and measurements. With today’s most used models, comparisons between the models and measurements have not yet been made. The objective of this thesis is therefore to compare the accuracy of the different models and find recommendations on which model can be used best in which situation.

Eight different models were chosen and compared. These are:

- Blum
- Brinch Hansen
- Broms
- Characteristic Load Method (CLM)
- Nondimensional Method (NDM)
- MSheet
- p-y Curves
- Plaxis 3D Foundation
- MSheet
- MPile
- Plaxis
- Plaxis 3DFoundation

The comparison between the different models on accuracy and theoretical background resulted in a multi-criteria analysis (MCA). Of the models, Broms and the CLM are least usable. The methods are unpractical and inaccurate. The NDM is very accurate, however very unpractical. Blum and Brinch Hansen, the ultimate strength models, cannot be compared on the basis of measurements, since the prediction of the deformations of the pile under working loads is not the way these models are originally supposed to be used. The three models which require the use of a computer, MSheet, p-y analyses with MPile and Plaxis, all score high in the MCA. The methods are approximately equally accurate, are easy to use and offer lots of possibilities. These are the models which are recommended to be used in the case of single pile design.

For a more substantiated choice between these three models, consider the complexity of the situation, the design phase and the amount of time available. In very early design phases, Blum can be used. However, great care is needed if Blum is used, since variations of this model exist.

From the research it became clear that on some subjects further research is desirable. Additional tests would increase the reliability on the statements made on accuracy. If these tests would reach failure, the accuracy of Blum and Brinch Hansen could also be examined. In Plaxis accuracy could increase if the stiffnesses are more precisely determined. Development of better correlations between strength and stiffness could also increase the accuracy of Plaxis. Considering the good results of the NDM, the accuracy of the use of p-y curves in MPile can be examined. Also p-y curves can be developed specially for Dutch soils. Finally, it can be concluded that single pile design is a tedious procedure and all models should only be used while considering their limitations, possibilities and theoretical backgrounds.

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Civil engineering theses

Watermanagement
Validation of SMOS satellite data over Ghana and Burkina Faso

Introduction
Soil moisture (SM) is an important parameter in weather, climatologic and hydrologic models. A way to obtain SM data over the entire earth is using satellite imagery. In November 2009, the European Space Agency (ESA) launched the so-called Soil Moisture and Ocean Salinity (SMOS) satellite. This satellite measures at a lower frequency than other satellites now used for determining SM content. This means it experiences less hindrance from vegetation and it should be better capable of determining SM. ESA has set a error bound of 4%.

Problem definition
In West Africa, agriculture is mainly based on precipitation. Rainfall has a monomodal regime, but over the last years, rainfall has declined. Less rainfall can cause droughts that can have a large impact on communities. More knowledge on SM can help get a better understanding of the climate. The SMOS satellite could become a helpful source for this data. The research question therefore became:
How well does the SMOS algorithm perform for northern Ghana and Burkina Faso, West Africa?

Research
This question is answered by executing a sensitivity analysis and by comparing SMOS data to both SM data derived from field measurements and from satellite measurements, and to precipitation data. Comparisons were done with the statistical coefficients Mean Difference, Root Mean Square Difference, Pearson coefficient and Nash coefficient. Correlation was determined by looking at the derivative of SM compared to precipitation data. Besides that, scatter plots were created and data was inspected visually.

Results
1. The sensitivity analysis showed that a wrong determination of the roughness of an area, the temperature of ground and/or canopy, the scattering albedo and the litter characteristics can lead to large differences in SM. Change is however not necessarily linear.
2. Comparison of SMOS data with field data shows a relatively low SM value for SMOS. It also shows a weak reaction to precipitation (has a smaller normalized range) than field data.
3. SMOS data react well to precipitation, it goes up with rainfall and down when it is dry. Comparison with other satellite data shows the best correlation for areas with limited precipitation. Areas with higher precipitation and/or more vegetation show lower correlation.

Conclusions and recommendations
1. Concluded, it can be said that SMOS gives relatively low values, and although it reacts well to precipitation, correlation in wet areas with other datasets is not good due to small changes of SMOS data. SMOS will therefore probably fall within 4% of the real value in dry areas, but not in wet areas.
2. More research should be done into the effect of erroneous values for parameters and whether changing these values also has a positive effect on the range SMOS SM data shows.

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De doelstelling van dit onderzoek is het ontwikkelen van maatregelen in het waterbeheer voor het verbrakken van de noordelijke deel van polder Westzaan. Onderzocht wordt, hoe het chloridegehalte van het openwater van polder Westzaan kan worden gehandhaafd op het voor de ecologische systeem gewenste niveau van 2000 mg/l, zonder dat dit leidt tot problemen voor de waterkwantiteit zoals hogere peilen en wateroverlast. Om de bovengenoemde doestelling te behalen is er een model ontwikkeld waarbij het water ingelaten wordt vanuit het Noordzeekanaal. Onderdeel van het onderzoek is daarom in eerste instantie het bepalen van een tracé van het Noordzeekanaal naar het noordelijke gedeelte van de polder. Hierbij wordt water uit diepere lagen van het Noordzeekanaal als brakke bronstroom gebruikt. Het aanpak van het onderzoek is hieronder aangegeven.

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Analyzing the effects of large-scale green roof implementation in Singapore

Introduction
Singapore's water management strategy encourages the development of on-site stormwater measures, like green roofs, in order to mimic predevelopment site hydrology by reducing and delaying the runoff volume and peak rate of flow. Hydrological effects of green roofs were the main focus of this thesis, which was performed in cooperation with the Singapore-Delft Water Alliance.

Problem definition
Green roofs are considered as an interesting on-site stormwater measure with great large-scale implementation potential in existing and newly developed urban areas, because roofs account for 20-50% of the total urban land cover. The effects of green roofs on the rainfall-runoff in a tropical country, like Singapore, are not yet proven by scientific research however. Moreover, present hydrological green roof studies pay more attention to experimental measurements than to a more practical large-scale representation of green roofs and their effects.

Research
My research focused on 1) analyzing the effects of green roofs on the rainfall-runoff in Singapore and 2) determining the quantitative hydrological contribution of large-scale green roof implementation to sustainable stormwater drainage systems in Singapore. A research approach, which combined green roof measurements with model simulations, was successfully developed. The approach had two steps:
1. Analyse the runoff characteristics of 66 rainfall events from 1 m² extensive green roof platforms and develop a model (HYDRUS-1D) that can simulate the green roof rainfall-runoff.
2. Couple the output from the rainfall-runoff model to an existing hydraulic routing model (SOBEK) for an accurate simulation of the scaled-up green roof effects in the case study area.

Results
1. Experiment measurement and model simulation results clarified the green roof functioning. Retention, peak detention and peak discharge reduction are provided until the maximum storage capacity of the soil media. Runoff from green roofs continuous for up to 3 hours after the last rainfall.
2. Large-scale extensive roof greening does not provide a significant peak discharge reduction and delay under tropical extreme rain conditions. Saturation of the soil media at the time of the rainfall peak and a dilution effect that is caused by a limited building coverage are the main causes for this.
3. Standard extensive green roofs provide a negligible reduction of non-natural water level variations in the drainage system of the case study area. Analysis results showed that peak discharge reduction is conditionally significant, but green roofs are not able to provide a base flow during dry spells.

Conclusions and recommendations
This research showed that a standalone large-scale implementation of 12 cm extensive green roofs does not significantly contribute to the quantitative hydrological goals of Singapore's ABC Waters Programme. The hydrological contribution of green roofs to sustainable stormwater drainage systems in Singapore can be enhanced when the design fundamentals and implementation strategy are reconsidered and adapted to the proposed hydrological effects and site specific requirements.

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Clogging of permeable pavements in semi-arid areas

Urban development and consequently covering more areas by the impervious surfaces, has led to the decrease in natural process of rainfall infiltration and as a result deduction in ground water recharge. This decrease in ground water recharge has caused number of environmental concerns such as the decrease in base flow in streams and drying up of drinking water supplies. In arid and semi-arid areas with low annual rainfall and high evapotranspiration (P/ET<0.5) no excess water for run-off or ground water recharge would be available. Therefore capturing the rainfall for water supplies in such regions is more important. Due to these problems and by considering the role of permeable pavements in capturing water and replenishment of aquifers, using this kind of paving has been considered as a sustainable solution.

Although permeable pavements have been used as a sustainable way to reduce the impacts of urbanization on water quality and improving water management in urban areas but they also have some disadvantages. Clogging in these pavements is the main problem which causes the decrease in infiltration rate. Review of existing researches shows that most of the researches about clogging have been limited to western countries with almost the same climatic condition and the effect of climate on clogging has not been considered yet, especially in dry regions. Although in these areas capturing more rainfall to recharge ground water is really vital. Therefore the effect of climate on clogging of the permeable pavements should be investigated more to choose the proper pavement for dry climate and increasing the infiltration rate.

In order to investigate the effect of semi-arid climate on clogging of the permeable pavements, porous concrete was chosen in this research as the proper type to apply in these areas. As the fine dust in these areas is the main cause of clogging, the pavement behavior under this condition was evaluated by the lab experiment. During the lab experiment different sub-bases (sand and stone) were also examined to see the differences in clogging process under various conditions.

The results from this research shows that the wind suspended particles, as the main cause of clogging in semi-arid areas, can be washed through the pavement and cause a very slow clogging process. Comparison the results of different sub-bases shows the significant effect of the pores size in the sub-base on the clogging process. In case of higher porous sub-base, sediments can be migrated from the pavement to the sub-base easily. But in case of less porous sub-base the blocking of the interface and first layers of the sub-base can create more resistance through the flow migration. As the clogging in case of larger particles happens rapidly, therefore in order to design the pavement, average size of particles that can go through it should be taken into account.

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The main objective of this thesis is to find a method for observing the moment of tidal slack in an estuary. The method to determine the exact moment of tidal slack, that is developed during this thesis, is based on the use of a simple handheld GPS. The GPS device is attached to a shipping lane buoy, which is fixed to the bottom of the estuary with a long chain. The chain gives enough space for an amplitude between 25 and 90 meters. The data from the GPS results in a good view of the path that the buoy travelled. The moment that the buoy switches direction should be the moment of tidal slack. The Westerschelde is an alluvial estuary in the south of The Netherlands and is chosen for this study.

The locations where the measurements were carried out are near: Breskens, Terneuzen, Hansweert and Prosperpolder. Breskens is located near the mouth of the estuary, Prosperpolder close to Antwerp. The data gathered in the field are basically the coordinates of the location of the GPS device, measured every few seconds. To obtain tidal slack from the data three methods were developed namely: the 'angle' method, the 'minimum radius' method and the 'velocity' method. Looking at the results of the analyses, the first thing that stands out are the very long phase lags in Breskens. The reason for this is at this moment unknown. Probably it happens because of 3D effects at the mouth of the estuary. To confirm these speculations some more research has to be done.

What can also be deduced from the results is that in general, the phase lag becomes shorter more upstream in the estuary. However the results from September 2010 show that this does not apply for the most upstream cross section, Prosperpolder. There the phase lag (especially between high water and high water slack) increases again. The decreasing phase lag in upstream direction was expected and can be explained by the theory of Savenije (2005). The increasing phase lag in the Prosperpolder cross section can be explained by the fact that the Scheldt river has more influence in upstream direction. A more riverine character means that the wave type becomes more progressive and the more progressive the wave, the longer the phase lag. Furthermore it is remarkable that for all the cross sections apart from Prosperpolder, the phase lag between LW and LWS is longer than the phase lag between HW and HWS. Only in the cross section Prosperpolder it is the other way around. This means that at a certain moment there is a switch. The reason for this switch is unknown, but it has been noticed before in other research (Graas (2001), Horrevoets (2002) and Nguyen (2008)).

Results that were obtained in the cross section Hansweert in September 2010 show clearly that the flood tide lasts longer in the flood channel and the ebb tide lasts longer in the ebb channel. The difference between the moments of LWS are the biggest. In this case the ebb tide slacks 20 to 30 minutes later in the ebb channel than in the flood channel. The difference between the moments of HWS lie in this case between 0 and 10 minutes.

When the results are compared to the theory (Savenije 2005), they coincide upstream better than downstream. In Hansweert and Bath the measured phase lags lie very close to the theory. In Prosperpolder they even coincide perfectly. The fact that this happens in Prosperpolder can be explained by looking at the assumptions made in the theory. For the phase lag equation, Savenije assumes that the estuary has one channel. In Prosperpolder the Scheldt estuary consists of only one channel. Overall the conclusion can be made that observing the phase lag by the use of GPS, is a method that works. Besides that it works, it is affordable and easy. Still some improvements have to be done, especially when it comes to the lifetime of the batteries and reading the data of GPS devices on the buoy from the shore. When the use of GPS is applied on larger scale, more exact data will be available for all navigation in the estuary, both commercial and recreational.

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Low cost disdrometer

Introduction
In 2009 the department of Watermanagement started with the development of a low cost disdrometer for the TAHMO project. This disdrometer had to be simple, inexpensive and suitable for use in remote areas and tropical climates. The low cost disdrometer also lends itself for other large scale application, such as in urban area, because it makes measurements with a high spatial resolution affordable. The first working prototype made was based on the principle of an acoustic disdrometer and an audio recorder for data acquisition.

Objectives
The main objectives of this thesis are the improvement of the design of the sensor and data acquisition, testing the new prototype and develop a method to validate the measurements.
- The design of the sensor has been improved in terms of sensitivity and the method of production. Two negative effects were observed in the new prototype, however these effects do not have a visible effect on the measurements.
- A new data logger was developed for the sensor to reduce the amount of data that has to be stored and to increase the time that the disdrometer is able to measure. The logger can be used in two configurations, as a standalone unit and in a setup with multiple disdrometers.
- For the calibration of the low cost disdrometer an experimental calibration setup is used. Calibration of the disdrometer showed a clear relation between the signal energy of a drop and the size of the drop.
- A method is developed to validate the outcome of the low cost disdrometer, in terms of drop size distribution, if there are no other disdrometers available to compare to. With this method it is possible to get insight in the expected drop size distribution based on the data of a tipping bucket.

Case study
To test the low cost disdrometer in an urban environment two case studies were conducted. Around the EWI faculty in a setup with multiple disdrometers and in Singapore with a standalone disdrometer. The results from the measurements in the case studies showed a large underestimation of the total amount of rain. This underestimation only takes place during rain events with high rain intensity. The maximum intensity measured with the disdrometer is 26mm/hr where the tipping bucket measured 150mm/hr. Several tests showed that this underestimation is caused by an error in the logger of the disdrometer. So far it is unknown what the exact error is.

Conclusion and recommendations
The main conclusion drawn from the conducted research is that the sensor of the current prototype performs better than the first prototype and that in general the principle works. However the logger designed for the disdrometer is not capable of giving a right representation of the reality under all circumstances. Before the low cost disdrometer can operate in the field for longer periods, first the problems with the data logger have to be solved. Also the work on the calibration process and the sensor has to continue to optimize the disdrometer for production on a large scale.

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Swale filter drain system: The inflow – discharge relation.

The principle of a Swale filter drain system (SFDS) is as follows: The precipitation in the urban area is transported to the SFDS by means of a storm water sewer system or a gully. The water ends up in a deepened grassplot and infiltrates into a soil improvement underneath the grass. Within the soil improvement a drain is installed which leads to the surface water or a storm water sewer system nearby. The water is partly infiltrated into the original surrounding soil and partly discharged by the drain.

The research focuses on the quantitative features of the SFDS. From this perspective the SFDS provides retention, infiltration and delayed discharge of the runoff through the drain. The research question for this study is: 'What is the inflow – discharge relation of Swale Filter Drain Systems, with respect to the total discharge reduction, the discharge peak reduction and the peak delay?'. The purpose of this research is to determine the characteristics that have effect to the inflow – discharge relation and how these characteristics affect the relation. By monitoring a SFDS in Utrecht, the actual working of the system in practice is examined. Hydrus 2D is used to make a two dimensional numerical model of a SFDS. This model gives the opportunity to investigate the effect of some characteristics of the SFDS and its surrounding on the relation.

Conclusions and recommendations

The main findings of the effects of the characteristics to the inflow – discharge relation are presented here.

- No clear inflow – discharge relation is found. This is caused by the different initial conditions for the measured events. Furthermore the distribution of precipitation events differ. Therefore during the analyses a rough distinction is made between all the measurements and those with a shallow initial water level in the trench.
- For all measured events the peak delay has a range between 10 minutes and 108 minutes. The peak reduction has a range between 40% and 100%. The total volume reduction is between -8% and 100%.
- The events with a shallow initial water level in the trench give some different values. The peak delay is between 10 minutes and 41 minutes. The peak reduction is between 40% and 89%. The total volume reduction values are between -8% and 89%.
- The difference between the start of the inflow and the start of the outflow is between 1 minute and 28 minutes.
- The most affecting physical characteristics are the drainage level and the groundwater level. Starting with a drainage depth of 30 cm a 40 cm deeper drainage depth gives a 15% smaller peak reduction and a 30% to 35% smaller total volume reduction. Starting with a groundwater level of 30 cm depth a 100 cm deeper groundwater level gives a 46% to 65% larger total volume reduction.
- For all outflow characteristics it must be noted that the emptying time of an SFDS for the native soils with a small hydraulic conductivity is relatively large. Because of this it takes more time after a precipitation event to get back to the maximum storage capacity of the SFDS.
- More research is recommended on clogging of the SFDS. Measuring during more years will give interesting data to study this clogging. There are many different SFDSs, therefore it is recommended to measure more and different SFDSs. Several changing characteristics during the year may have effect on the efficiency of the SFDS. For instance the weather conditions, the groundwater level and the vegetation in the SFDS may change. Due to this it is recommended to measure a whole year.

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Conditioning of aggressive water

Introduction
Worldwide limestone (CaCO₃) filtration is used in many treatment plants for the conditioning and (re)mineralization of drinking water. The goals are to increase the concentrations of Ca²⁺ and HCO₃⁻, the pH and the Saturation Index (SI), thereby improving the quality of the water regarding corrosion control, buffering and taste. Typical applications include (very) soft groundwater with (very) low alkalinity and desalinated water. In Norway, some plants use a product made of ground natural limestone, called Micronized CaCO₃ Slurry (MCCS), which is dosed as a slurry of fine particles (order of 1-2 μm) into the raw water.

Research
The present study was started to investigate the feasibility of MCCS as a general alternative for limestone filtration in conditioning and (re)mineralization applications. Potential advantages in the typical Dutch groundwater application might be either lower costs (in case MCCS could be used to replace limestone filters) or better water quality (in case MCCS could be used to convert CO₂ directly in the raw water, preventing it’s escape to the air during the aeration process). Also no extensive infrastructure is needed for implementation, just a dosing pump and a storage silo. The increase in pH and HCO₃⁻ concentration in the raw water could be beneficial for the iron and manganese removal.

Results
Initial dissolution rates are fast when using small grained calcium carbonate, but the rates slow down during the dissolution process. Partial dissolution of the grains reduces the presented surface area, this greatly effects the dissolution rate. The dissolution process is practically stopped before equilibrium is reached and thereby keeping the solution turbid. When dosing far under chemical equilibrium (50%), results are improved. Within 30 minutes dissolution time turbidity levels are under 1 NTU.

Conclusions and recommendations
The overall conclusion for practical applications is that it is impossible to dissolve the powdered CaCO₃ products (currently on the market) completely in a contact tank within acceptable contact times (less than 30 minutes), when applying a dose equal to the CDP. Part of the CaCO₃ particles will always remain in suspension, which will have a detrimental impact on the turbidity and sediment load to clear water tanks and the distribution system. One might speculate that in future it might be possible to develop CaCO₃ powders with significantly smaller particle size than 0.1 μm; at that time this conclusion might be reconsidered.

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Civil engineering theses

*Transport & Planning*
Gaining new insights regarding traffic congestion, by explicitly considering the variability in traffic conditions

In hydraulic engineering it is known that for the evaluation of the performance of a system, a probabilistic approach is preferable to a deterministic one. The essence of such a probabilistic approach is that random variability/uncertainty is explicitly taken into account. In this graduation project, this probabilistic way of looking at a system is applied to the traffic system, in the context of analyzing (ways to alleviate) traffic congestion.

Basically, the mechanism behind traffic congestion can be described as a process of interaction between the traffic demand and supply on a road network. Both the traffic demand and supply show a significant level of temporal variability, which makes the resulting traffic conditions variable as well.

Traditionally, in evaluations of the effectiveness of proposed congestion relief measures this variability is taken into account only in a limited or simplified way, or even not at all. Often simply a kind of 'representative' situation is calculated. The main objective of this research project was to reveal what kind of new insights can be obtained if we actually do explicitly/systematically take into account the variable nature of daily motorway congestion.

After a comprehensive study into the sources of the variability in the traffic conditions, and the selection of appropriate performance indicators, a quantification model was developed. The main principle of this model is that a large number of traffic simulations are performed for varying traffic demand and supply values. Subsequently, the desired performance indicators are computed from the combined set of simulation results. In order to explore the (potential) new insights obtained by explicitly considering the variability, the developed model was applied to a reasonably sized real-life motorway network. From the results it is clear that a 'representative' calculation (in which all demand and supply variables are taken at their 'representative' level, which for example could be the mean or median value) does not give a good impression of the performance of the traffic system. It underestimates the congestion in certain respects, and – obviously – does not provide information on the uncertainty in travel times (which is an important factor in the societal costs of traffic congestion). The research has shown that if the variability in traffic is explicitly considered, new insights can be obtained into the relative importance of different (variable) influence factors. This was demonstrated by 'deactivating' these influence factors in the model (one at a time). The results of this demonstration indicate that the capacity variations due to the intrinsic randomness in human driving behavior play a central role in (peak period-related) congestion. Such information yields important insights into how traffic congestion can be remedied most effectively.

By considering the example of a rush-hour lane, the research has shown that new insights can also be obtained into the effectiveness of specific measures that are proposed to alleviate traffic congestion. It turned out that the 'traditional' way of evaluating may actually result in a significant underestimation of the benefits of a measure. The precise nature and extent of the additional/revised insights will be highly context and measure specific, however. Of course, these new insights are not necessarily all positive in nature. Some more negative aspects of a measure could be brought to light as well.

The above implies that in practice more systematic attention should be given to the variability in traffic, when evaluating the effectiveness of measures that are proposed to alleviate congestion. Because of the complexity involved, this would have to be done by using a model in which the different sources of variability are explicitly accounted for, such as (a further developed version of) the model developed in this project.

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Accelerating the introduction of electric bicycles

A study into the effects of electric bicycle ownership and use

At the end of the nineties the electric bicycle was successfully introduced at the Dutch market for the first time. An electric bicycle assists the biker with an electric motor. In the early years this bike was popular among elderly people or among people who are physically disabled. In recent years also other groups of people use the electric bicycle, like commuters. The Dutch sales figures have strongly been growing over the last five years. In 2009 more than 150,000 new electric bicycles have been sold in the Netherlands. The regional authority "Stadsgewest Haaglanden" wants to find out the influence of the electric bicycle on the total bicycle use in the Haaglanden region.

The research goal is formulated as:

Getting insight in the influence of the development of the ownership and use of an electric bicycle on the transport demand and the travel mode choice.

There is little scientific research on the ownership and the use of electric bikes. The scarce data that are available only allow conclusions on the major user groups. These are:

• Elderly (60 years and over) using the bike for recreation
• Commuters using the bike for commuting
• Disabled people who cannot use a normal bike, but can use an electric one.

There is a lack of knowledge about the factors determining why someone owns and uses an electric bicycle.

By using interviews it was investigated which factors play a role in the ownership of the electrical bike. Subsequently a regression model was made to give quantitative insight, displaying a statistical relationship between these factors and the ownership of an electric bicycle. A dataset was used from 2007 that was compiled from a market research on electric bikes. Not all factors could be related to the data and consequently not all factors were quantified.

This research has provided a large qualitative insight into the factors that determine who owns and uses an electrical bike. The research offers many leads for policy and further research. The available quantitative information is not sufficient to have a quantitative picture of the ownership and use of the E-bike. Therefore, not all research questions could be answered quantitatively. Nevertheless, the regression models that are made in this research can be used as a basis for further research on the ownership and use of electric bicycles.

To further stimulate the use of (electric) bicycles, several recommendations are made.

The use of bikes by commuters in Haaglanden can be influenced positively by organizing projects to stimulate the use of bikes at companies. This was already successful in other regions, but it needs to be directed to the correct user groups to be effective.

Furthermore it's advisable to carefully watch the market for electrical ways for transportation. Many new developments are expected in a short time.

It is recommended to collect quantitative information about the ownership and use of electric bikes. Very few data are available, which makes it difficult to model the factors that describe the ownership and use in a reliable way.

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_Last year’s Theses_
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

Building Engineering

Damage investigations in concrete buildings
Student: Carolina Miró-Downey

Sustainable Facade for the Energy museum
Student: S. Esmailzadeh

Structural feasibility study and design of a portable stadium
Student: A.H. den Hollander

“Parametric Collaboration Tool” from architectural input to engineering output
Student: Oswald Verbergt

Design tool for determining the sustainability of structural designs
Student: F.T. Tool

Crack formation in structural slabs on underwater concrete
Student: W.H. van der Woerdt

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. Labrujere

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 armour 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: 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*
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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*

Rütte-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*

Air-gap assessment during severe weather conditions
*Student: Bart Slingerland*
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

Building Engineering

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

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
Student: Marco Spikker  
Binnenvaart Service Centrum op Maasvlakte 2, een haalbaarheidsstudie  
*Student: Robert Zuidegeest*

### 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 verkeersmissies 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 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 Wielen*

The added mass effect in centrifugal pumps  
*Student: J.M. van Wijk*
Master’s Theses October 2009

Civil Engineering Theses

Structural Engineering

Comparison of load redistribution in concrete bridges by theoretical and Finite Element approach
Student: Bilal Ahmad

Impact of initial investment on repair and maintenance strategy
Student: M.E. Becht

Achieving neutral stresses in renewed railway switches and crossings
Student: S. Boogaerdt

The ultimate load carrying capacity of laterally restrained concrete decks
Student: Godfrey Chamululu

Building acoustic aspects of IFD-units, Research to the nowadays quality and possibilities for improvement
Student: A.M.J. Hietland

Numerical analysis of load-carrying capacity of thin-webbed post-tensioned T-beam using ATENA
Student: Enny Kurniawati

The durable hybrid bridge. The use of fibre-reinforced plastics in concrete bridges
Student: A.J. Langedijk

Maximum possible diameter of the Great Dubai Wheel
Student: Wout Luites

Dynamic nonlinear finite element analysis of structures subjected to explosions
Student: Shen Ma

Development of a mix design method in the laboratory for mixes with Recycled Asphalt Pavement in the drum mix facility
Student: Girum Mengiste Merine

Maintenance strategies for the TANZAM highway in Tanzania
Student: A.K. Mwinchande

Fiber Reinforced Cementitious Composite Tailoring through 3D Lattice Fracture Simulations
Student: Herry Prabowo

Stability design for frame type structures
Student: R.P. Veerman

Hybrid concrete elements in a marine environment
Student: N. Waterman

Building Engineering

The appreciation of the thermal indoor environment in practice
Student: Dennis Faas

Sustainability, Flexibility and Costs of High-rise
Student: Ing. S.C.B.L.M. van Hellenberg Hubar

The extent to which the EMVI instrument has contributed to the achievements of the business objectives of Rijkwaterstaat
Student: C. Otto

Living Apartment Concept
Student: C. Sekanyambo

Tool to design masonry double-curved shells
Student: T.J. van Swinderen

Improvement through insulation: insulation on the interior of existing dwellings
Student: R.M. Tersteeg

A supply-driven approach applied to the Contractor’s organisation
Student: Martijn Verster

Regeneration of zeolites used for ammonium removal from anaerobic groundwater
Student: Y. Mikkers

Transport & Planning

Towards Sustainable Urban Water Management in Brazil
Student: Elwin F. Bakker

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

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

Calibrating a traffic microsimulation model with a phase based algorithm to make the trajectories suitable for traffic emission predictions.
Student: Frank de Groen
Verbetering vervoeringsproces GVVP's

Student: R.J. in ‘t Hout
Optimization traffic control using route information

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

Student: Jun Li
Reducing Travel Time Loss in Financial Services

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

Network Performance Degeneration in Dynamic Traffic Assignment
Student: Wouter Schakel

Vrouwezand, island in lake IJsselmeer
Student: Bart Simon

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

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

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

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**Offshore Engineering Theses**

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

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

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

Grab Dredger Optimization
Student: Rikrik Gantina

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

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

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

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

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

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

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

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

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

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

Influence 90 degrees bends on the pressure losses in slurry transport
Student: A.R. Verschoor

Structural Design of North Side of Breda Central Station
Student: Yirui Yao

Hydraulic & Geo Engineering

Non-hydrostatic modelling of waves in layered fluids
Student: S.H. Balkema
<table>
<thead>
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<th>Title</th>
<th>Student</th>
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<tr>
<td>Formulation and Quantification of the Distributed Collinear Triad Approximation</td>
<td>Matthijs Benit</td>
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<td>Stability of a single top layer of cubes</td>
<td>R. van Buchem</td>
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<td>How biofilms influence morphology.</td>
<td>Myron van Damme</td>
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<td>Dune growth on natural and nourished beaches</td>
<td>Thijs Damsma</td>
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<td>Toe structures of rubble mound breakwaters. Stability in depth limited conditions</td>
<td>R.E. Ebbens</td>
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<td>A Numerical Study on Design of Normal &amp; T-Head Coastal Groins</td>
<td>Sepehr Eslami Arab</td>
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<td>The functional flexibility of lock design, applied on the Meuse route</td>
<td>Ramon de Groot</td>
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<td>Wave physics in a tidal inlet – Part I &amp; II</td>
<td>Paul J. van der Ham</td>
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<td>Simulation studies to openings of the Calandbrug</td>
<td>B. Hiemstra</td>
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<td>Implementation of a wetting and drying algorithm in a finite element model</td>
<td>Anna Kroon</td>
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<td>Using Texel Inlet as a sediment transport belt</td>
<td>J.W.A. Lakeman</td>
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<td>The energy polder</td>
<td>Leslie Mooyaart</td>
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<td>King Abdullah Economic City Port Master Plan, Kingdom of Saudi Arabia</td>
<td>J Nammuni nee Krohn</td>
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<td>New Orleans Storm Surge Barrier</td>
<td>Ruud Nooij</td>
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<td>Failure of Peat Dikes due to Drought</td>
<td>Nterekas Dimitrios</td>
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<td>Modelling the 1775 storm surge deposits at the Heemskerk dunes</td>
<td>A.D. Pool</td>
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<td>Loads on underwater concrete floors and tension piles due to swell</td>
<td>Rogier Schippers</td>
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<td>Generating electricity from waves at a breakwater in a moderate wave climate</td>
<td>J.E. Schoolderman</td>
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<td>Constructing a parking garage underneath historical city canals – a case study</td>
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<td>Analysis of wave impact on the elastocoast® system</td>
<td>R.W. Sluijsmans</td>
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<td>Evaluation of Material Models for Liquefaction</td>
<td>Anteneh Biru Tsegaye</td>
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<td>Water jets surrounded by an air film</td>
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<td>Movable water barrier for the 21st century</td>
<td>Floris van der Ziel</td>
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<td>Stability of morphological cells to dredging-dumping activities</td>
<td>Nicolas Zimmermann</td>
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<td>Effect of the concrete density on the stability of Xbloc armour units</td>
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<td>Water management</td>
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<td>Water use of jatropha</td>
<td>Roel Blesgraaf</td>
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<td>A new perspective on continental moisture recycling</td>
<td>R.J. van der Ent</td>
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<tr>
<td>A function-oriented methodology of flood vulnerability assessment</td>
<td>Zhen Fang</td>
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<tr>
<td>The influence of clay cracks on the rainfall-runoff process</td>
<td>H.E. Geertsema</td>
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</tbody>
</table>
Optimization of the rainfall-runoff response in urban areas by using controllable drains
Student: David Haro Monteagudo

Improved disaster management with use of Statistics Netherlands data
Student: J.T.M. Kuilboer

Investigation subsurface iron and arsenic removal: anoxic column experiments to explore efficiency parameters
Student: H. van der Laan
Research groups and professors within the faculty of Civil Engineering and Geosciences

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<thead>
<tr>
<th>Specialisation</th>
<th>Name</th>
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<td><strong>Design and Construction</strong></td>
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<td><strong>Construction Mechanics Research Group</strong></td>
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<td>Construction mechanics</td>
<td>Prof. J.G. Rots</td>
<td>83799</td>
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<td>Dynamics</td>
<td>Prof. A.C.W.M. Vrouwenvelder</td>
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<td>Numerical mechanics</td>
<td>Prof. L.J. Sluys</td>
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<tr>
<td><strong>Materials Science and Sustainable Construction Research Group</strong></td>
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<td>Acting chairman</td>
<td>Prof. K. van Breugel</td>
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<td>Fund. and Applied Materials Science</td>
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<td>Road Construction</td>
<td>Prof. A.A.A. Molenaar</td>
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<td>General Construction Design</td>
<td>Prof. L.A.G. Wagemans</td>
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<td>Concrete structures</td>
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<td>Concrete modelling &amp; materials</td>
<td>Prof. K. van Breugel</td>
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<td>Building physics and installations</td>
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<td>84581</td>
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<td>Steel construction of buildings</td>
<td>Prof. J.W.B. Stark</td>
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<td>Prof. J.N.J.A. Vamberský</td>
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<td><strong>Product Design Research Group</strong></td>
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<td>Methodical Design</td>
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<td>Prof. G.S. Stelling</td>
<td>85426</td>
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<td>Environmental hydro informatics</td>
<td>Prof. A.E. Mynett</td>
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<td>General Fluid Mechanics</td>
<td>Prof. J.A. Battjes</td>
<td>85060</td>
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<tr>
<td><strong>Hydraulic and Offshore Engineering Research Group</strong></td>
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<td>Probabilistic design and</td>
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<td>Hydraulic Structures</td>
<td>Prof. J.K. Vrijling</td>
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<td>Coastal Engineering</td>
<td>Prof. M.J.F. Stive</td>
<td>84285</td>
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<td>Ports and Inland Waterways</td>
<td>Prof. H. Ligteringen</td>
<td>84285</td>
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<td>River morphology &amp; River Engineering</td>
<td>Prof. H.J. de Vriend</td>
<td>81541</td>
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<tr>
<td>Offshore Engineering</td>
<td>Prof. J. Meek</td>
<td>84777</td>
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</table>
Water Management

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

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

Transport & Planning

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

Applied Earth Sciences

**Applied Geology Research Group**
- General Geology: Prof. S.B. Kroonenberg 86025
- Production Geology: Prof. S.M. Luthi 86019

**Resource Engineering Research Group**

**Petroleum Engineering Research Group**
- Oil- and Gas production systems: Prof. P.K. Currie 86033
- Reservoir Technology: Prof. W.R. Rossen 86038
- Reservoir Engineering: Prof. C.P.J.W. van Kruijsdijk unknown

**Applied Geophysics and Petrophysics**
- Geophysical Imaging Methods: Prof. W.A. Mulder 83666
- Integrated Time-Lapse Methods: Prof. R.J. Arts 85190
- Technical Geophysics: Prof. C.P.A. Wapenaar 82848
- Reservoir Systems & Control: Prof. J.D. Jansen 87838

**Geo Engineering Research Group**
- Soil mechanics: Prof. F. Molenkamp 85280
- Groundwater mechanics: Prof. F.B.J. Barends 85423
- Foundation Engineering: Prof. A.F. van Tol 85478
- Underground Space Technology: Prof. J.W. Bosch 82844
- Geo environmental engineering: Prof. J. Bruining 86032