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CONSTRUCTIEF ONTWERPEN

Koersief

EDITION 102
May 2017

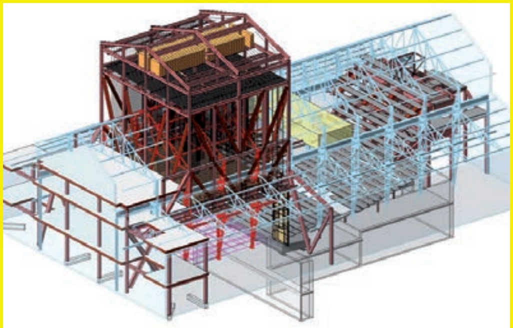
Water Engineering

Slimme en efficiënte constructies voor nieuwbouw en hergebruik

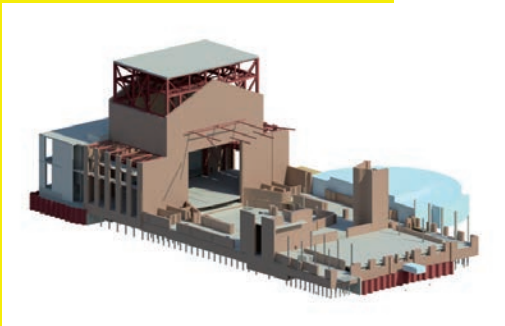
IMd

Raadgevende
Ingenieurs









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Editorial

Dear reader,

Water covers 71% of the Earth's surface and is vital to all known forms of life. Humans use approximately 119 liters of water a day (2013). So it is not strange that cities are built near water. These cities are still expanding: not only on land or in the sky, but also on water. Due to global warming, the risk of floods has increased and these dense populated areas are in danger. We, as structural engineers, are building the future and have to take on the battle with water. For that reason, this edition of the KOersief is about how to deal with water: 'Water Engineering'.

But what does water engineering mean? Water engineering focuses on how water interacts with all aspects of the built and natural environment. This includes tasks, such as agriculture (draining), coastal and flood protection, and to secure future water supply.

In this edition of the KOersief, we focus on the structural part of water engineering, namely: protecting the coast, building the largest aqueduct of the world in Muiden, and even building an airport on water! Since the Netherlands is already world leading in fighting water, of course, we cannot ignore the Delta Project.

As some of you might have noticed, I have been part of the editorial board of the KOersief for quite a long time (this is number eight). However, this is my first edition as editor-in-chief. So, I hope you will enjoy reading this edition of the KOersief.

On behalf of the editorial board,

Angelique van de Schraaf
Editor-in-chief KOersief 102

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Chairman's note

Dear KOers members and relations,

That went fast! Almost three-quarters of the way into this academic year. 2017 started in an educational way with two courses, one on SCIA engineer and one on MatrixFrame. The courses provided the students with extra knowledge that helped even the mostly autodidactic students to optimize their workflow and to perfect their work. The first lunch lecture this semester was on the structural puzzle that is called the Nhow Amsterdam RAI hotel, a collaboration between architect OMA and Van Rossum. Steven Schoenmakers (an old board member) worked on the structural design of this building and was able to answer all the questions of the KOers members.

After the mid-year General Members Meeting and some skiing, one of the big events of the year took place, namely the KOers Design Challenge. Participants enjoyed a full day of lectures on the design of structures optimized to resist earthquake loads; A theme that is very hot right now. After the lectures, the student groups were presented different materials and were tasked to build a tower with a height of 2 meters. These structures were tested in the Structural Design laboratory by subjecting them to a seismic load. The successful day came to an end with a networking drink. As chairman, I would like to thank the committee that organized this day for all their work and dedication to teaching their fellow students.

In a few weeks, KOers will visit the city of Copenhagen. A city that knows a lot of trendy, new, and modern buildings and, of course, a little mermaid. The participating KOers members will visit local engineering companies, marvel at newly built structural wonders, and, of course, get to know each other better.

KOers is also very sporty this year, as we will join in not one, but two concrete canoe races. The first one in the Dutch city of Enschede and the other in the German Cologne. The speed and strength of the members will be tested and the ingenuity of the Concrete Canoe Race Committee is shown with a new unique canoe that is under construction. In short, plenty to look forward to.

On behalf of the 47^{th} board of KOers,

Lars Croes
Chairman of the 47^{th} board of KOers

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CONTINU

Intermediair voor bouw en industrie

Kijk eens goed om je heen, al je medestudenten zijn na je studie jouw concurrenten. Oriënteren en specialiseren tijdens de studie is dus nog niet zo'n slecht plan. Want direct je droombaan vinden na je afstuderen is niet vanzelfsprekend. Met de juiste persoonlijke begeleiding en kennis van de markt helpt Continu jou met die eerste stap in je carrière. Daarvoor zijn we tenslotte intermediair.
Je carrière wacht op je, waar wacht jij nog op?

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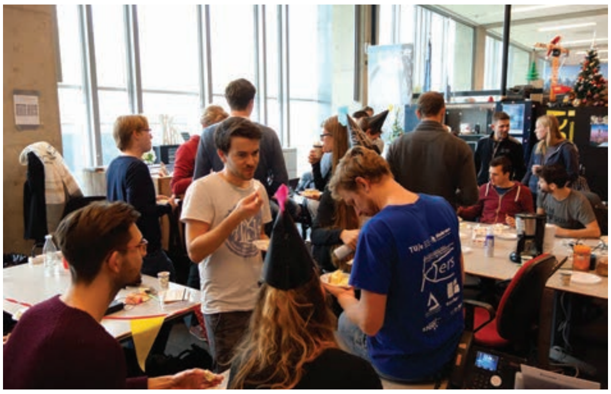
Agenda

Sinterbock drink — *December 6th*



Dies Natalis KOers — *December 21st*

Excursion Sapa — *January 13th*

Beerpong battle royale with Mollier — *February 2nd*

KOers Coffee Time

Weekly — KOerscorner, Vertigo floor 2, TU/e

Every Wednesday during the lunch break, KOers serves a nice cup of coffee or tea. Allow yourself to have a break and join us on Wednesday between 12:30-13:30h on floor 2.

Concrete Canoe Race

May 12th till 14th — Enschede

June 9th till 11th — Cologne

This year, KOers will participate at the Concrete Canoe Race twice. The first challenge will be in Enschede. Here, we will not only compete for the speed prices, but also for the innovation price with a printed canoe. Four weeks later, we will show Germany what we are capable of in Cologne.

Excursion Witteveen+Bos

May 18th — Amsterdam

Currently, the A9 Gaasperdammerweg is being expanded to two times five traffic lanes. A part of the new road will pass through a land tunnel, to improve the livability of the surrounding residents of the Gaasperdammerweg. The structural design will be presented at the office of Witteveen+Bos and we will visit the site afterwards.

Continu Career Event

May 30th — TU/e

This event is a collaboration between Continu and KOers. In this afternoon, KOers alumni will tell their story about being a starting employee. What steps they have taken to find a job and what obstacles they have encountered. Also, companies will introduce themselves to you during this event. You might even find your future employer?

Excursion Royal HaskoningDHV

June 2nd — Utrecht

Utrecht Central Station is the largest transport junction of the Netherlands. Due to the rapidly increasing number of travellers, the station gets a total transformation. Two of these new projects are the bicycle parking and station square East (SPO), and the North building, in which Royal HaskoningDHV is involved. They will inform us about the structural design of these projects and we will visit the site.

SCIA Engineer course — *February 17th*

Innovatief en duurzaam

BAM heeft de ambitie voorop te lopen in duurzaamheid en innovatie. Robotisering, 3D-printers en drones bieden nieuwe mogelijkheden in het bouwproces. Met internet of things, data en virtual reality kan slim worden ingespeeld op de behoeften van eindgebruikers. En wat is het effect van zelfrijdende auto's op de infrastructuur van de nabije toekomst? De klant, de eindgebruiker en de omgeving staan centraal in ieder project, daarom zoeken wij voor elke vraag een duurzame oplossing. **BAM vernieuwt. Jij ook?**

Wil je weten hoe het is om te werken bij BAM?
Kijk op onze website en social media voor verhalen van jonge BAM-medewerkers en lees wat jouw mogelijkheden zijn:

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Constructing in water

By: Denise Kerindongo
Editor KOersief

As the name of the country 'the Netherlands' already mentions; living in the Netherlands means that one has to deal with a lot of water, because part of the land is positioned below sea-level. For centuries, the Dutch have been dealing with water. Over time, the Dutchmen have developed quite some knowledge about how to keep the water away from the land by building all kinds of structures. Now, even abroad the Dutch knowledge is wanted.

The Netherlands is surrounded by water. To protect the land from water, dikes were built. In 1953, an essential lesson was learned in the Netherlands. Due to the massive northwesterly storm, and a spring tide, dikes broke and a huge area flooded. This event triggered several measures. In order to prevent such a flood from happening again, plans were made for the Delta Project. The plans involved strengthening the coast. All connections to the sea were closed off by surge barriers and several dikes were reinforced.

If the Dutch word for water engineering structures is literally translated into English, these structures are called waterworks. And indeed, water does work. Due to the forces of the water, it is needed to design these kind of structures. In the Netherlands and in other parts of the world, all kinds of water engineering projects have been realized. These are structures such as dikes, dams, weirs, and sluices. Each type has the purpose to keep water away, but each type has its own way of doing this. In order to prevent confusion while reading this KOersief, the structures will be explained.

Weirs
A weir is a general term for all water constructions that have the function to prevent water from entering a certain area. These constructions can both be man-made or occur naturally. They can be the boundary between two areas with different water levels or just a way to avoid water getting into a certain zone.


Figure 1: Norris Dam (left) and Sluice Engelen (right)

Dikes
A dike is a man-made tall wall, placed along a river or sea. The function of a dike is to keep the land behind it dry. A dike is made by raising a part of the soil. Dikes are not only used to protect against high water levels, but they are also used to regulate irrigation. There are different kinds of dikes, these kinds are based on the sort of water that they need to stop, for instance sea water or river water.

Dams
A dam is a long, relatively low elevation of the soil to stop water, placed straight through a water area. Dams are artificially made by men or they can be made by beavers naturally.

Figure 2: 'Westerschelde' dike

Figure 3: Dunes of Texel

Sluices
Sluices are movable water retaining structures with the function to form both a separation and a connection between two water areas with different water levels. Once the doors of a sluice are closed, the water level of the enclosed area can be regulated. Similar to this concept, locks make it possible for ships to bridge different water levels.

Dunes
Dunes are sandy hills naturally formed by wind. The dunes also form a wall of protection against the water of the sea.

More in depth structural information about different water engineering projects can be read in this KOersief. Other relevant projects are a part of this edition as well, not only in the Netherlands but also in other places in the world. One can see that the same problems, concerning water engineering, exist everywhere. The difference can be found in the way one deals with these challenges to design with water. ◄

Figures:

1 *S. Skutnik (2012)*
2 *J. van Tussenbroek (n.d.)*
3 *H. van Reeken (2007)*
4 *Victor Lancee (n.d.)*

The Delta Project: The Maeslant barrier

By: Lieneke van der Molen
Editor KOersief

As known, the Netherlands is mostly below sea level. Back in the days, migrants settled in the Netherlands and built their houses on high embankments near the shore. In order to protect themselves against high water, they built mounds on which they took refuge when necessary. Over time, the technique to protect our country against the sea evolved, which resulted in the creation of dams, canals, dikes, locks, and windmills. In 1953, a flood occurred that took the lives of 1,853 people and over 200,000 pieces of cattle, engulfed 200,000 hectares of fertile land, and damaged over 47,000 houses, factories, and offices. Such a disaster had to be prevented in the future, and therefore a special appointed Delta Committee came up with a plan. This plan resulted in the Delta Act, which was approved by parliament in 1957. In addition to providing protection against the sea, the Delta Project would improve water management, reduce soil salination, produce freshwater reservoirs, and create new recreational areas, while the new dams would greatly improve the access to the south-west of the Netherlands.

The Delta Project presented Dutch hydraulic engineers with an enormous challenge. Back then, no other nation in the world had ever closed off tidal inlets of this size and depth before. Also, the know-how and technologies that were needed to do so did not yet exist. Thus, the conclusion was that these new technologies had to be developed fast. One of these innovations was prefabrication and it was soon to be widely applied. In addition, new specialist equipment was developed, including the introduction of lock caissons in 1961 and a cableway with gondolas to carry out work on wider inlets. New laboratory techniques allowed for increasingly sophisticated hydrodynamic research, computers gained ground, and measuring techniques and weather forecasts became increasingly accurate. Together, a new age had dawned for hydraulic engineering, and it looked as if the Delta Project would be completed within 20 years. The timeline in *Figure 1* shows when each part of the Delta Project was completed.

The original Delta Project involved sealing off as many sea inlets as possible in the south-west of the Netherlands. However, the Western Scheldt and New Waterway had to remain open, to allow shipping to reach the ports of Rotterdam and Antwerp. Therefore, a major dike reinforcement along both waterways was necessary. These reinforcements required historic structures to be demolished, which led to some protests. The solution was to build a storm surge barrier in the New Waterway, for which a competition was held.

The Maeslant barrier
The winning design of the competition, known as the Maeslant barrier, consisted of two curved gates of 210 meters wide each (*Figure 2*). The construction of the project started in 1991 and was completed in 1997. When Rotterdam is threatened with water levels 3 meters above Amsterdams Ordnance Datum (AOD), also known as above mean sea level (MSL), the Maeslant barrier closes off the New Waterway of 360 meters wide and 17 meters deep. The barrier has a number of highly innovative components. The gates may be the most striking, but much smaller and

1958
Hollandse IJssel storm surge barrier

1960
Zandkreekdam

1961
Veerse Gatdam

1965
Grevelingendam

1969
Volkerak lock

1971
Haringenvlietdam

1971
Brouwersdam

1986
Eastern Scheldt dam

1986
Oesterdam

1987
Philipsdam and Krammer lock

1987
The Bath Discharge Canal

1997
The Maeslant barrier

1997
Europoort and Hartel barrier

Figure 1: Timeline Delta Project

less visible are the special ball hinges. Both components are unique in the world. A computer system decides whether or not to close the Maeslant barrier, calculating possible water levels in Rotterdam and Dordrecht on the basis of water and weather forecasts.

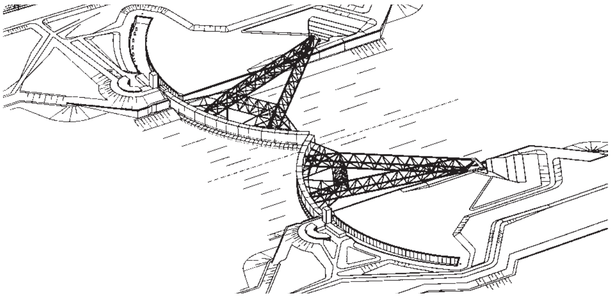

Figure 2: Drawing of the Maeslant barrier

The delta
The ancient Greeks called the area around the mouth of the Nile the 'delta'. In later years, this name was given to all river estuaries with several distributaries. The Rhine, the Meuse, and the Scheldt form the biggest delta in north-western Europe. Deltas are vulnerable to flooding, but their location, their fertile soil, and their varied fish stocks have always drawn people to them. These are very attractive places to live and because they provide excellent opportunities for farming, fishery, trade, and industry, they are of great economic importance. This is why people throughout the ages have settled in delta areas, despite the flood hazard.

The gates
Each gate consist of a steel barrier and a truss. The truss is composed of 28 hollow compartments and has a length of 245 meters. The steel barrier has an arch length of approximately 200 meters with an average height of 22 meters. The force distribution is as follows: local water pressure acts on both sides of the steel barrier, the differential pressure is transferred to the longitudinal stiffeners, the load is then transferred to the transverse truss, followed by the so-called 'super beam'. Since the structure is rather slender, the stability check was of great importance. In order to cope with the complex force distribution, a finite element model was constructed of the complete structure. In addition, local models were made to describe different load bearing behaviors in different structural elements.

Normally, the gates are kept in docks on the shores (*Figure 3*), but when a storm surge threatens, the docks are submerged resulting in floating doors. Within 30 minutes, the doors are able to move to the middle of the New Waterway. Once the two gates meet, the valves in the walls open with the result that the gates sink and stop above the concrete sill on the river bed. The powerful current under the gates flushes sludge from the sill, and within an hour, the gates have landed on the clean sill, protecting the area behind from flooding.

Figure 3: The gate on shore

The ball hinge
The extreme horizontal load on the barrier during a storm equals 350 MegaNewton. The ball hinge, located at the end of the gate, must be able to rotate under these loads. In addition, the hinge must allow vertical rotation, when the docks are submerged. The ball hinge is 10 meters in diameter and has a weight of 680 tonnes. *Figure 4* indicates the weight of different elements within the ball hinge.

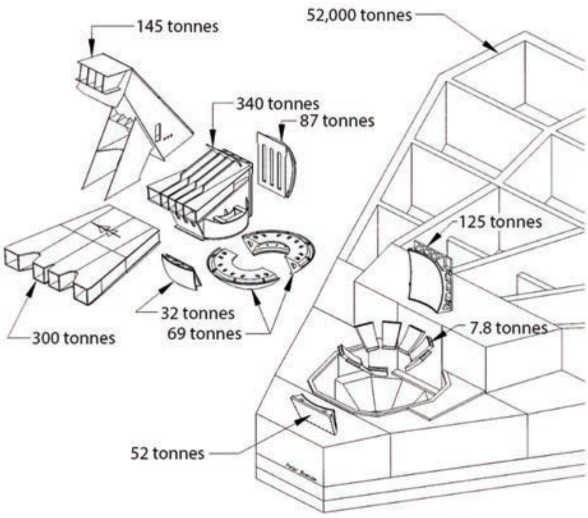

Figure 4: The gate on shore

The load on the barrier in combination with half of the weight of the gates determines the size and direction of the resulting force on the ball hinge. This resulting force is transferred to the hinge foundation by cast iron bearing seats that are positioned in accordance with the direction of the resulting force. Due to frictional moments, the resulting force will not act on the midpoint of the ball, which creates a great number of different loading cases that make equilibrium with external forces. In addition, the load history is of great importance, because this determine the direction and the size of the frictional moments. The ball hinge is a complex system, and therefore only a finite element model can be used to simulate the stress distribution in the hinge. ◀

References:
[1] *Ministry of Transport, Public Works and Watermanagement and Rijkswaterstaat, 2001, The Delta Project for safety, wildlife, space, and water*
[2] *Berenbak J., 1991, Maeslantkering algemene inleiding – uitvloeisel van Deltawet, Bouwen met Staal 101*
[3] *Kerstens J.G.M, Pollemans P.J.Th. & Timmerman G.K., 1994, Maeslantkering, Nieuwe Waterweg – Gestructureerde berekeningsaanpak vormt de basis voor beheersing van het ontwerp, Bouwen met Staal 121*

Figures:
1 *https://www.rws.nl/water/waterbeheer/bescherming-tegen-het-water/waterkeringen/deltawerken/index.aspx*
2-4 *Bouwen met Staal*

"Omdat het oog heeft voor de ontwikkelingen in de maatschappij en de markt èn voor zijn medewerkers." *Margot van de Moosdijk, adviseur*

Advies- en ingenieursbureau Movares, actief op het gebied van infrastructuur, mobiliteit, ruimtelijke inrichting, water en energie stimuleert mensen zichzelf te zijn. Wij geven je de ruimte om je leven in te richten op een manier die bij je past en die je capaciteiten tot zijn recht laat komen. Bij ons werk je aan duurzame oplossingen voor maatschappelijk relevante projecten. Met een grote mate van eigen verantwoordelijkheid en volop ruimte voor flexibiliteit en persoonlijke ontwikkeling. En de mogelijkheid om mede-eigenaar te worden. Spreekt dit je aan? Praat eens met ons.

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An interview about a fascinating engineering field

Hydraulic engineering

Interview with: Fokke Westebring
Civil engineer and project manager at LievenseCSO

By: Thomas van Vooren & Eline Dolkemade
Editors KOersief

The Netherlands and water are inextricably linked. It is a constant threat to our low-laying country which caused several disasters over the years. However, as Johan Cruijf would have said: "every disadvantage has its advantage". That is why the Netherlands is world famous in the fields of land reclamation, water management, coastal engineering, and flood protection. One of the companies in the Netherlands that has a lot of specialized knowledge and experience in these fields is LievenseCSO. We spoke with Fokke Westebring, civil engineer and project manager at this company.

Can you introduce us with LievenseCSO?
LievenseCSO has fused twice, which led to many different departments such as, pipelines, buildings, infrastructure, and environmental research. These departments also work together. A great example is the lock in Terneuzen. For this project, we did a two year planning study at the start of the project. However, the company has experience in many fields. For other projects, we do the detailed design until the last bolts. Nowadays, most projects are 'design and construct', which ensures close cooperation with the contractor. If we get the assignment, we stay with this contractor and we will be responsible for the whole project. Sometimes, we also do supervision work, where we check the contractor at site.

About Fokke
Fokke studied Civil Engineering at the Delft University of Technology. He started working for LievenseCSO 15 years ago. Fokke started as a structural engineer, but is nowadays project manager for projects in the field of hydraulic engineering mainly in the planning phase. This field is his passion and he is specialized in quays, locks, dikes, and water security.

What are the differences between the structural design in built environment and the structural design that involves hydraulic structures?
The similarity with structural design is to find out what the client wants. An important difference between these two fields is the variation of the boundary conditions for hydraulic engineering, which always includes water. Structural engineering has standards for most loads, like wind or variable loading. This is not the case for hydraulic engineering, because currents, waves, and tides are different everywhere. The large amount of margins makes it difficult and time consuming to determine all boundary conditions. An experienced engineer can more easily determine which factors are more important than others.

How do you deal with these kinds of loads?
Some calculations can be done by hand, but for other calculations, large models are needed. This is also the case for large waves, where simulations are necessary to determine the forces caused by waves on, for instance, a

jetty. Besides the present water conditions, the rising sea level is an important aspect that must be taken into account. Coastal structures should now be designed for impact of waves of the future, which could increase because of the changing climate. The Royal Netherlands Meteorological Institute (KNMI) predicts scenarios of the rising sea level, which also depend on rainfall intensity and wind. A lock often has, in addition to retaining water, a draining function. For these kinds of locks, rainfall is very important and sometimes, the whole basin behind a canal needs to be analyzed.

Figure 1: Cruise terminal in Grenada

Which project was the most interesting and challenging for you?

The lock in Terneuzen is a large project in the planning phase. For this project, I did the technical management in the planning phase. This involves not only the design of a structure, but handling all the boundary conditions like roads, noise, etc. For all these boundary conditions, a study had to be carried out. I led these studies and used them for the design of the lock, not by just doing calculations, but by determining how the lock fits best into its surroundings. In the Netherlands, we define the design in a Route Decree (Tracébesluit) that anyone is able to look at. The designs almost always go along the Council of States, which can result in a delay of months or even years. Since this was not the case for the lock in Terneuzen, it was a confirmation that we had done it correct. Another interesting project was the cruise terminal in Grenada (*Figure1*), which was my first project as Project Manager. Unfortunately, I have never been to the location. It becomes more common with projects in foreign countries that the engineers in the Netherlands never visit the project. We then hire a local engineer to help with communication and collecting information. This is not a full time job, therefore it is not profitable to send someone of our own to the project.

Are we, as structural engineers, suited for the job?

For geotechnical engineering there are similarities, like the design of construction pits. A lot of our employees graduated from Delft University of Technology as civil engineer where they also get courses about fluid dynamics. Experience is very important for this field, but some knowledge about waves and currents from your study is a must. There are not many individual courses you can follow about these subjects.

What do you think of hydraulic engineering in the future?

The Netherlands is at a leading position, considering the field of flood protection. We are still developing our skills and the way to deal with this subject. Currently, there are some new standardizations introduced, considering the rising water level and climate change for structures at the coast, which should, of course, be taken into account

LievenseCSO

LievenseCSO is a prominent representative of the specialized knowledge and experience in the fields of which our country of origin - The Netherlands - is world famous: land reclamation and physical planning, flood protection and water management, hydraulic and coastal engineering, and environmental management and engineering.

The prosperous birth of LievenseCSO in 2013 resulted from the merger of the renowned Dutch consulting firms Lievense and CSO.

Prior to this event, both firms had proven their successful cooperation on many projects in their joint fields of focus and activity: coastal areas, river plains and deltas, the environmental issues ensuing from human activities, and economic developments in these densely populated and vulnerable areas.

Lievense was founded in 1964 and afterwards developed into a specialized international engineering consultant in the fields of civil engineering, port development, rivers and waterways, coasts, polders, water management, and transportation pipelines. Lievense's expertise is rooted on geotechnical, hydraulic, and structural knowledge and analyses. Their services cover the entire range of project development phases: feasibility study, master planning, field investigation and environmental impact assessment, design, permit application, cost assessment, tender preparation, contracting, construction supervision, contract management, and institutional support.

CSO, founded in 1982 and rooted in the earth sciences, grew after its establishment to a consultancy firm of scientists, planners, and technical specialists, active in the field of soil and subsurface, (ground)water management, water safety, and environmental analyses and technology. It covers the disciplines physical geography, geology, hydrology, environmental sciences, ecology, spatial planning, and law and legislation. Their services include spatial planning, survey, field investigation and laboratory analysis, assessment, pollution remediation and monitoring, hydraulic and environmental modeling, process optimization, and environmental management.

In 2015, the engineering consultancy Bartels Consulting Engineers was added to the LievenseCSO group. This international consultancy company has over 150 employees in the Netherlands, Poland, Ireland, Germany, and Ghana.

for future projects. More landward, the future amount of precipitation influences the way of designing. Another important item is the automization of ships and the method of loading and unloading ships in the harbor. Harbors, and thus coastal structures, have to be designed for future systems.

Can you give us students some tips?
Good question. I would say, do not spend all your time on studying. Personally, I had a period during my study where I had less motivation. I started sailing and got a skipper certificate. Eventually, this helps me in my current job to get better understanding of the preferences of the shipping industry when designing sluices and so on. I know it is not ideal to take a pause in your student time nowadays, but I would recommend to do some interesting stuff besides your study to develop and improve yourself. ◀

Figure:
Header, 1 *www.LievenseSCO.nl*
Portrait *www.linkedin.com/in/fokkewestebring*

Lock in Terneuzen
The current lock system Ghent-Terneuzen is a bottleneck for many passing inland and seagoing vessels. In 2012, Flanders and the Netherlands therefore decided to prepare the construction of a new, larger sea lock. The new lock is 427 meters long, 55 meters wide, and 16 meters deep. LievenseCSO is responsible for the execution of all related research. In addition to the elaboration of an appropriate technical design, shipping simulations, groundwater modeling, salinization, studies on noise, effects on nature and air quality, external risks, and morphological studies have been done.

Fokke: "There is a west, middle, and east lock. Because the lock was at its limit, the middle lock will be removed and replaced by a longer, taller, and deeper lock. A lock is a kind of traffic light, which results in queues and 'traffic jams'. For this lock, the waiting periods became too long, because of a combination of larger and more vessels. Both inland and seagoing vessels have different requirements that need to be taken into account. After the replacement, ships that can pass the Panama lock are then also able to pass the lock in Terneuzen."

Cruise terminal, Grenada
To facilitate more and larger cruise vessels, the Caribbean island of Grenada wished to develop a new cruise terminal. This terminal includes land reclamation, quay walls, and a jetty. The land reclamation of 400 acres is reserved for a visitor center, offices and apartments. The main quay wall and the jetty can accommodate two mega cruise ships, including the latest generation cruise vessels of over 335 meters in length. The tender quay is specially designed to enable tender vessels to shore passengers.

A floating structure

Kansai International Airport

By: Caroline Koks
Editor KOersief

Kansai airport, a floating airport, built on an artificial island in the Osaka Bay, Japan. The construction of both the airport and the island, is one of the largest construction projects in the world, designed by the architect Renzo Piano and the structural engineer Peter Rice. It is designed to resist earthquakes, heavy wind loads, and to keep floating. Nowadays, Kansai International Airport is one of Japan's airports. Recognized by the world as one of the most incredible engineering marvels of the 20th century.

Osaka is the ancient capital of Japan, and home to 2.6 million people. The place has become the commercial and industrial center of western Japan. In order to bring in more people, a new big airport had to be constructed to meet the demands of the day and of the future. The only problem was to find a big flat slab of open land in Osaka, because the area is partially mountainous and heavily populated. But how to construct a new airport, without the noise pollution that has spoiled many backyard gatherings?

Therefore, officials decided to locate the new airport offshore. In 1987, the world's biggest man-made island was realized in the middle of Osaka bay. Seven years later, the world has its first international airport, floating out in the middle of the sea all by itself.

The design
Kansai was built 5 kilometers from shore, is 18 meters deep, and contains 530 hectares of landfill. The artificial island covers a massive rectangle of 4 kilometers long and 1.2 kilometers wide. It is connected to the land with the world's longest, two-tiered, bridge. A lot of challenges had to be overcome, because they had never built so far from the land and so deep in the water. Besides, it is located in the middle of the Pacific Ring of Fire, where many earthquakes, tidal waves, and some of the worst weather on the planet occurs, due to the adjacent tectonic plates. A balance had to be found between resisting all the loads of the artificial island, without it collapsing into the very soft layer of clay, which is not the most suitable type of soil. To solve this problem, engineers used a new sand draining technique: sucking the water out of the sand, so it could support the airport's foundation. In addition, an 11-kilometers-long seawall of concrete blocks outlines the artificial island, which keeps the water away and minimizes the sinking of the island. The inside of the seawall is filled with 180 million cubic meters of landfill. It was made sure that the level of compaction was uniform everywhere, by measuring the soil layer height using radio waves, to prevent differential sinking (*Figure 1)*.

The airport terminal's structure had to be light enough to minimize sinking, but it also needs to be strong enough to resist the climate conditions in an area where typhoons and earthquakes occur. Renzo Piano came with an integrated design: a wing-shaped, elongated terminal, made of steel and reinforced glass, of one mile long. The terminal design is a space-saving and architectural wonder, stacking arrivals and departures onto four floors. The ceiling is 30 meters high and 300 meters long. The design of the building is very open. One can see the upper levels from the ground floor. There are 88 escalators and 92 elevators. The 5,000 windows in the facade are all held

Figure 1: Building the artifical island

in place with flexible joints, designed to withstand the most extreme weather conditions. The Sky Gate Bridge is designed to transfer heavy loaded trucks, passengers, and employees to the airport. It is constructed with floating cranes; the workers built each of the bridge's piers one at a time and composed the pieces afterwards. It is the world's longest double-decker truss bridge of 3,750 meters long, allowing two train tracks below and six lanes of traffic on top (*Figure 2)*. The aerodynamic airport opened for business on September 4th 1994.

Figure 2: The Sky Gate Bridge

Occurring problems

After a few years, the airport started to sink a little faster than expected. During construction, the sand draining appeared to take care of strengthening. This accelerated the sinking process, resulting in a stable soil package before the commencing construction of the terminal. Nevertheless, further sinking occurred in deeper soil layers which couldn't be drained. These layers consisted of alluvial; a loose, unconsolidated soil. Since no documentation on how that type of soil settles on the bottom of the sea, engineers tried to estimate the degree of settling that would occur. In 1999, it became apparent that these estimations were totally wrong, as the entire island had already sunk over 8 meters. In schedule, this level of sinking was not expected until 40 years after construction.

To prevent the structure from splitting at the seams, cracking under the pressure caused by uneven settling, engineers gave a small lift to the 900 giant columns, which support the terminal building (*Figure 3*). Each column is equipped with a sensor that is connected to a computerized system. When the island is sinking, the system sends signals where the powerlifting must take place and technicians rush in. Hydraulic jacks, each capable of lifting 300 tons, are inserted between the floor and the column in question. The huge support is lifted and metal

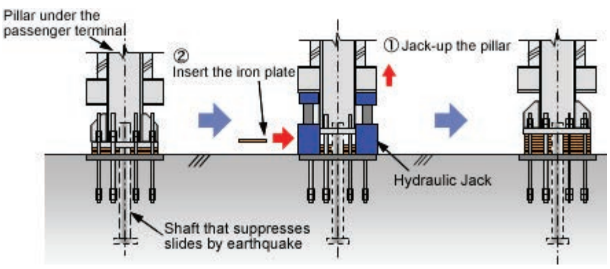

Figure 3: Lifting of the columns

plates are added to raise the height of the upper floors back to level once again. At the end, the basement floor remains at the same level, while the first floor moves up.

But when the roof is raised, the joints of, for example, the floors and the stairs will not fit anymore. Therefore double walls were installed that hang on the first floor. When the floor is jacked up, the walls follow the first floor. Just like the building services ducts in the basement. They are bolted to the ceiling instead of the floor. Otherwise the wires and such will be pulled apart as the building starts to grow. The staircases get one or two extra steps, which are added to the bottom. They will appear after the columns are lifted up.

A second runway

To stay competitive with the other regions, a second runway was addressed. The number of flights can be doubled from 30 to 60 planes an hour. This could also double the airport revenues, since the bills from building the first runway had yet to be paid off. A new island needed to be built in the middle of Osaka Bay. In July 1999, Kansai had launched the construction of its second runway. The building site of phase 2 is situated only 200 meters away from the first island.

The construction of the second island brought issues that no one had foreseen. First, the fact that the island was being built even further away from the mainland. Second, the deeper water meant softer soil under the seabed. Resulting in a possible sinkage of six meters more than its neighbor. On top of that, the additional weight of the second island could even lead to the first island sinking further.

One of the biggest issues of building the first island was the distribution of the landfill, in order to get an even settling. The second island was an even larger island, with a landfill of 250 million cubic meters of mountain sand. However, technology has improved over the last 12 years, and measuring the landfill positioning is changed from using simple radio waves, to the use of global satellite. The maritime safety center, operating 24 hours a day, took a close watch with huge binoculars over the construction vessels, now sharing space with fishing and tour boats, to keep the whole process safe. The reason for this is that the construction site could form a danger to vessels entering the area. Besides, new engineering methods need to be tested. In contrast to the first island, everything had to be constructed only 200 meters next to another artificial island, where people would keep on traveling. Nevertheless, the engineering team managed to open a second runway with its terminal on August 2nd 2007, with a capacity of 66 planes. ◄

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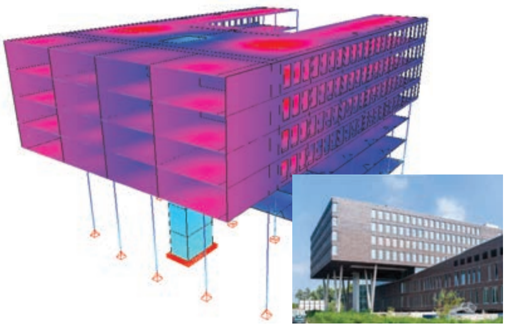

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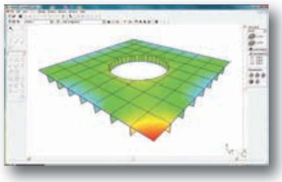
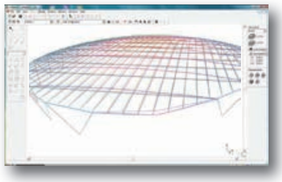
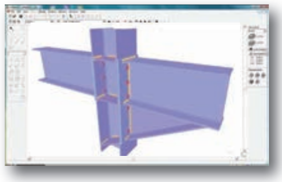

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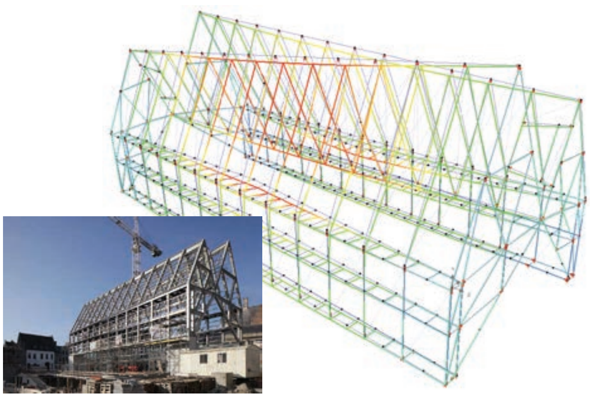

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Building with Nature: passive coastal protection using wind, waves, and tides

The Sand Motor

By: Denise Kerindongo
Editor KOersief

Nowadays, after completion in 2011, one of the largest scientific experiments in coastal protection is still taking shape: the Sand Motor off the coast at Ter Heijde, the Netherlands. The Sand Motor is an artificial peninsula designed to nourish this part of the Dutch coast for the upcoming 20 years. It is an innovative and sustainable alternative to the traditional methods of coastal protection. Under the influences of waves, tides, and wind, the Sand Motor slowly spreads sand towards the beaches and dunes. Nature does its job and creates a constant changing landscape available for natural developments and recreation. Different plants, birds, and other animals emerge, while nature lovers explore the fascinating and unique coastal landscape of the Sand Motor.

Extra space for nature and recreation

The Sand Motor is a pilot project initiated by mankind, but with nature doing the rest of the work. The Van Oord - Boskalis consortium constructed the artificial peninsula by depositing a large quantity of sand in the form of a hook. The approach is seen as a climate-robust and nature-friendly way of preventing coastal erosion, while at the same time new areas for nature are developed. This project is unique, because it has never been performed in a similar way before. Normally, annual beach nourishment operations take place to defend the coast against erosion. With the initiative of the Sand Motor, a lot of sand is added at once in one location. This is done with the help of trailing suction hopper dredgers (*Figure 1*). Eventually, an area of 128 hectares of new beach and dunes is formed. Since the frequency of disturbance is way less, compared to the traditional methods of coastal protection, nature gets the chance to develop new ecosystems for a longer period with more biodiversity than before.

Figure 1: Trailing suction hopper dredger

Approach

To build the Sand Motor, 21.5 million cubic meters of concentrated sand supplements needed to be placed 5 meters above sea level (*Figure 2)*. To plan the realization of the Sand Motor, financial resources, knowledge, skills, and collaboration of all parties involved was essential. For such a large scale project, it was quite a challenge to get everyone on the same page.

Eventually, three goals were defined:

1. Contributing to coastal safety;
2. Adding an attractive area for leisure activities and nature development;

Figure 2: Construction of the Sand Motor (left and right)

3. Stimulate knowledge development about coastal management (to export the knowledge abroad, because it has never been applied in this way before).

At the start of this ambitious project, there were only calculated assumptions about what was going to happen in the next couple of years (*Figure 3)*. There were lots of challenges and numerous questions, like:

- How fast will the sand spread?
- Will it attract more fish and birds?
- Will the changed currents affect swimmer safety?
- How will visitors use the new landscape?

Monitoring

Right after its completion, the Sand Motor was still a largely empty peninsula of sand, ready for nature to spread its sand to the beaches. To carefully monitor this process, a large team of scientists from research institutes, universities, the government, and engineering firms joined forces. They monitor the development of the beach and the seabed, the currents, the dunes, groundwater levels, flora and fauna, as well as the safety of swimmers, the administrative implications, and the value for leisure activities. One way of monitoring is with a laser car. This car scans the sandy area with the help of a laser and measures in a range of 100 meters. The car drives across the beach with a velocity of 20 kilometers per hour and the laser records 100,000 times per second. This method is used to measure the spreading of the sand, compared to the previous spreading. In addition to the growth of the dunes on the Sand Motor, the dunes in the area behind the Sand Motor are monitored. The transfer of the sand on the beach to this area is measured. This is done with the help of sandcatchers and saltcatchers. Every two weeks, the sandcatchers and saltcatchers are taken to the laboratory for further investigation.

Morphological research is performed with a 40-meter high 'Argus mast' equipped with eight cameras. These cameras picture the Sand Motor every half hour. Jet skis are also used to get a view of the morphological changes of the Sand Motor. The jet skis are used at places of the Sand Motor where it is harder to get a view of the changes with the cameras. Monitoring is done in two phases; the first phase is presented in 2016 and the last evaluation will be presented in 2021. The developments until now are found in *Figure 5*. Monitoring the developments is important for justification and communication with stakeholders.

First results

Five years after construction, the time has come for the first conclusions. There are some exciting results that contribute to the knowledge of coastal management.
So far, the Sand Motor has done its job when it comes to spreading sand along the coast. Coastal erosion is prevented and possibilities for nature and recreation are stimulated. Calculations show, that the Sand Motor could be effective much longer than the 20 years that were originally expected. The wind and currents spread the sand mainly in a north-east direction on to the beach and into the dunes. A lagoon formed along the beach, and sometimes cliffs, appear at the northside. Over time, the lagoon became longer and shallower. In 2016, a new canal was formed as a result of a passing storm (*Figure 4)*.

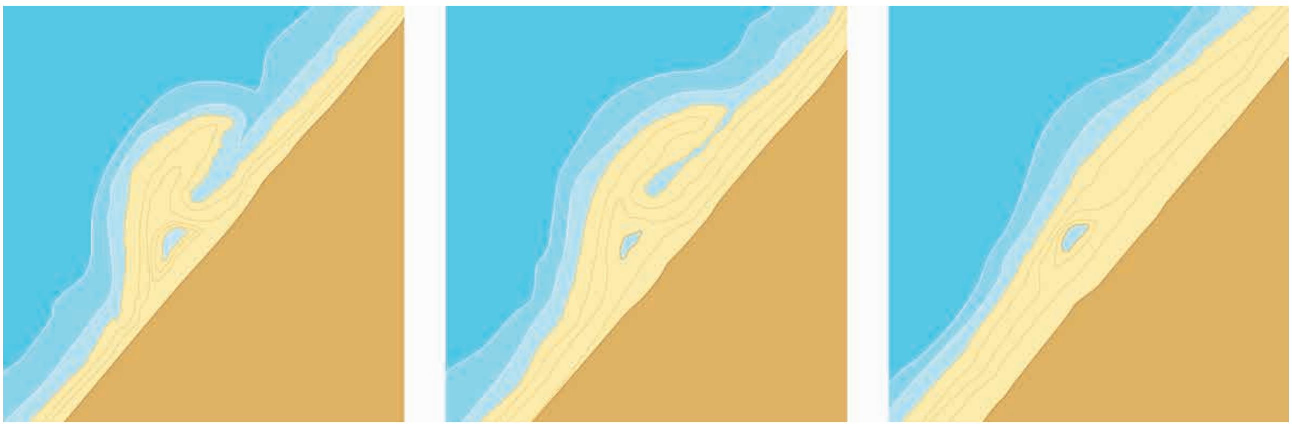

Figure 3: Expected development of the Sand Motor over the years: 2011, after 10 years, after 20 years

Developments

The results of the monitoring process show a slower dune growth in the first five years than has been expected. This is mainly because the sand had to travel a long way to the dunes. On its path, the sand first comes across the lagoon of the dune lake. Once these are filled up more, it is likely that the sand will find its way to the dunes faster. Fortunately, dunes did develop well on the previously built coastal reinforcement.

Characteristic types of beach grass have settled on the Sand Motor. Also the seaholly, a protected plant species, has found its home. At this time, it is not yet possible to say whether the Sand Motor is better for seabed life than traditional coastal nourishments. Therefore, a longer period of research is needed. So far, the researchers encountered small animals such as the bultic clam and the sandtube worm in the lagoon. These species are not often found on the coast of North- and South-Holland. The new coastline creates new types of currents. Therefore, swimmer safety is carefully monitored. Rescue services are very satisfied with a newly developed app, which can also be tailored for other beaches in the world. Leisure activities on and along the beaches near the Sand Motor have increased. Research shows that visitors appreciate this new landscape because of its space and quietness.

Figure 4: Overview of the Sand Motor (2012)

Products

Based on the results of the Sand Motor experiment, the 'Building with Nature' program developed the following products:

- Practical guidelines for the design and implementation of coastal management projects;
- Instruments for a fast assessment of optimal location, volumes, frequency, and form of supplements;
- Detailed simulation models for the prediction of the morphological development in time, the process of the shaping of the dunes, and the effects on the environment;
- 'Lessons learned', including the potential of the concentrated sand supplement to enlarge the coastal protection, while it offers possibilities for nature and recreation;
- Advice concerning the management.

These products might help to apply the concept of the Sand Motor in other locations.

Prospects

Over the past five years, a lot is learned about Building with Nature, but still there are many years to go and a lot of work to do. It is expected that much more knowledge about this ambitious project is gained in these years. Knowledge that contributes to the future of coastal management plans and alternative beach nourishments. Research shows that the concept of the Sand Motor is applicable in other places along the Dutch coastline, as well as in the rest of the world. One of the first concrete follow ups of the plans for a Sand Motor is in Norfolk, north-east of London, England. All the efforts in creating and researching the Sand Motor have proven to be very rewarding so far, and these efforts and findings are very promising for the future.

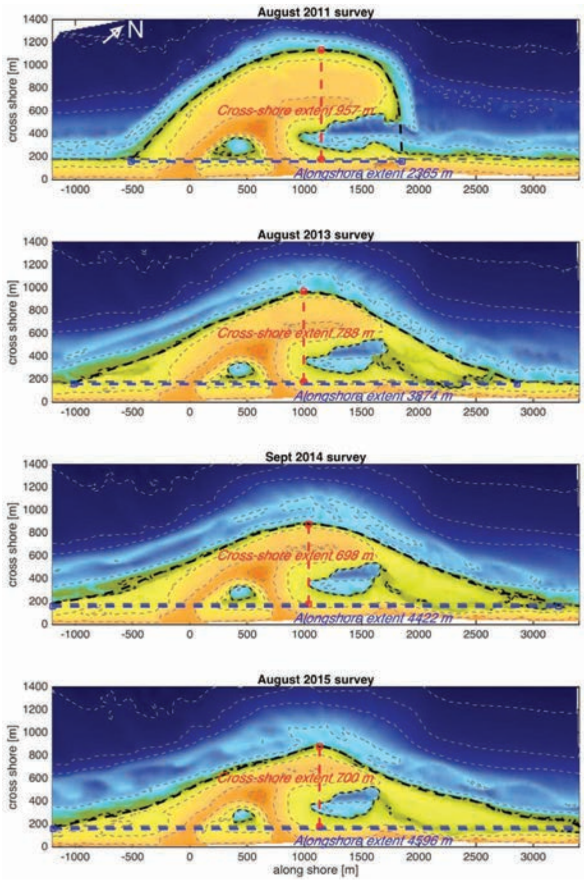

Figure 5: Measured morphological changes Sand Motor

The method of Building with Nature can be used for several different applications. If the developments keep going in the way they are, the pilot project of the Sand Motor will be an inspiring experiment for coastal management and other hydraulic engineering challenges. ◀

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Muiden Aqueduct

The Muiden Aqueduct is the widest aqueduct of Europe. These pages feature photos and facts of this impressive project.

Client:	Rijkswaterstaat
Construction:	Consortium SAAone (VolkerWessels, Boskalis, Hochtief, and DIF)
Foundation:	Vroom Funderingstechnieken
Pile contractor:	Vroom Funderingstechnieken

Factsheet:

- Width: 194 meter;
- Length: 620 meter;
- Accommodates a 65-meter-wide waterway and a wildlife crossing;
- Accommodates 12 driving lanes;
- Approx. 57,000 cubic meters of concrete is used;
- Approx. 8,000 tonnes of reinforcement is used;
- Approx. 120,000 cubic meters of excavation took place;
- 5,822 foundation piles, driven by Vroom Funderingstechnieken, are used:
    - 1,161 prefab concrete piles;
    - 4,211 Vibrocombi-piles.

Royal HaskoningDHV
Consultancy, Engineering & Management

Royal HaskoningDHV is een onafhankelijk internationaal adviserend ingenieurs- en projectmanagementbureau met meer dan 130 jaar ervaring. Ons hoofdkantoor is gevestigd in Nederland, met belangrijke kantoren in het Verenigd Koninkrijk, Zuid-Afrika, India en Zuidoost Azië.

Wij voeren wereldwijd, vanuit 100 kantoren in 35 landen, projecten uit die de leefomgeving raken. Onze 7000 professionals voelen zich hierbij gesteund door de kennis en ervaring van hun collega's. Door de combinatie van wereldwijd opgedane kennis en kennis van de lokale situatie leveren we toegevoegde waarde voor onze klanten in hun projecten.

Wij zien een belangrijke rol voor onszelf in innovatie en duurzame ontwikkeling. Daarom willen we bijdragen aan oplossingen om onze maatschappij duurzamer te maken, samen met onze klanten en anderen die eenzelfde visie hebben.

Stage lopen of een afstudeeronderzoek doen bij Royal HaskoningDHV is een goed begin van een succesvolle carrière. Vaak ben je lid van een projectteam en werk je mee aan onderdelen van een project. Nieuwe inzichten en kennis zijn zeer welkom bij het zoeken naar de meest ideale oplossing voor een klantvraag.

Op onze website staat meer informatie over wie we zijn, waar we ons in de praktijk mee bezig houden en ons actuele aanbod afstudeeronderzoeken, stages en vacatures.

"Duurzaam bouwen draagt bij aan een positieve invloed van gebouwen op mens en milieu, nu en in de toekomst. Dat vergt een innovatieve aanpak met het oog op de hele levenscyclus van een gebouw."

Michiel Visscher, Constructief Ontwerper

royalhaskoningdhv.com

Reducing flood risk

‘Room for the River’

By: drs. Clara Spoorenberg
Senior Project Manager at Fugro

In order to maintain the Dutch flood defense in times of climate change, the national ‘Room for the River’ program has been initiated. More than 30 projects have been defined by the Dutch government in order to contribute to the task to create a safer place to live, work, and recreate. The Nijmegen location in the river Waal was the main bottleneck in the Dutch river system, and therefore a key project in the ‘Room for the River’ program. The ultimate aim for the project was to dig a secondary channel on the river in order to lower the water level and increase the river’s capacity; therefore reducing the flood risk. This was accompanied by the relocation of an existing dike 350 meters further inland and building three new bridges and a new quay. Due to the construction of the secondary channel, the existing area transformed into an island in the center of the river that is set to host a mix of new living, recreational, cultural, and natural spaces.

The winning contract strategy
A single bypass for the highway was the key qualification for contractor combination i-Lent (Dura Vermeer and Ploegam) to win the contract in 2012. The client, the government and authorities of Nijmegen, wanted minimal impact on the city’s traffic during the building phase. Despite it being a relatively large secondary project, the single bypass (approx. 320.000 cubic meters of soil and a steel construction of 120 tonnes) also meant a cost-saving measure by eliminating the need to have multiple solutions for different phases of the work.

DURA VERMEER
Waarmaken van ambities

PLOEGAM

In addition to this, presenting a strong design that met the client’s specification for a striking part of the city that made a statement was also key to winning the contract. Whilst other competitors offered lower cost solutions, i-Lent’s balance between delivering a project on budget and on time, meeting the client’s demands for aesthetics of the structures and landscaping seemed to be the better fit.

Multidisciplinary design team
Having a great architectural team and a strong position on BIM engineering not only enabled i-Lent to offer an appealing design but also a clever, workable design in terms of construction. The contractor winning the contract was committed to subcontracting the preselected architect of each of the three bridges crossing the secondary channel.

A total of four architectural and seven engineering firms were subcontracted during the design and constructing phase. Fugro was responsible for the interface between the spatial design of the river park (coordinated by HNS) and bridges (three architects) and the geotechnical and hydraulic design challenges (several engineering firms). Typically for geotechnical design issues, the best solutions are invisible once construction is finished. Nevertheless, a well thought out subsoil layout is indispensable in order to guarantee the functionality and usability of the constructions and facilities.

Figure 1: Extended Waalbrug

Building the bridges: the challenges
Two new bridges and an extension of an existing bridge were part of the project. The bridges connect the new island to the northern part of Nijmegen (the town of Lent). Furthermore, in the former floodplain, the new secondary channel crosses the existing railroad bridge, which had to be provided with fortified piers.

The Waalbrug bridge (1936), a steel arch bridge across the river Waal, had to be extended (*Figure 1*) in order to cross the secondary channel. The architectural design of Zwart Jansma did not provide in a second arch. With respect to the 'Old lady of Nijmegen', the lower side of the new bridge and piers is accented.

The new bridge extension is constructed at the exact location of the former ramp. This 15-meter-high soil construction created a certain amount of compaction of the subsoil due to 80 years of loading. In order to build the foundations of the piers, this soil ramp had to be excavated, resulting in an expansion of the compressed soil layers. Recompression, due to reloading during the pouring of the concrete, was a severe risk for the quality of the concrete. Ten-stage compression-unloading-recompression tests were carried out. The PLAXIS calculations, performed by Fugro, proved that the replacements fell within the critical margins of the concrete construction.

Figure 2: 'Lentloper' bridge

Between the 'Waalbrug' and the existing railroad bridge, a new bridge to the new island is constructed. This 'Lentloper' bridge is intended for walking, cycling, and car traffic (*Figure 2)*. This Ney-Poulissen bridge design appears to be intended for staring dreamily into the water or enjoying the sunset, instead of the fastest connection between two points. The walking level is situated significantly below the narrow carriageway and includes two shortcuts to cross under the bridge.

Next, architects made the design for the gracefully swinging 'Zaligebrug' footpath and cycling bridge in the river park (*Figure 3)*. The bridge enables a tour around the river park, provided the water level being normal. With rising water levels, the stepping stones make an alternative access to the bridge, but during design water levels, the complete bridge is allowed to flood. Furthermore, the 'Zaligebrug' will occasionally be used as a supply access and for emergency vehicles during events on the island.

The existing railroad bridge crosses the current floodplain. Due to the excavation of the secondary channel, the existing piers had to be fortified. Although this was not part of the contract, the influence of the adapted piers to bottom scouring had to be assessed. A complication was the oblique position of the piers with respect to the currents in the channel.

Figure 3: Zaligebrug

Underneath the railroad bridge, a new dike including a seepage wall had to be constructed. The boundary condition for the construction was not to influence the railroad timetable. An extensive monitoring system of displacement and vibration sensors enabled Fugro to quantify the performance limits for the construction.

A fifth bridge forms the crossing 'Oversteek' between the city of Nijmegen and the north shore. This bridge was not part of the contract either, but obviously had to be integrated in the design of the river park. The building activities of this bridge were merely parallel to the excavation of the secondary channel and coordination between both contractors was therefore crucial for a satisfying result.

The river park: functionality and pleasure in one design
The primary purpose of the urban river park as designed by HNS landscape architects was to result in a water level reduction of 34 centimeters during a 1/1250 flood event. From an extensive soil investigation, some typical

Figure 4: Reinforced piers railroad bridge

geotechnical problems of the area were determined. Due to the high water-permeability of the subsoil, inhabitants of the nearby town of Lent would face severe seepage problems from the secondary channel during high water periods. As a preventive measure, a 20-meter-long cement-bentonite wall was installed to block the seepage flow under the dike and quay.

Besides an icon with recreational function, the 1,600-meter-long new quay includes a partially hidden eight-meter-high L-wall which also performs as a water retaining structure. Therefore, the design of the connecting structure between the seepage construction and the L-wall demanded special attention. The challenge was not solely technical, but merely required interface management between the different disciplines.

Since every construction and element above and below the surface was designed three-dimensionally and combined in a Building Information Model (BIM), regular clash control revealed the problems in an early stage of the multidisciplinary design process. This method proved to be efficient as well as cost-reducing in the overall planning.

In the western part of the river park, nature and water prevail. This area is suitable for walking and recreating along the shores of the river Waal and the secondary channel. Inhabitants of Nijmegen come out here for fresh air or hang out on the beaches of the river Waal. On the event site, appealing cultural activities can be organized. The central part of the island 'Veur-Lent' exudes an urban atmosphere. The area connects the Nijmegen old town with the new residential areas on the north shore 'De Waalsprong'. On the island itself, new houses and urban development is foreseen. The water of the secondary channel is excellent for rowing and other water sports. East of the Waalbrug, the peninsula and channel are more forested. Equipped with boots strolling along the shores, it is excellent for bird watching from the dike or fishing along the Waal shores: this is the place to explore the river, flora, and fauna, just outside the town borders.

Figure 5: Construction of the new dike

Figure 6: i-Lent formwork for the extended 'Waalbrug'

The new quay 'Lentse Warande' on the north shore of the channel stretches from the extended 'Waalbrug' to the railroad bridge and is part of the new dike. The design consists of an inclined paved slope, disappearing into the water. Along the quay, one can enjoy cycling, walking, and relaxing on one of the terraces or along the boat jetties. At the upstream entrance of the secondary channel, a dam was constructed in order to manage the distribution of the water. At different levels of the dam, six inlets provide a constant inlet of fresh water for the channel during low river discharges. At a certain water level, the dam will overflow utilizing full flow capacity of the channel during river floods.

A successful Room for the River project
Highlighting the excellence of i-Lent's work in Nijmegen, the 'Verlengde Waalbrug' extended bridge won the 2015 Concrete Award in the bridges and viaducts category. Equally as significant, the Room for the Waal project as a whole was recognized for its collaborative success by winning the Dutch Bouwpluim award in 2015.

Whilst the market is growing in the Netherlands, with more large and interesting projects coming to market, it is still tough and companies are having to offer smart solutions in order to win contracts. ◀

Figures:
Header, 1-6 *Fugro*

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Internship experiences with KOers

By: Gido Dielemans
Master student Structural Design

From February 2016 until February 2017, I have done an internship at Van Boxsel Engineering in Oosterhout. I have chosen to do this internship parallel to my studies, filling two days with work experience every week. In this article you can read about some of my experiences being an intern.

Van Boxsel Engineering specializes in calculating and modeling prefabricated concrete construction elements. Their eye for innovation, automation, and efficiency drew my interest. The company consists of a handful of functions: administrative employees, software modelers, and structural engineers with director ir. W.A.J. (Willem) van Boxsel at the helm. Van Boxsel Engineering, soon to turn 50 years, was founded by his father ir. W.A. (Wim) van Boxsel and was handed over from father to son.

The projects I have worked on as an intern were very diverse, which to me is very fortunate as I was able to gain knowledge about many aspects in practice. This gave me insight to tackle various kinds of problems. My contributions varied from calculating (prefab) concrete elements to timber trusses and connections to steel cable structures. Even though these contributions were small, I was still able to gain insight in the design process of a structure, which is very valuable as you must define the problem before attempting to solve it. This requires the knowledge to assess the situation and set the goal. Among these projects, I have also worked on a report of a building which was subjected to fire. By the use of photographs and building plans, the report was made, in which the necessary structural replacements were defined which in turn get executed.

Due to my interests ranging from structural design to programming and automation, I was also asked to delve into the Eurocode for development purposes. I have written some small programs which, for instance, determine the concrete cover on the basis of some variables filled in by the user or the necessary length of rebar to ensure anchorage. Similarly, I have made a program for timber connections which calculates the strength of the connection in accordance with the Eurocode for various types of connections and timber classes. These development projects were all done using of Microsoft Excel.

My biggest project was the development of a parametric calculation for a new type of floor system called 'KanaalBreedPlaat' (*Figure 1* and *Figure 2*). This traditionally reinforced concrete prefabricated element has an ever changing geometry, and therefore it is impossible to create a single calculation. By the use of automation, the calculation time spent per floor element is reduced drastically, the efficiency increase hereby is 300%. More about this topic can be found in Cement 2017/1 or on www.cementonline.nl.

In conclusion, my internship has been quite productive. It has shown me how work is done in practice and what each function in a small business entails. This has given me some guidelines on how I want to develop my skills and on what I want to become within the building industry. Therefore, I would advise everyone to do an internship, as you can better define your goals if you know where your ambitions lie. ◀

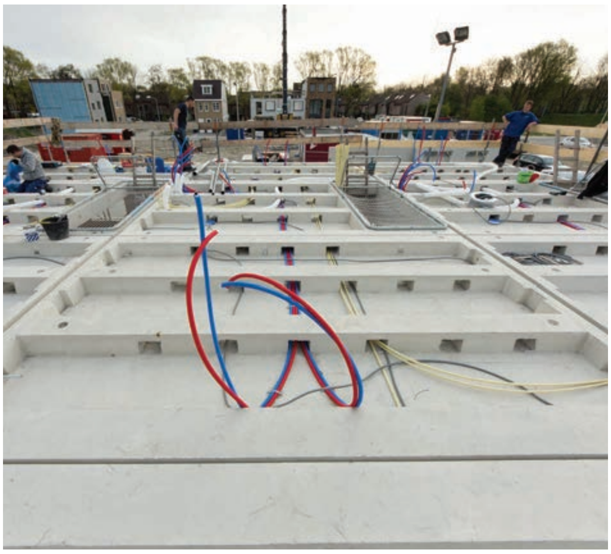

Figure 1: Floor system 'KanaalBreedPlaat'

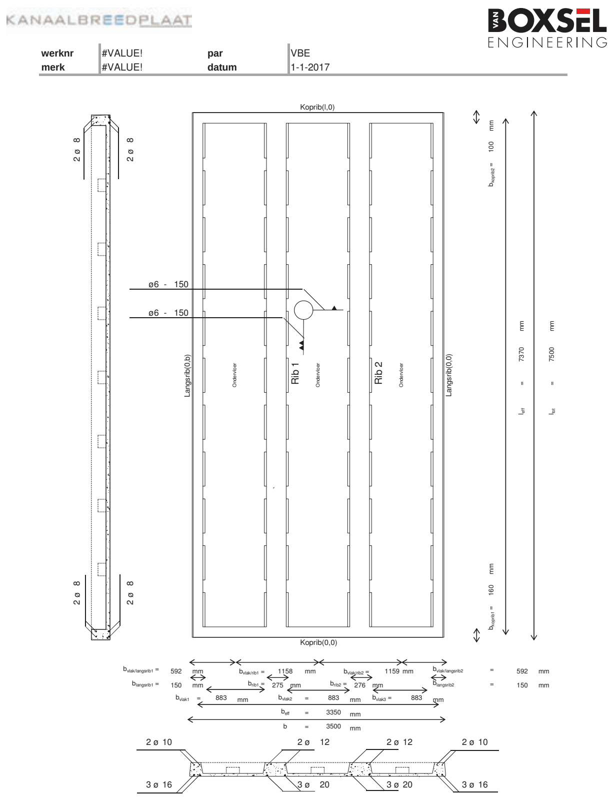

Figure 2: Technical drawing of a 'KanaalBreedPlaat'

Quaking Towers

KOers Design Challenge

By: Gido Dielemans and Esther Brouwer
Members of the KOers Design Challenge Committee

After a few months of preparation, the day finally arrived: on the 22nd of March, the KOers Design Challenge was held. In the early morning, everyone was welcomed at Plaza with a cup of coffee to wake up before the start of the competition. With this year's theme, Quaking Towers, the day was kicked off by our very own professor in seismic behavior: Simon Wijte.

After a short introduction by our chairman Dion Goris, Simon Wijte followed with a summary of the basics of dynamics. This allowed the students to attain a grasp of the type of loading as a result of earthquakes. Through examples, Simon managed to convey the basics of calculating earthquake resistance. He also provided a simple program that the students could use during the design process, which would give an estimation of the design's resilience. To give the information some time to sink in, there was a short coffee break before starting the next lecture. This second lecture of the day was given by Joep Tünnissen of Centrum Veilig Wonen (CVW). The topic of the lecture was the social-economic vision of the reinforcement and renovation of housing in Groningen. During this lecture, Joep managed to provide the students with a few of the many perspectives in the problematic situation of artificially induced earthquakes in the northern part of the Netherlands.

After these inspirational lectures, the students started to work on their own solutions of problem. The design objective was to build a tower with its structure standing two meters tall and being connected to one plate at the top and one at the bottom. The designs needed to be connected to these plates within a predefined area, creating an increase in width of the cross-section. To help the groups in designing a structure that could withstand the test, a group of experts was called in. These experts, who also formed the panel of judges to determine the best structure of the day, consisted of: Ralph Henderix (Dura Vermeer & Advin), Joep Tünnissen (Centrum Veilig Wonen), Rudi Roijakkers (ABT), Michiel Visscher (Royal HaskoningDHV), and Simon Wijte (TU/e). Within one hour of design time, the six groups came up with some interesting designs. While some groups were interested in decoupling a part of the structure, others decided to alter the rigidity of the structure.

Figure 1: Teams ceating their designs with help of the judges

After this quick design session, the students attended the third and final lecture of the day given by Rudi Roijakkers. Rudi told the students about the process of reinforcing buildings, showing the different stages in development up to and including the execution. He showed the use of this process by presenting a number of examples of previous structures. After this lecture ended, it was time for the groups of students to start realizing their designs.

The construction of the structures took place at Forum, just after the lunch at the same location. All groups picked their working area and started realizing their ideas, during which different building philosophies could be observed. Some groups had a clear division of roles with a well predefined plan, while others were applying a more adaptive building technique. During this two-and-a-half hour long building session, the experts helped the students with their ideas and provided helpful tips for constructing the structure.

Figure 2: Winning team in action

At three o'clock, the groups were told to lay down their tools and move their creations to the laboratory. Here, the structures were tested by bolting the bottom plate to the test rig and applying a load of 15 kilograms to the top of the system. The jack created a simulated earthquake by moving the bottom plate in a horizontal manner that formed large deflections in the tower. When a structure did not fail during this test, the amplitude at which the bottom plate moved was increased until the structure did fail. For this, two different signals were used, one resembling an earthquake provided by Simon Wijte and the other being a sinus function. After this test, the judges took some time to consider their distribution of the points.

Figure 3: Enthusiastic spectators while testing the towers

The structures were graded based on three criteria: the test result, the efficiency of materials used, and the judges' opinion. The efficiency was defined as the weight divided by the height of the structure, while the last category largely consisted of how innovative a design was deemed to be by the judges. Each criterion was awarded with a number of points ranging from 1 to 6 with 1 being the best score. In case the teams did not stick to the rules set by the assignment, penalties could be given which increases the total score. The team that had the fewest points in total became the winner of the KOers Design Challenge 2017. Some results of the test turned out to be surprising. For example, a structure that appeared to be solid design ended up being too rigid and thus quickly failed the simulated earthquake test. The flexible structures, however seemed more capable in surviving the test, as timber is capable of resisting high deflections.

Structure types per team:

1. Meer voor mannen: beter stijf dan slap
   A stiff triangular shaped tower
2. The Rolling Timbers
   Base isolation principle, wheel-based
3. sTorend
   Base isolation principle, rail-based
4. Team Flex
   Flexible single pole shaped structure
5. Bevende Bevers
   Flexible harmonica structure
6. Flop Isolation
   Base isolation principle, roller-based

Figure 4: Serious judging; f.l.t.r.: Michiel Visscher, Joep Tünnissen, Rudi Roijakkers

The winner in the efficiency category was Team 5 – Bevende Bevers, while the winner of the test and the most innovative design became Team 6 – FLOP isolation. By combining the points, the winner of the KOers Design Challenge 2017 turned out to be Team 5 – Bevende Bevers consisting of Willem Bouwsema, Michelle Bliek, Jelme Pennings, and Tim Schellekens. Congratulations to the winning team and thanks to all participants for joining in this event!

Figure 5: Committee and winning team; f.l.t.r. Qiao Ben, Lia, Dion, Esther, Gido, Eline, Tim, Willem, Michelle, and Jelme

Lastly, a word of gratitude to our sponsors: Dura Vermeer, Advin, ABT, Boels, Centrum Veilig Wonen, Jumbo, and Royal HaskoningDHV. Furthermore thanks to the TU/e and Zwarte Doos for providing permission to use the aforementioned locations. Special thanks to the Pieter van Musschenbroek Laboratory for creating the testing rig, giving the practical insight during the development, and helping during testing of the structures. ◀

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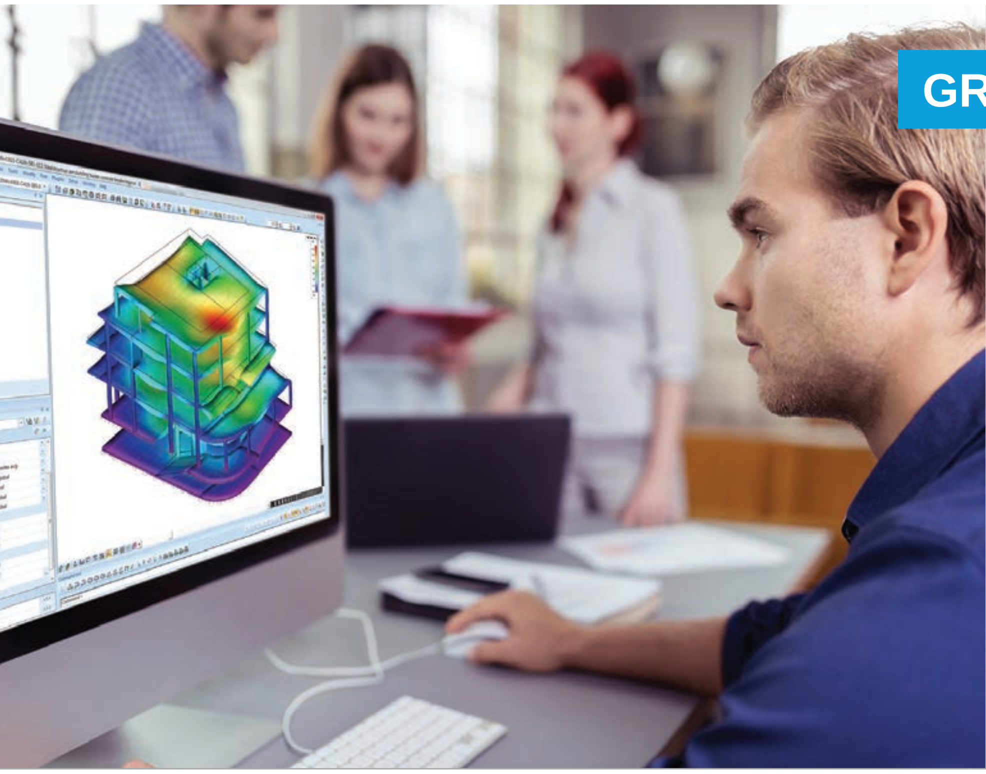

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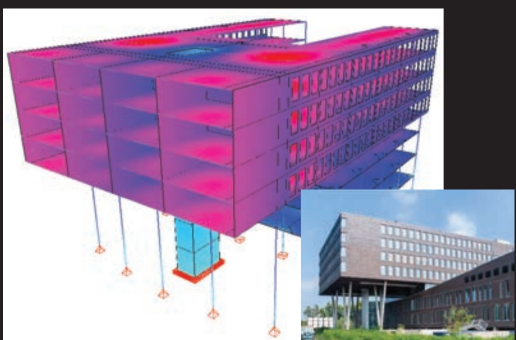

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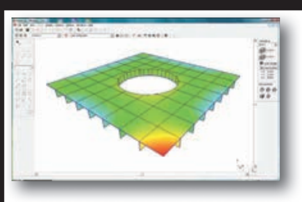

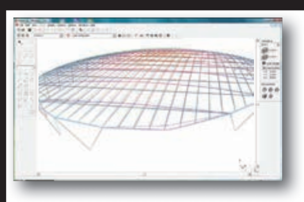

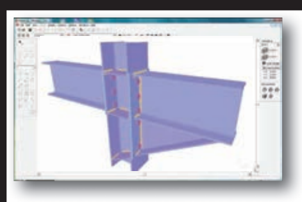

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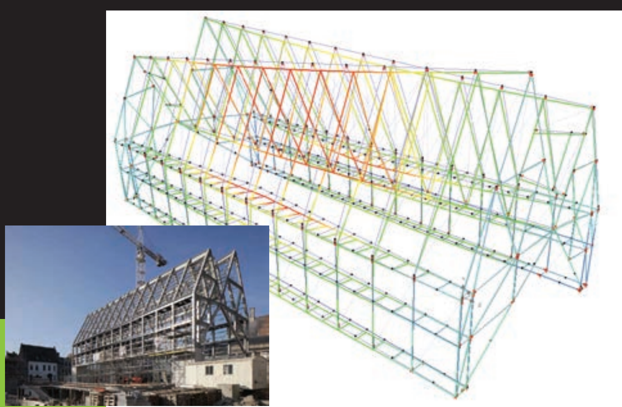

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Coupled buckling of hollow section braces and chords in optimized welded lattice girders

By: A.R.J.E. (Arno) Poels MSc
Supervisors: Prof.ir. H.H. (Bert) Snijder, dr.ir. P.A. (Paul) Teeuwen, prof.ir. S.N.M. (Simon) Wijte

Many of today's buildings and structures rely on steel lattice girders as their bearing structure or as part of the stability structure. Much is however still unknown about the buckling behavior of these girders. Eurocode 3 provides design rules in order to prevent lattice girders from buckling. These design rules are based on the Euler buckling formula, in which a buckling length factor is used to determine the buckling length. In EN 1993-1-1 [1], buckling length factors are prescribed for hollow section lattice girders. However, these factors are fairly superficial and do not include the geometric parameters of the lattice girder.

Lattice girders are essentially a triangulated system, consisting of straight structural members. The advantage of using lattice girders is that virtually only normal forces occur in the structure. The virtual absence of moments means that the members of the structure can be relatively slender and the material usage can be reduced. In order to simplify calculations of the force distribution, the connections between braces and chords are often schematized as hinges, even though most lattice girders have welded connections between brace and chord. The influence of this simplification is negligible for the force distribution. This simplification can however not be applied for buckling of the members. For buckling, the support conditions to a large extent determine the buckling load. EN 1993-1-1 prescribes a buckling length factor of K=0.9 for buckling of the chord and K=0.75 for buckling of the brace, based on the Euler buckling formula (*Equation 1*).

$$F_E = \frac{\pi^2 EI}{(KL)^2} \qquad (1)$$

Previous research by Boel [2] has shown that the buckling length factors, prescribed by EN 1993-1-1, are often too conservative and sometimes not conservative at all. In that study, the buckling length factors of various combinations of braces and chords were determined. These configurations always consisted of the same dimensions for both chords and the same dimensions for all braces. Due to the force distribution in lattice girders, the location of the first occurrence of buckling could often be predicted before the analysis. The highest normal forces in the chords occur at mid-span, while the highest normal forces in the braces occur in the braces near the supports. Therefore, buckling was often found at one of these locations. This is shown in *Figure 1*, in which thicker lines indicate higher forces. As a result of these higher forces, buckling was often found at one of these locations. The resulting buckling modes are shown in *Figure 1* as well.

The current research however focuses on the effects of buckling on an optimized lattice girder. This optimization involves a variation in the brace dimensions towards mid-span. When the dimensions of the braces are

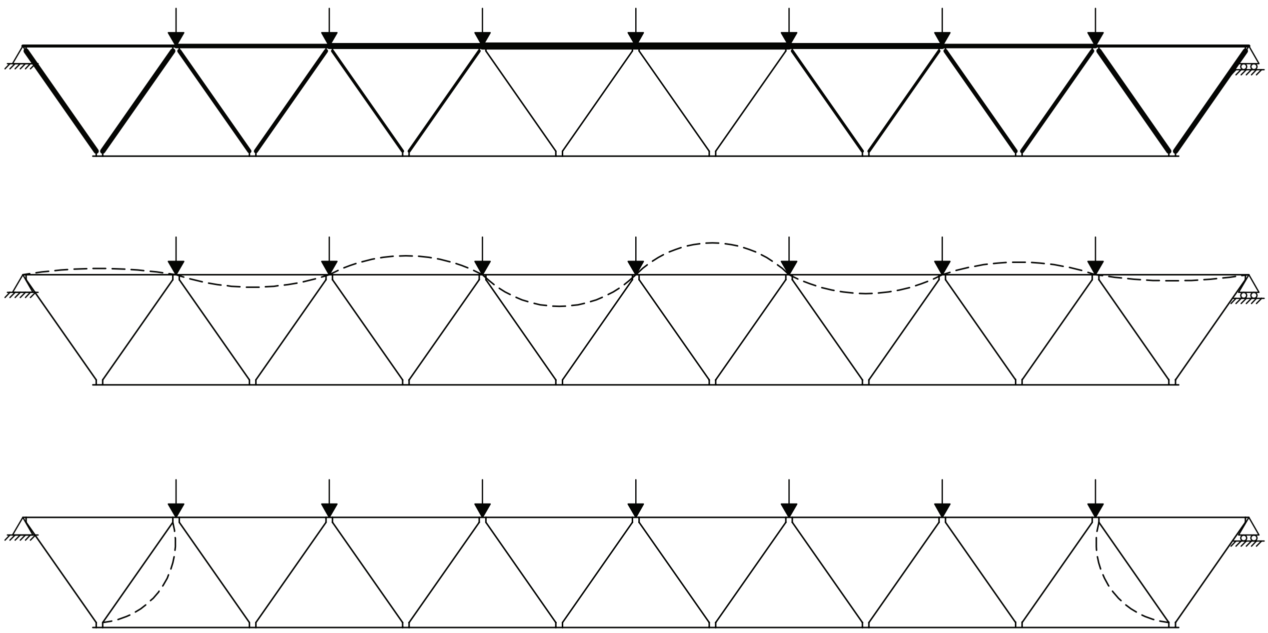

Figure 1: Force distribution in a lattice girder (top) and buckling of the top chord (middle) and the braces near the supports (bottom)

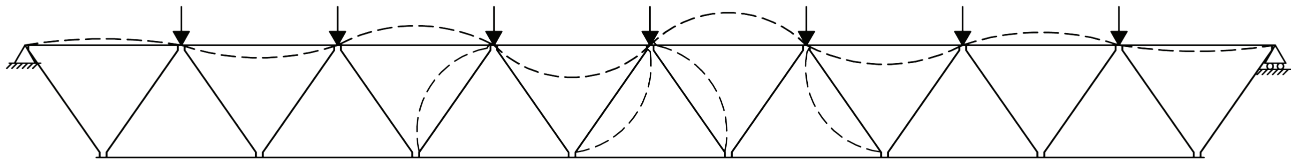

Figure 2: Expected buckling mode for coupled buckling

optimized for the force to which they are subjected, buckling might occur in several braces at the same load on top of the structure. In addition, the chord dimensions can be altered as such, that buckling of the chord occurs at a similar load as buckling of the braces. This might lead to simultaneous buckling of all members in the structure, which could lead to higher buckling length factors than prescribed in EN 1993-1-1. The expected buckling mode is shown in *Figure 2*.

This research involves combinations of square hollow section (SHS) chords and braces, SHS chords and circular hollow section (CHS) braces, and CHS chords and CHS braces. Due to the difference in cross-sections and therefore difference in the connection stiffness, the buckling length factors may differ as well. In addition, both in-plane and out-of-plane buckling is considered.

Numerical model

In accordance to the research by Boel, a Warren truss is evaluated in this research (*Figure 1*). The structure is loaded by point loads in each of the nodes of the top chord and simply supported at both ends. In addition, rotation about the longitudinal axis is restricted at both ends and lateral supports are applied in each node of the top chord.

A numerical model, consisting of beam elements, is created to determine the eigenvalues of the structure. A beam element model is used instead of a full shell or solid element model, due to the reduction of computational time. The deformation behavior of the connection is included in the beam element model by rotational springs. The value of the spring stiffness is determined by performing linear analysis on one node of the structure using finite element software. This node is modeled with shell elements to include the deformation behavior of the connection. A unit moment is applied to the end of the brace, after which the local vertical displacement (w) is measured (*Figure 3*). This displacement occurs due to a combination of bending of the brace and rotation of the connection. The rotation due to the connection is determined by subtracting the displacement due to bending of the brace from the total deflection. This is done for both in-plane and out-of-plane loading.

FE analysis

Afterwards, finite element analysis is used to determine the eigenvalues of the full beam element model. The lattice girder is loaded by a unit load in each of the nodes of the top chord. Eigenvalue analysis is used to determine the factor with which the load on top of the structure must be multiplied to find buckling. Using this eigenvalue and the Euler buckling formula (*Equation 1*), the buckling length factor (K) of the various members can be calculated.

Optimization

In order to find coupled buckling of the braces and the top chord in a lattice girder, all members should buckle at a similar eigenvalue. Therefore, the brace dimensions must be decreased towards mid-span. In addition to the internal forces in the braces, the connection stiffness between the chords and braces might influence the buckling behavior as well. First, the member dimensions are calculated using the buckling rules in EN 1993-1-1. Next, linear buckling analysis (LBA) is performed to find the buckling length factors of this configuration. These buckling length factors are afterwards used to optimize the structure with respect to the internal forces. Using these buckling length factors, the new dimensions of the braces are determined.

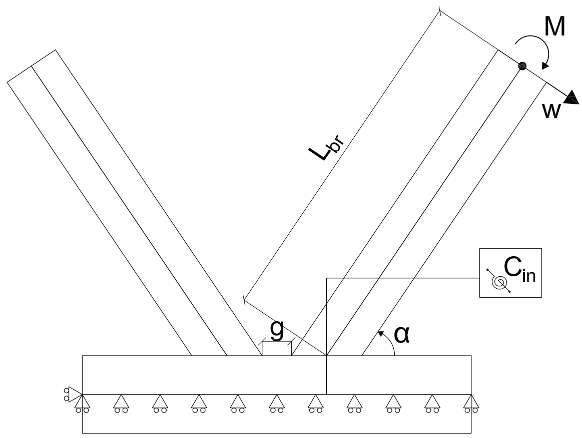

Figure 3: Structural scheme for determination of the rotational stiffness

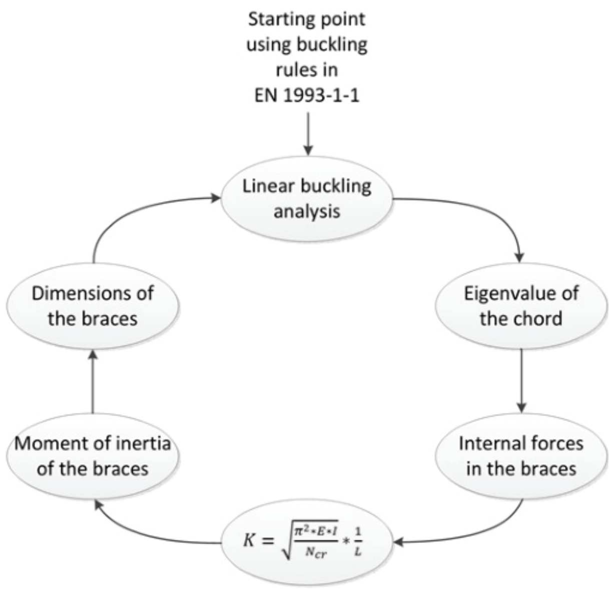

Figure 4: Optimization process

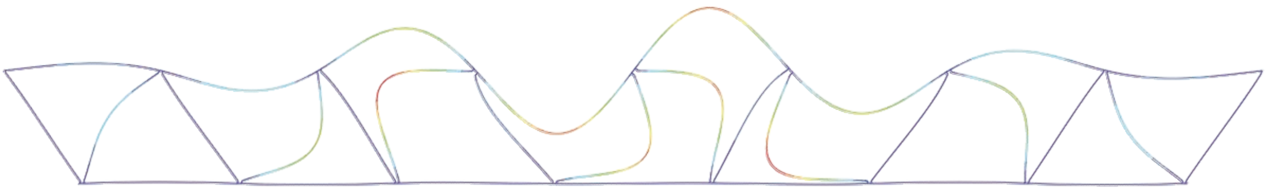

Figure 5: Result of LBA on optimized lattice girder

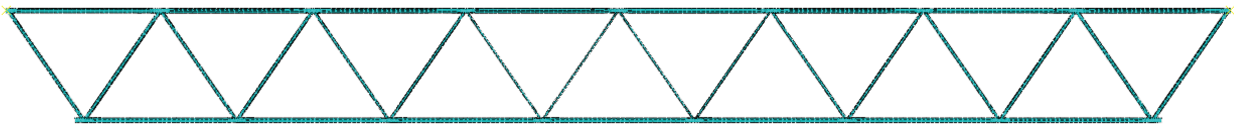

Figure 6: Shell element model of the full girder

After two cycles, an optimized structure is found. The optimization process is shown in *Figure 4*.

Figure 5 shows the result of LBA on the optimized configuration; coupled buckling occurs for the top chord and the braces that are close to mid-span. The resulting buckling length factors for both the top chord and the braces were consistently higher than the buckling length factors, prescribed by EN 1993-1-1. The highest buckling length factors found were 1.0 for chord buckling and 0.84 for brace buckling.

Nonlinear analysis

The eigenvalue analysis assumes a linear-elastic material and no imperfections in the structure. In practice, however, imperfections are inevitable and the material behavior is non-linear. In order to include these effects in the model, a full shell element model of the complete girder is created (*Figure 6*). The beam element model was found to not accurately describe the nonlinear behavior of the connection. Using the full shell element model, a geometrical and material nonlinear analysis with imperfections (GMNIA) is performed to assess the failure mode of the structure.

The results of the GMNIA show that buckling of the lattice girder is often not the governing failure mode. Before the buckling load is reached, plastification of the nodes occurs (*Figure 7*).

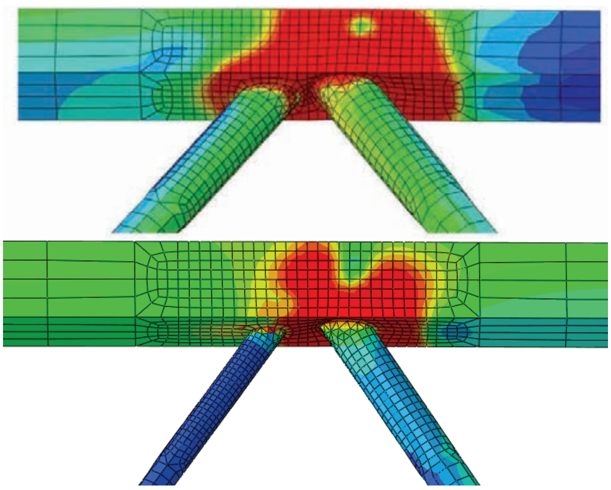

Figure 7: Plastification of the nodes near the supports (top) and near midspan (bottom)

As can be seen in the figure, plastification of the nodes occurs more severely near the supports than near midspan. This plastification leads to a reduction of the moment resistance in the node, leading to a less stiff support condition for the braces. This leads to premature buckling, resulting in much higher buckling length factors for the braces in particular.

Conclusions

In conclusion, coupled buckling has a negative influence on the buckling behavior of an optimized lattice girder. In order to find the practical influence of coupled buckling, the capacity of the connection should not be governing over buckling of the structure. Further research, including these strength properties, should indicate the changes that should be made in the codes.

From this research, it can be concluded that:

- Using linear buckling analyses, coupled buckling occurs for nearly all configurations investigated in this research. In-plane buckling is mostly found before out-of-plane buckling occurs;
- The buckling length factors, found by linear buckling analyses, generally exceed the prescribed values of K=0.9 for buckling of the chord and K=0.75 for buckling of the brace in EN 1993-1-1. The maximum buckling length factor found was 1.0 for chord buckling and 0.84 for brace buckling;
- Geometrical and material nonlinear analyses show that the buckling load is often not reached in the girder, due to plasticity. Plastification of the connections occurs before buckling, let alone coupled buckling, can occur. Plastification of the nodes mostly occurs in configurations with square hollow sections;
- The effects of plasticity mostly influence the buckling behavior of the braces. Due to plasticity in the nodes, the support conditions of the braces allow for rotation to take place. The load at which buckling of the braces occurs is approximately 60% of the load that is found by linear buckling analyses of the structure. ◀

References:

[1] *EN 1993-1-1 (2011), Eurocode 3: Design of steel structures.*

[2] *Boel, H.D. (2010). Buckling Length Factors of Hollow Section Members in Lattice Girders. MSc thesis, Dept. of Architecture, Building and Planning, Eindhoven University of Technology, the Netherlands.*

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Master's thesis

Dynamic behavior of timber concrete composites

By: M.H. (Maurits) Roks MSc
Supervisors: dr.ir. A.J.M. (Ad) Leijten, prof.ir. S.N.M. (Simon) Wijte, ir. R.H. (Remko) Wiltjer (IMd Raadgevende Ingenieurs)

Renovation of historic buildings is an important topic for the building industry, especially in big cities where open space for new buildings is lacking. Demolishing existing buildings or rehabilitating them instead of building new ones is now often considered. Reinforcing an existing timber floor with a concrete slab on top could be efficient in various aspects, especially for vibration and acoustics issues. Although the improvement of the vibrational behavior is claimed, it is generally poorly documented. This thesis tries to shed more light on this aspect.

The vibrational behavior is not the only case that requires attention during renovation. The design criteria of floors have become stricter compared to the older design criteria. Some existing timber floors will not fulfill the standard requirements when a new use function is decided with higher design loads. In practice, due to this extra loading, the deflection criteria are often exceeded. By connecting the timber elements to the concrete, the stiffness of the structure could be increased, and therefore the total deflection can be decreased.

The structural behavior strongly depends on the type of connection. If the timber is well connected to the concrete, the concrete is mainly loaded in compression and the timber in tension parallel to the grain. In existing timber floors, the floor often has to be levelled due to creep of the timber or settlements of the foundations. Therefore, the extra concrete slab is an ideal solution. The concrete slab could also provide thermal mass activation and allows to incorporate floor heating.

A connection that is often applied in renovation projects is the Tecnaria dowel (*Figure 1*). This dowel consists of a toothed base plate which will be hammered into the timber, a dowel welded on the toothed plate to connect the concrete and two screws to fix the toothed plate to the timber. With this connection type, it is possible to use the existing timber floor deck as formwork. This method is often used in buildings with historical decorated ceilings which find support in the floor joists. This allows the ceiling to be preserved. The thickness of the concrete slab is usually set between 50 and 70 millimeters.

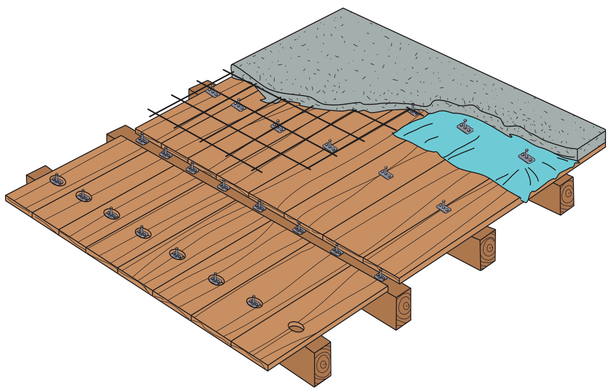

Figure 1: Application of Tecnaria dowel in an existing timber floor

Although there is a growing market for these timber concrete composite floors and connections, the current Eurocode 5 lacks specific vibrational design rules and requirements. In this thesis, the influence of the concrete layer on the dynamic floor behavior was studied. A comparison was made using several models aiming at predicting the structural behavior as well as design assessment methods that account for the vibration criteria. The results from experimental test data were finally compared to these vibration assessments.

To bring a structure into vibration, a certain load (energy) is needed (*Equation 1*) [1]. The energy of a single footstep is often regarded in vibration criteria. The amount of external energy (F(t)) that is needed to bring a structure into vibration mainly depends on three variables: the mass of the structure (m), the damping ratio (c), and the stiffness of the structure (k). Compared to a traditional timber floor with joists, based on this theory, more external energy will be required to get a timber concrete composite (TCC) floor into a vibration mode since the mass and stiffness will increase.

$$F(t) = m\ddot{x}(t) + c\dot{x}(t) + \mathrm{k}\mathrm{x}(\mathrm{t}) \quad (1)$$

This equation was implemented by the method of Hivoss [2], where the dynamic behavior of the floor is divided into several user and comfort classes. The mean velocity caused by a single footstep is used for a comparison between the floor classes. Once the eigenfrequency, damping, and model mass are determined, the floor class can be determined. However, it is still unknown if the eigenfrequency, damping, and modal mass of TCC structures prediction using the Hivoss method is valid, and therefore requires more research. Values for these properties were determined from experimental research, which allowed to make a sound comparison with a traditional timber joists floor.

For the experimental research, six timber beams with a length of 4 meters were used. According to the eigenfrequency *Equation 2* [1] and the Hivoss method, the stiffness, eigenfrequency, damping, and mass have to be determined first. In this experimental research, two main types of experiments were executed. First, the stiffness of the beam was determined using a four-point bending test (up till 40% of its estimated capacity).

Figure 2: Test setup for the TCC beam

By weighting the beam and using *Equation 2* [1], the eigenfrequency was determined. The eigenfrequency was also determined by a dynamic test; a load was hanging at mid-span and after detachment, the vibration of the beam was measured by accelerometers. From these vibration test, the eigenfrequency, acceleration, and damping were established. If the eigenfrequency from the static test is equal to the dynamic test, the eigenfrequency could be well predicted from current design rules.

$$f_1 = \frac{\pi}{2L^2}\sqrt{\frac{EI_l}{m}} \quad (2)$$

After the experiments with the timber joists were done, they were reinforced with a concrete slab (600 by 60 millimeters, *Figure 2*). The static and dynamic test were performed once again. The test specimens were divided into two test series; three elements were enforced with Tecnaria dowels spaced 200 millimeters apart and three elements with the same dowels but now spaced 400 millimeters apart.

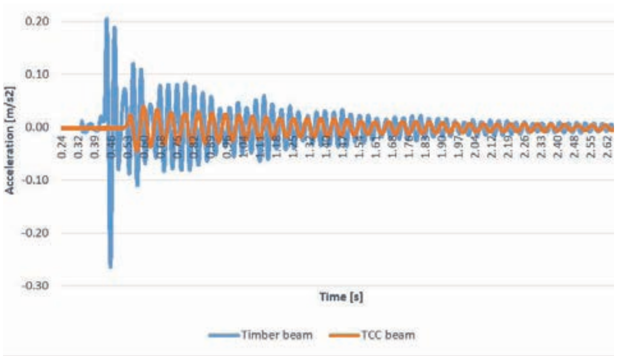

Figure 3: Comparison between the beam acceleration of the timber and TCC beam

Evaluating the eigenfrequency determined experimentally and predicted by theory, the conclusion was drawn that both were in good agreement, and therefore mass and stiffness were adequate for a good prediction. However, a significant difference between the eigenfrequency of the TCC static and dynamic test was found. The eigenfrequency of the TCC dynamic test yielded higher eigenfrequency values than the eigenfrequency derived from the static test. The difference was caused by a different slip behavior of the connector. The slip behavior of the Tecnaria dowel is not linear and it behaves stiffer when exposed to lower load levels than the load level of the static test. During the static test, the TCC beam was loaded up until 40% of its estimated maximum capacity. In the dynamic test, the dowels only had to transfer the self-weight of the beam, resulting in a higher effective bending stiffness and thus a higher eigenfrequency. The mean eigenfrequency of the timber joist was 32.7 Hz, which dropped to 21.3 Hz in the (dynamic) TCC test. With an average eigenfrequency of 15.7 Hz for the static test, the prediction by the model in Eurocode 5 gives an underestimation compared to the dynamic behavior.

The acceleration of the TCC beam in the dynamic test was five times lower than for the timber joist. Because acceleration can be felt by residents, this could be a

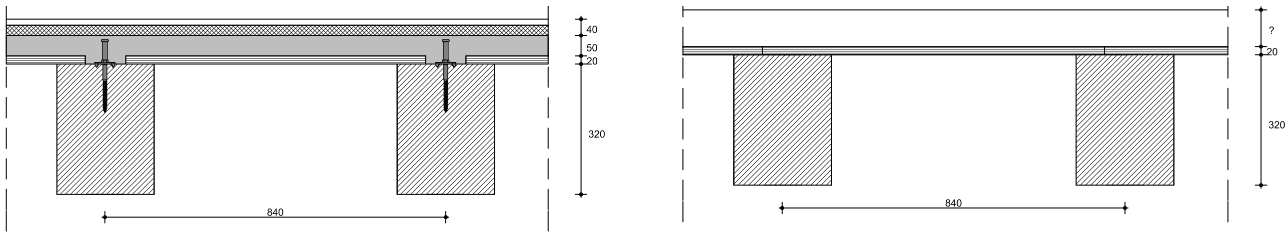

Figure 4: Left, timber concrete composite floor ; Right, current timber floor

relevant factor to take into account in vibration comfort assessment. However, this parameter is not (yet) implemented in the Eurocode. The acceleration caused by a walking person is still a topic that requires more research. In conclusion, the concrete slab, connected to the timber with Tecnaria dowels, increased the vibrational performance.

To bring this experimental research into practice, a comparison was made between an existing timber floor with and without a 50 millimeter concrete slab. Due to high design loads, the floor failed at the instantaneous deflection criteria. By connecting the concrete to the timber with Tecnaria connectors spaced 300 millimeter, the stiffness of the floor was more than doubled. Due to this increase of stiffness, the instantaneous deflection criterion problem was solved. The next step was to check the vibration criteria. In the comparison of vibration assessment the Hivoss method yielded the most elaborated assessment.

The Hivoss method divides vibration criteria in comfort and user classes, where the Eurocode 5 only makes a distinction in use (gymnastic or residential areas). Using three parameters (eigenfrequency, vibrational mass, and damping of the structure), the comfort class of the floor can be assessed as shown in *Figure 5*. The comfort class of a floor structure used for a restaurant must be class E at minimum, where class D is recommended. With the current knowledge, the comfort class of the floor shifted from F (without concrete) to class E (with the concrete). Despite this improvement, the vibrational mass of only one beam was taken into account by the Hivoss method. The structure was therefore modeled in Scia to check the load distribution of a single footstep. *Figure 6* shows the amount of mass activated in the middle of each beam. It was concluded that compared to the traditional timber joist floor a remarkable higher percentage of vibrational mass is activated. If the extra mass is taken into account using the method of Hivoss, the comfort class shifts to class D which satisfies the requirement for a restaurant. Because the amount of vibrational mass has a large influence on the vibrational comfort rating, this topic could be very relevant for further research.

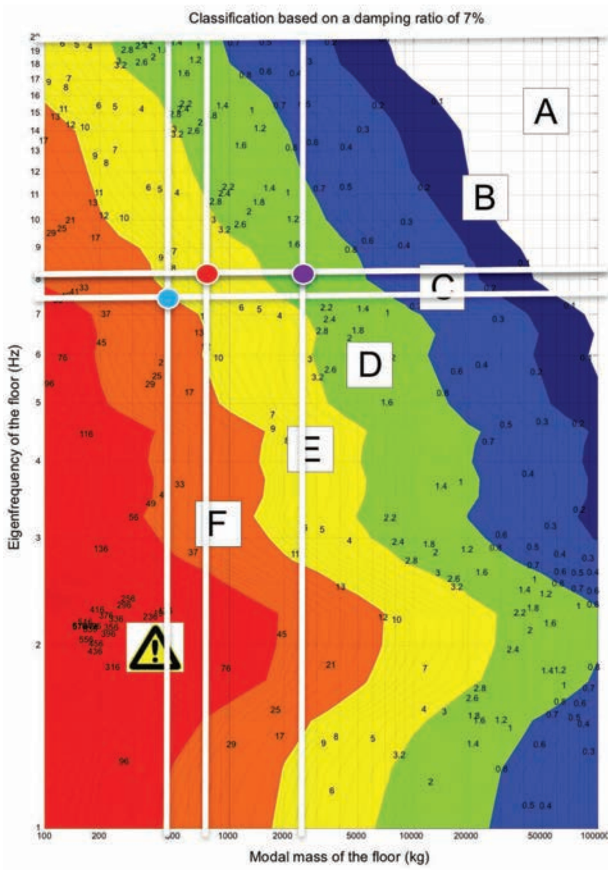

Figure 5: Vibrational class rating by method of Hivoss

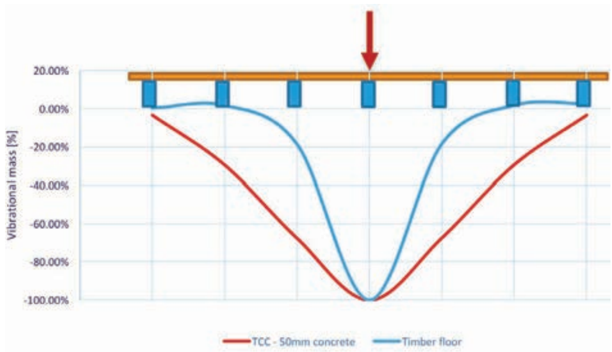

Figure 6: Amount of mass that is brought into vibration by a walking person

Strengthening timber floors with concrete is an effective way to increase the comfort and safety of the end-user. If the timber is strong enough, the concrete could even be uncoupled from the floor resulting in lower costs and the possibility to create a floating concrete floor above the timber. By connecting the concrete to the timber, the stiffness could be three times stiffer and the acceleration of the floor could decrease up to almost five times. Because acceleration can be felt by residents, this could be an interesting factor to take into account for vibrational comfort rating. ◀

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[1] *EN 1995-1-1, Eurocode 5: Design of timber structures.*
[2] *Human-induced vibration of steel structures (Hivoss)*

Figures:

1 https://tecnaria.com/en/restoration-of-wood-floors-1/concrete-floors-connector-calculation/ (Tecnaria.com)
5 SBR - Trillingen van vloeren door lopen, P.H. Waarts, 2005

Graduation Project topics

The Unit Structural Design consists of a several research chairs and design areas. This section consists of a selection of potential graduation topics from different chairs. Contact the responsible professor for more information.

Steel Structures

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Design of a data center in Groningen [design]
Google intends to build a large data center in the Eemshaven in Groningen. Data centers are characterized by high floor loads. These loads combined with earthquakes, when building a high rise, result in heavy steel structures. Eurocode 8 covers several stability systems for steel structures. What are the advantages and disadvantages of the various systems that result in the most economic structure? What is the impact of advanced computing tools on the amount of steel used?

Floating construction; design a floating … (t.b.d.) [design]
Floating construction is becoming an increasingly topical subject due to increasing urban density. Especially for events, sports, shelters for refugees, …

3D-Stability of steel frames [research]
Design and calculation tools are stronger and better than ever before and can easily handle 3D steel frames. Our design rules for stability are mainly based on 2D failure modes. Finite element work (Geometrical and Material Non-linear Analyses including Imperfections, GMNIA) has to be performed on 3D steel frames and the load bearing capacity obtained needs to be compared to the load bearing capacity as predicted by design rules. Do the design rules really cover all possible 3D failure modes?

Inclusion of bracing forces in design rules for stability of steel [research]
Currently, the design rules for checking the stability of steel frames do not have an easy-to-use option for inclusion of bracing forces additional to the compressive force in the column that is checked. An adaptation of the current design rules in Eurocode 3 needs to be developed for that, based on the way this was treated in the former Dutch code NEN 6771. Subsequently, the validity of this design rule needs to be checked by comparing the resistance of relevant steel frames according to the developed design rule with Geometrical and Material Non-linear Analyses including Imperfections, GMNIA.

Improved design rule for capacity design [research]
Capacity design means designing for the gross cross-section to yield before the net cross-section fails. Capacity design enhances deformation capacity which is extremely important in earthquake prone structures. The design rules for both failure mechanisms need to be statistically investigated in combination, taking correlations of yield and tensile strength into account. Numerical analyses support the statistical investigations.

Masonry Research Area

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Graduating in the Masonry Research Area does not only include experimental research. On the contrary, combining experimental and numerical research will be stimulated. The emphasis can be on:

- Experimental research with numerical support;
- Numerical research with experimental support;
- Design; both shaping and dimensioning.

When a student comes up with a thesis topic, this is always negotiable. Out of the long list of thesis topics, the following main subjects are selected:

1. The earthquakes in Groningen and their effects on masonry structures.
    - Design a (residential) building in masonry that resist the earthquakes of Groningen;
    - Complex sections and vertical joints at wall connections (horizontal L-, H-, or T-sections);
    - Push-over behavior of stability walls.
2. The structural interaction between soil and masonry.
    - Vaults and shells (above or below ground level, historical aspects);
    - Interaction of loads (e.g. by soil) and curved shapes. The design of shells.

Graduation Studio 3D Concrete Printing (3DCP)

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dr.ir. F.P. (Freek) Bos - f.p.bos@tue.nl

3D Concrete Printing is poised to take the construction industry by storm. The potential advantages of mass customization, absence of formwork, reduction of labor and material use, production speed, and automation are highly appealing and have instigated an exponentially growing number of pilot projects around the globe. But fundamental understanding of this technology is still very limited. The chair of Concrete Structures is one of the very few research groups in the world active in this field. We have a wide range of MSc graduation topics available. Key areas of research include:

- Concrete behavior during printing, and its dependency on print process parameters (experimental research and/or computational modeling);
- Development of 3DCP concepts for structural applications, including fiber reinforced printed concrete, printed concrete with cable-reinforcement, and sandwich constructions (small to large scale experimental research and/or computational modeling);
- Tessellation and connections, developing and testing connection concepts, and tessellation strategies (design, structural analysis, experimental research);
- Integrated design of buildings / pilots (design, structural analysis, experimental research);
- Process automation, development of measurement systems providing real-time feedback to improve printing strategies (process programming, measuring techniques).

Together with the student, we can further define the graduation topic, tuned to his/her personal interest. We also encourage students to bring forward their own ideas and preferences. Depending on the focus of the project, other chairs can be involved, within the unit SD or in cross-unit collaborations. (www.tue.nl/3dconcreteprinting) ◄

The experience of...

By: Eline Dolkemade
Editor KOersief

In 'the experience of...' a person from the business community tells their story about his or her experience in and around the built environment. This time it is Gijs Schalkwijk who, in collaboration with his partner Joost Huijgen, turned his graduation project into a successful engineering company.

Located in the 'Klokgebouw' on trendy Strijp-S, you can find the office of B-invented. No small offices or working stations, but a modern looking area with a relaxed vibe and young hard-working people. B-invented does not only employ structural engineers, but also architects, manufacturing engineers, and has its own construction team. It is clear from the start: "Product development is not the goal, but process optimization is."

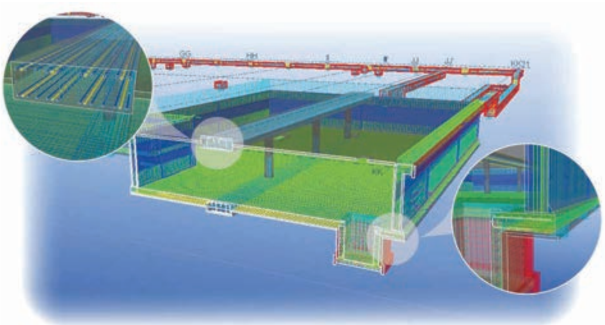


Figure 1: Total engineering foundation B-smart. Foundation + sprayput

With this quote Gijs started our conversation: Take a foundation for instance, in which already so many parties are involved. Each party has its own specialty and is often unwilling to look beyond their product or material. These parties barely collaborate and still run after each other in every process. Improving this process will provide more durable, economical, and creative solutions. The process of a foundation is the beginning of B-invented, called B-smart. With no specific product bound background Gijs and Joost were able to come up with an integral product, in which engineering, production of elements, and construction are all in the same hands. It began with a single beam and now B-invented offers the whole foundation. Gijs explains: "We take on the entire foundation and take time to engineer the best product. This means fast production, as little reinforcement as possible, and the strongest structure. We know the people who produce and construct the elements and know how they do it, this gives us the opportunity to lower margins and spend more time designing". The structural engineer adds more value, because there is more room for an optimal design. The short communication lines give the engineers the possibility to directly implement feedback from the factory and construction workers.

It all started with an assignment to write a business plan, for which lecturer F. Moonen had a product on his shelf. This was the B-smart foundation. "Our plans even won competitions, so it seemed to be a proper product. During our graduation project we developed the product and in the end we applied for a subsidy, that gave us the opportunity to extend the research for two more years. After the research, we found a company that helped us to launch the product, a multinational in cellular polystyrene. The idea was that we would engineer and they would do production and sales. This turned out to be a mismatch, because of the company type, mainly mass production, and the product, which is a system. However, this collaboration gave us much experience and we were able to show that our concept worked and we could do everything on our own. Four years ago we found an investor and nowadays we do everything ourselves: sales, engineering, production, and construction."

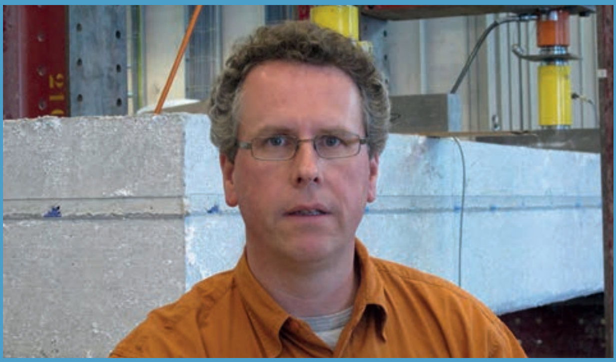
Figure 2: Foundation church. Floors and foundation by B-smart foundation

The people behind B-invented prove that process thinking works. They are now investigating where they can further apply their process, because conventional construction shows there is much to improve in this area. Currently, the company has four units: foundations, development, engineering, and construction partner. For the last unit, B-invented fills the role of co-developer and offers the total process of a building, from business plan up to and including completion. ◄

Column

Bring in the Dutch!

Hans Lamers



We, people from the Netherlands, are famous for our struggle against the water level of rivers and the sea. Throughout the history of more than 2000 years, we have built dikes and windmills to power pumping stations to keep our feet dry. We turned wetlands into fertile agricultural land. The spring tide in 1953, resulted in the great flood in Zeeland. This became the reason for the 'Delta Project', a plan to reduce the Dutch coast line by 700 kilometers, to keep the Netherlands safe from the stormy sea. One of the remarkable objects is the 'Eastern Scheldt dam' with vertical sliding baffles. It was considered as the ultimate innovative solution for the conservation of the natural habitat of flora and fauna in the 'Eastern Scheldt'. These sliding baffles have a length of 42 meters, a maximum height of 12 meters, and a maximum weight of nearly 500 tons. Indeed an engineering miracle of steel and hydraulics. The building started in 1960 and the opening (actually, it was the closing of the baffles) was on 4 October 1986.

Many details and a lot of facts can be listed about the famous Delta Project, but most of us forget these things after some. The point is that 30 years ago, the Dutch civil engineers achieved the impossible. The attention for this great achievement has diminished after all these years. The competition with Asian engineering companies is tough. Our reputation is no longer enough to attract new big challenges in the water - infrastructure sector, like building harbors and coastal works. Just like the waves of the water, we Dutch cannot always stay at the top. So there is a great challenge for the new generation of young engineers. Go for it!

Colophon
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