STUDIEVERENIGING KOers
CONSTRUCTIEF ONTWERPEN

Kersief

EDITION 105
March 2018

Extreme loadings

Dear reader,

The North Sea flood of 1953 in the Netherlands, better known as the 'Watersnoodramp', is a natural disaster, which most of you are familiar with and some of you even have experienced. Over 1,800 people were killed, 8,000 farms and houses were destroyed, and 80 percent of the total amount of dikes were damaged. As a response to the storm, major studies have been carried out on the strengthening of the coastal defense and extensive storm surge barriers were built.

Due to climate change, extreme weather is on the news more often these days, resulting in lots of damage and casualties every year. Hailstorms with hailstones like golf balls and heavy gusts of wind. Not only in the Netherlands, but all over the world extreme weather, like floods and extreme snowfall, is an issue. Structures have to endure a lot and engineers must pay more attention to the extreme loading. Therefore, we dedicated a theme specifically to this subject.

In this edition, you can read how engineers deal with fire safety, floods, snowfall, earthquakes, and explosion danger. In addition, an article is published about the new wind tunnel on the TU/e campus and Simon Wijte is writing about the collapse of the parking garage at Eindhoven Airport.

I would like to thank Tom Godthelp, former editor of the KOersief, for his input to this editions theme and I hope you will enjoy the articles. I also want to thank the editorial board for their input and enthusiasm, which again has resulted in this edition of the KOersief.

On behalf of the editorial board,

Caroline Koks
Editor-in-chief KOersief 105

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Chairman's note

Dear members of KOers,

Read and behold: the new edition of the KOersief about extreme loadings! A subject that we are all familiar with as structural designers.

Firstly, in the form of extreme applied loads; unfortunate environmental circumstances for us as structural designers, because they mostly determine the structural dimensions of a building. Only occurring briefly, which enables our buildings to withstand them.

Secondly, in the form of extreme workloads; unfortunate circumstances for us as structural designers, because they may have a negative influence on our wellbeing. Some of us seem to be able to withstand extreme workloads forever, but for most of us it is wise to take a rest after an extreme load just like the buildings we design.

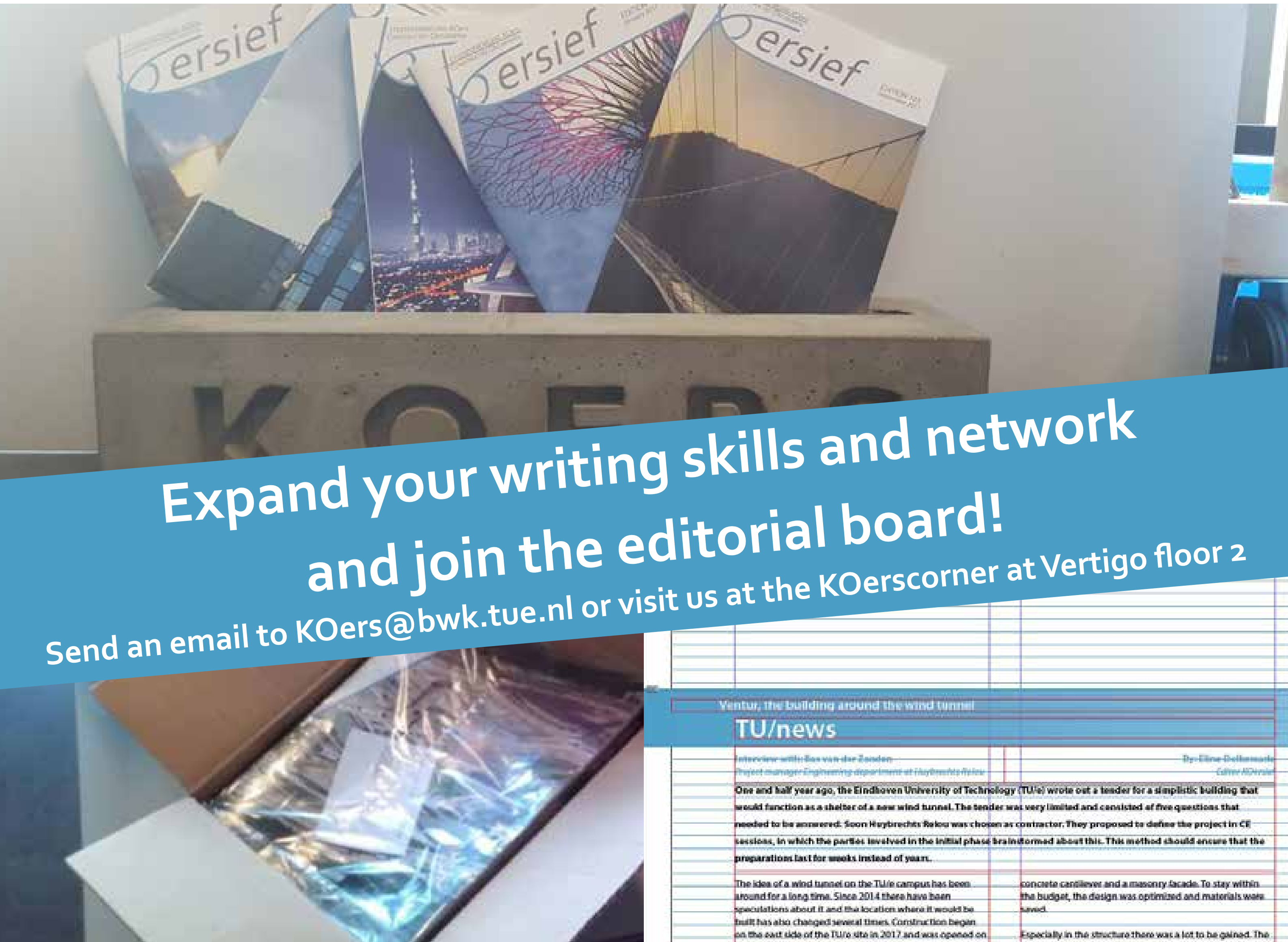
Extreme loads are not all negative, however, they enable our buildings to resist the unforgiving and extreme character of nature by standing stiff in the hardest winds and coldest winters and enable us to surpass our own limits in times when our intellect is needed most.

So, keep an eye on your workload. After your deadlines are due, plan your vacations and join some of the activities of KOers, which you can find on the next page.

I would like to thank the editorial board for their efforts in creating this KOersief so that we can escape from our extreme workloads for a while.

Yours sincerely,

Derk Bos,
Chairman of the 48th board of KOers.



Agenda

Lunch lecture Van Rossum *November 23rd*

Sinter-kaas drink *December 6th*

Excursion Octatube *December 15th*

KOersKnOtsbal *December 20th*

KOers Coffee Time

Weekly KOerscorner, Vertigo floor 2, TU/e

Every Wednesday afternoon, during lunch break, KOers gives you the opportunity to have a nice cup of coffee or tea. Join us for this weekly event between 12:30-13:30. Relax and have a short break with the board and your fellow students.

Excursion Van Rossum, nhow RAI hotel

March 28th Amsterdam

KOers will visit Van Rossum in Amsterdam, where a short office tour and a lecture on the nhow RAI hotel will be given. The 91-meter-high building was designed by the Office for Metropolitan Architecture (OMA). After these activities, we will visit the construction site of the nhow RAI Hotel.

'Typical Olden Dutch Games' Drink

End of April SkyBar! Underground, Eindhoven

Have you always wanted to awaken your inner child? Then join us for this drink! During this afternoon you will be able to play old Dutch games like 'koekhappen', 'spijkerpoepen', 'zaklopen', and many more. The winner will be awarded properly.

Concrete Canoe Race

May 25th - 27th To be announced

This year the Concrete Canoe Race will take place in our very own Eindhoven! The committee for the organization and the committee for the race itself are working hard to make this all possible. Are you not afraid to sit within a canoe made of concrete? Are you looking forward to an active and amusing weekend? Then join us for this weekend, participate in several races, and help us win a lot of trophies again.

ABT Design Challenge

June 6th To be announced

It is time for a design challenge again! This time it will be organized in collaboration with ABT Engineers. The day will start with different informative lectures which will inspire you to craft beautiful structures with random materials in the afternoon. Of course the best design will be rewarded, so join this challenge and maybe you will win a price!

Dies Natalis KOers *December 21st*

Lessons learned from recent fires in tall buildings

Fire safety of high-rise buildings

By: Ruud van Herpen MSc. FIFireE
Fellow Fire Engineering TU/e; Technical director Nieman Consulting Engineers

In the Netherlands, buildings taller than 70 meter are considered high-rise buildings. This building height is beyond the scope of the Dutch building code (Bouwbesluit). Therefore, additional measures are necessary to guarantee a similar safety level as in low-rise buildings. The fire in the Grenfell residential tower in London started two discussions:

- **Are the requirements of the building code safe enough for high-rise buildings within the scope of the building code, e.g. with a building height between 40 and 70 meters?**
- **Do we need additional requirements for the reaction to fire for the facade in case of high-rise buildings?**

Building height between 40 and 70 meter
Since the building code contains requirements for buildings until 70 meters building height, there are no additional measures required for controlling fire and smoke in buildings between 40 and 70 meters tall in comparison to low-rise buildings. It is clear that fire safety risks of buildings between 40 and 70 meters is significantly larger than the fire safety risks of low-rise buildings. Both the probability of a fire start and the consequences increase because of the higher amount of floors in tall buildings.

The Grenfell tower is an example of a tall building between 40 and 70 meters. This raises the question whether a fire calamity like Grenfell would be possible in the Netherlands. And yes, of course that is possible. The building legislation in the Netherlands is not better than in the UK, the fire service in the Netherlands is neither, and the same goes for the building occupants. However, there is one important difference between the Netherlands and the UK: in the Netherlands there are not many buildings like the Grenfell tower. The building tradition in the Netherlands differs from the building tradition in the UK. In the 1970s, most new apartment buildings in the Netherlands had external traffic zones and escape routes (galleries) instead of an internal traffic zone. In the Grenfell tower, only one internal staircase was available as escape route. There was no redundancy for safe evacuation, while redundancy very effectively reduces risks.

Figure 1: Grenfell tower fire, London

In modern high-rise buildings, taller than 70 meters, al risk subsystems are redundant:

- safety of the building: redundant load bearing structure;
- limiting fire spread: sprinkler system and fire compartments;
- limiting spread of smoke: pressurized escape routes and smoke compartments;
- safety of escape and attack routes: at least two independent escape routes (staircases).

Engineering fire safety means engineering risk subsystems using a probabilistic approach. The probabilistic approach is necessary to take into account uncertainties in stochastic boundary conditions. In both building characteristics and fire characteristics the uncertainties in boundary conditions can be very large. Think about the fire load, the rate of heat release, the time constant for fire spread, the reaction to fire of load bearing elements and dividing structures, etc. In all risk subsystems, it is possible to compare the available safe time (AST) of the risk subsystem with the required safe time (RST). The required safe time can be determined by the thermal load, caused by a natural fire. At Eindhoven University of Technology, this is the core of the Fire Safety Engineering research program. With this research program, the Eindhoven University of Technology is distinctive compared to the Universities in Ghent, Lund, and Edinburgh, where fire engineering focuses on fire physics, fire dynamics, and loadbearing structures.

The research program already made clear that failure probabilities of fire resistant dividing structures is relatively high, even when they fulfill the requirements of the building code. A burn down scenario of the complete building is possible when there is no efficient support from the fire service. The former department Building and Architecture of Delft University of Technology is a good example of that scenario.

Figure 2: TU Delft department of Building and Architecture on fire: building completely demolished by a travelling compartment fire

Additional fire safety requirements for the facade?

In the Grenfell tower fire, the fire seemed to spread rapidly on the facade. The facade consisted of aluminium composite material (ACM) cladding with thermoplastic cores. Combustible materials in external dividing structures are acceptable according to the building code, as long as the reaction to fire (euroclass) meets the requirements. However, in the Grenfell case the cladding materials did not meet the euroclass according to the building code and the fire barriers at the story floors failed. The facade fire was able to easily spread to other compartments.

Figure 3: Residential tower 'Haut' Amsterdam

With efficient fire barriers in the facade at the story floors, combustible material in the facade is not a major issue. However, the detailing is more complex than when only non-combustible materials in the facade would have been applied. Therefore, the failure probability increases in case of fire in comparison to a facade containing non-combustible materials only.

Robust detailing is necessary to realize a fire resilient building. When failure probabilities of all risk subsystems (particularly the fire compartmentation) are low, a compartment fire remains a compartment fire. A traveling compartment fire, resulting in a burn down scenario of the whole building is unlikely. In that case, the building can be qualified as a fire resilient building, a sustainable concept.

Future developments

In Amsterdam, a tall residential building of 23 stories with a wooden load bearing structure will be realized (project 'Haut', Amsterdam, *Figure 3*). The load bearing structure consists of Cross Laminated Timber. It is possible to create a wooden loadbearing structure that can endure a compartment fire. Of course, it is absolutely necessary to prevent that the compartment fire becomes a traveling compartment fire. The fire compartment dividing structures have to be extremely reliable. In this project, a sprinkler system has been added to increase the reliability of the fire compartmentation.

On the other hand, the loadbearing structure may be sufficiently fire resistant, but it is not automatically fire resilient. After the fire, the affected wooden loadbearing elements should be replaced by new elements. This is a very complex operation, the question is whether this solution is really fire resilient. ◀

Figures:

3 *Volkskrant, November 2nd, 2017*

Building *the present,* Creating *the future*

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?**

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Blast resistant design for petrochemical facilities

BP Europoort Main Office

By: ing. Sander Molenaar
Structural Engineer at Ingenieursbureau IOB

In 2010, BP Nederland, a refinery and fuel vendor, took their new main office in operation next to their refinery in the Europoort, Rotterdam. The location of the new office was within the blast zone of a potential accidental explosion at the refinery. This had to be taken into account for the design of the structure.

In a plant explosion, buildings will be subjected to a lateral force resulting from the blast load on one side. The structure must be able to absorb this large lateral load without catastrophic failure.

The shockwave resulting from an explosion can be defined by the side on overpressure (P_{so}) and duration (t_d) (*Figure 1*). The values of these parameters depend on the total energy released and the distance from the source to the point of impact (the building). After a shockwave passes a point, there is a negative (suction) phase of lower intensity. The blast load is usually simplified as a triangular shape with equal overpressure and impulse. The negative phase is almost always excluded because it has little effect on the response of the building. Blast loads differ from many other dynamic loads since they are single non-repeating loads. Typically, only the fundamental natural frequency of a structure or component needs to be considered, higher order frequencies are very unlikely to occur.

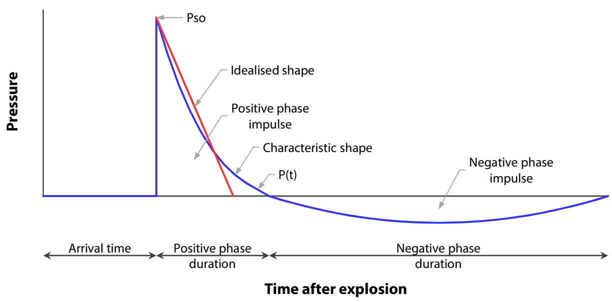


Figure 1: Shape of a shock wave

Each surface of the building experiences a different blast pressure based on its orientation relative to the direction of the shock wave (*Figure 2*). The sides of the building facing the source block the propagation and redirect the blast wave. This reflection process results in an increased pressure P_r. For this type of explosion (a vapor cloud conflagration), P_r is approximately 2.0 P_{so}. Blast loads on the sides of the building and the roof parallel to the direction of the blast wave are

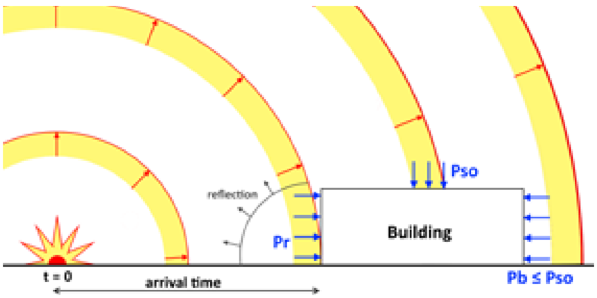


Figure 2: Blast loads on building surfaces

equal to the side on overpressure. The blast load at the back side of the building is conservatively neglected when the overall stability is considered because the direction of the load is opposite to the direction of the front wall load.

Structures subjected to a blast load are designed to absorb the explosion energy. This is done by allowing plastic hinges to form. This will result in some damage (permanent deformation). Depending on the type of structure and component, a certain amount of damage is acceptable. The damage level is defined by the allowed ductility ratio. This is the ratio between the displacement at first yield and the maximum displacement.

In many cases, structural components subjected to blast loads can be modeled as a statically determinate beam and an equivalent single-degree-of-freedom (SDOF) mass-spring system with a non-linear spring (*Figure 3*). The majority of dynamic analysis performed in blast resistant design of petrochemical facilities are made using such approximations. This will be illustrated with a uniformly loaded, simply supported beam.

The response of a simply supported beam has an elastic range and, after formation of a plastic hinge at midspan, a plastic range. In *Figure 3* the properties of the beam are shown: K_L and K_M are transformation factors to get equivalence

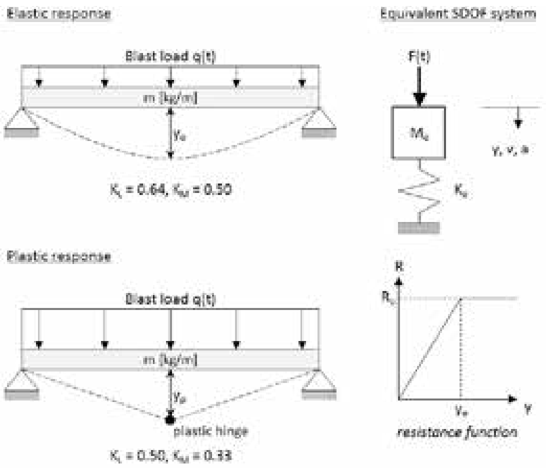


Figure 3: Example of a statically determinate beam

between the actual beam and the SDOF system. They are based on the deformed shape under the applied loading.

Concrete and reinforcement steel have greater strength under rapid strain rates that occur during a blast load. This is accounted for by using a dynamic design stress. For example, the increase compared to the static strength is approximately 20% for both reinforcement steel and concrete under bending.

The analysis can be performed using the dynamic equilibrium equation:

$$M_e \cdot a + R_e = F_e(t)$$

The component can be analyzed using the numerical time integration method. For each (small) time step, the displacement (y) is determined by solving the dynamic equilibrium equation using results from the previous time step to predict velocity (v) and acceleration (a) in the current time step.

The main load bearing structure of the BP main office consist of a grid of concrete columns and beams with in situ casted floors. The glass atrium roof and facades are supported by steel beams and columns. The blast resistant design of the glass facade and roof was done by the supplier. Part of the office building is also protected from a blast load by a dune. This dune is reinforced with so called 'geogrid': synthetic sheets which are layered with the soil in such a way that very steep slopes are made possible.

Properties	Beam	Equivalent SDOF
Resistance	$R = 8 \cdot M_{ud} / L$	$R_e = K_L \cdot R$
Elastic spring constant	$K = 384/5 \cdot EI/L^3$	$K_e = K_L \cdot K$
Plastic spring constant	$K = 0$	$K_e = 0$
Mass	$M = m \cdot L$	$M_e = K_M \cdot M$
Load	$F = q \cdot L$	$F_e = K_L \cdot F$

Figure 5: Properties of the beam and the equivalent SDOF system

A gap was made between the wall of the building and the dune. By doing so, the dune is self supporting and no lateral earth pressure is present against the building.

The steel structure and concrete roof have been modeled as statically determinate beams. The concrete structure could not be simplified to a SDOF system. Therefore, the concrete structure has been modeled in a FEM program as a multi-degree-of-freedom (MDOF) system using numerical time integration (*Figure 4*). No plastic hinge formation was used, thus only elastic response was taken into account. The reason for this is that for an unbraced frame, plastic hinges should only be allowed in beams and not in columns. However, the beams form a whole with the floor because the structure was casted in situ. Therefore, it was difficult to predict the exact behavior and ensure hinge formation in the beam instead of the column. The resulting symmetrical internal forces and displacement illustrate a rebound effect due to the dynamic load. The displacement is relatively small due to a relative stiff structure and a large mass (concrete) which requires a lot of energy to displace.

Blast loading also requires special attention to detailing for concrete structures:

- There is a reversal of component stresses and connection forces due to rebound after the initial deflection. Therefore, reinforced concrete components designed to resist blast loads should usually be symmetrically reinforced.
- Reinforcement bars should run along the entire length of the component. If that is not possible, splices should be located outside areas with high stresses.
- At the locations of plastic hinges, concrete crushing can occur. In that case, an adequate amount of stirrups should be present to prevent buckling in the reinforcement under compression. ◀

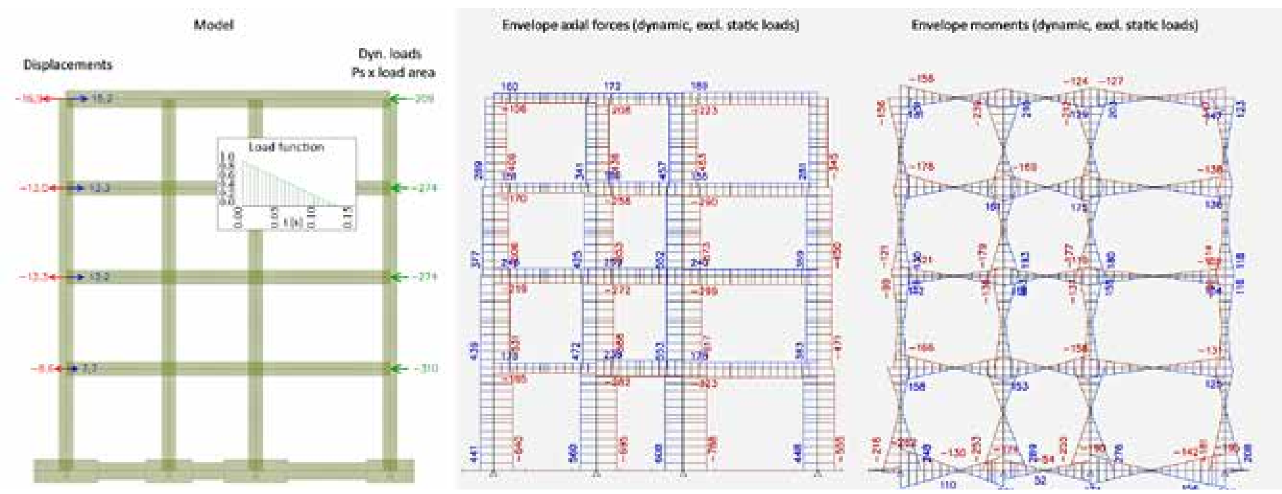


Figure 4: Results of the unbraced concrete frame subjected to blast loads

Dealing with residential areas in hazard zones

Avalanche mitigation measures

By: Stefan Margreth
Teamleader Snow Avalanches and Prevention Avalanche Protection Measures

Paraphrased by Caroline Koks
Editor KOersief

December 11th, 2017. The Royal Netherlands Meteorological Institute (KNMI), announced code red: an alarm whereby extreme weather has a huge impact on the society. The average amount of snowfall was between 15 and 25 centimeters and at some places more than 30 centimeters. This is exceptional for the Netherlands and that day, traffic was a chaos. A few days later, all the snow was gone and everything went back to normal. In for example the Alps, snow is present most of the time and when it comes to extreme snowfall, they have concerns on another level.

Research

Snow is one of the load cases which can be governing. In the Netherlands, it is extremely rare that snowfall will result in failure. Compared to the Netherlands, the snow load in the Alps plays a way more dominant role when it comes to structural engineering. In Zurich, Stefan Margreth is Head Protection Measures and Senior consultant at the WSL Institute for Snow and Avalanche Research SLF. The WSL-SLF is an interdisciplinary research and service center located in Davos Dorf, Switzerland, and is part of the technical university ETH Zurich. Its scientists conduct research on snow, the atmosphere, natural hazards, permafrost, and mountain ecological systems and develop innovative products that translate their knowledge into practical applications. Besides research, the WSL-SLF seeks for solutions for residential areas in hazard zones. Margreth published among others, two articles [1,2] about avalanche mitigation measures in two hazard zones; Siglufjörður in northern Iceland and Juneau in Alaska. In the following paragraphs, an introduction is given with a description of the different situations and what measures are taken for avalanche mitigation.

Siglufjörður

The avalanche situation of Siglufjörður in northern Iceland is unique because the residential area is located directly at the base of several large avalanche paths (*Figure 1*). Due to the topographical situation, large deflecting or catching dams cannot be constructed without the removal of

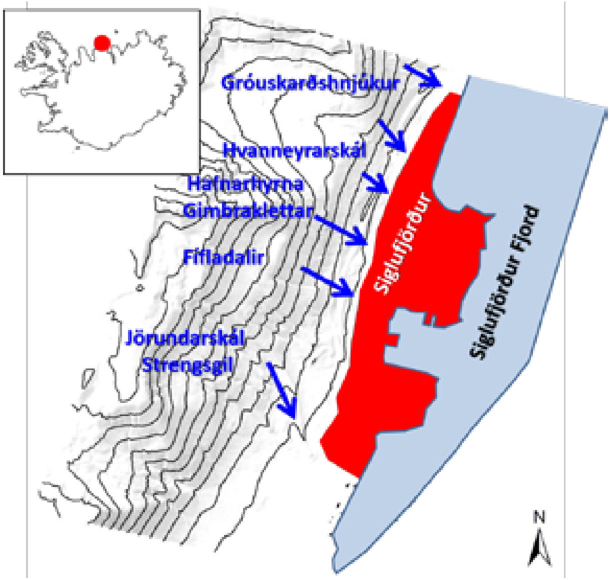


Figure 1: Map of Siglufjörður with avelanche paths

buildings except for the southernmost part of the town. Therefore, up to 8.4 kilometers of supporting structures in combination with small catching dams were proposed as protection measures for the central and northern part of the town. The main challenges for the application of snow supporting structures are the deep and heavy snowpack, irregular snow depths, rockfall, difficult ground conditions, corrosion problems, formation of large cornices, and the lack of experienced construction companies.

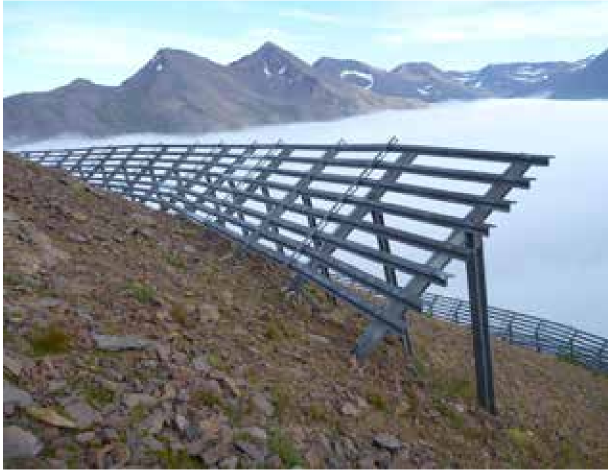


Figure 2: Steel bridges in the release area Gróus-karðshnjúkur built in 2004. The structural height is 3.5 meters and the length of the cross-beams is 4 meters

The protection plan of Siglufjörður is a good example of how comprehensive avalanche mitigation measures can reduce a high risk situation. The combination of supporting structures (*Figure 2*), and avalanche dams (*Figure 3*), provides an optimized protection for the town. An important point was to plan the mitigation measures proactively, instead of reacting only after a disaster. The chosen approach with regard to the planning of snow supporting structures with the initiation of snow depth measurements in the release area and with the installation of test structures could be adopted in other mountain regions as well. The participation of landscape architects in the dam design was essential for the acceptance of this large scale project by the community. The application of precise snow depth maps prepared by lidar technology proved to be very helpful for choosing the structural heights.

This technique might become standard for the detail planning of snow supporting structures. It is important for such a large scale project to evaluate the effectiveness and state of the structures regularly and to plan the maintenance in time. After the planned completion of the project in 2020, a challenging task will be the assessment of risk in the settlement below the structures and the formal adaption of the hazard zones [1].

Figure 3: Catching dam in construction: the steep top section is made of geocells

Juneau

Juneau, Alaska's state capital, has a serious avalanche problem. The last major avalanche event in 1962 (*Figure 4*), was the catalyst for the first proposition of avalanche mitigation measures. In 1972, a comprehensive geophysical hazard study was performed where avalanche hazard zones were suggested. The zones were re-evaluated in 1992.
In 2011, the SLF was mandated to investigate mitigation measures to decrease the avalanche risk in the two most dangerous avalanche paths. Besides structural mitigation measures, such as snow supporting structures or earth dams, the application of fixed installed remote-controlled exploders was investigated as well. The buyout of homes seems to be one way to effectively reduce the avalanche risk on the long-term. Currently, the only avalanche safety measures consist of an avalanche response plan, information and training for residents and responders, and an avalanche forecasting program.

Figure 4: View of Behrends Avenue with Gastineau Channel in the background after the 1962 avalanche: collapsed roofs because of overpressure and impacts of trees. The back-walls are not damaged

The avalanche problem is very serious in the runout zone of Behrends Avenue avalanche path (*Figure 5*). According to current standards, the risk is far beyond an acceptable level. The unacceptable risk to the residents in the hazard zones can be managed only on short term if the City and Borough of Juneau would order evacuations and close endangered areas during periods of high avalanche danger. Since the buildings in the hazard zones have no structural reinforcement, people inside these buildings are not safe. Continuing with the established avalanche hazard evaluation and forecasting service in the community during the winter months is recommended and is a very good starting point to develop an evacuation concept. Moreover, the education and awareness to the public about avalanches is valuable. While this is improving the situation, these measures are not sufficient with respect to the serious avalanche problem. The reduction of the avalanche risk with structural protection measures is prohibitively expensive and therefore not recommended. Furthermore, the artificial release of avalanches is not advisable, mainly because of the danger to people, property, and homes. The buyout of endangered homes in the avalanche path by the government is the only way to effectively reduce avalanche risk on the long term.

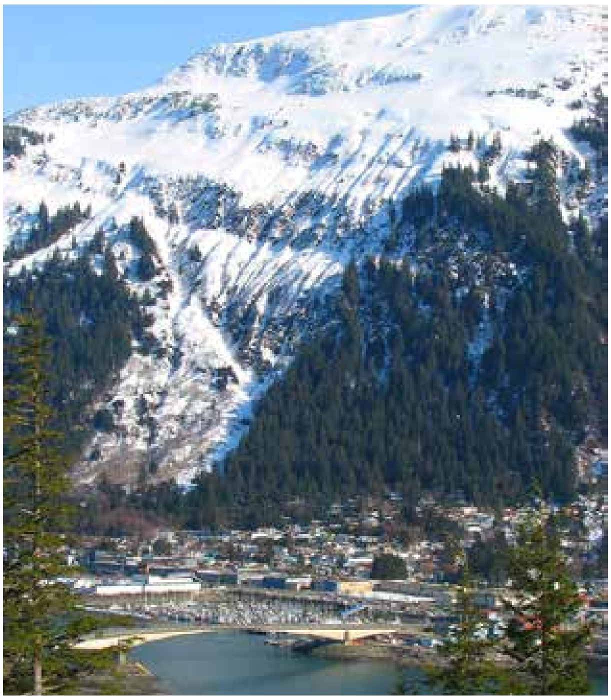


Figure 5: Overview of Behrends Avenue path

The buyout of homes would assure a permanent solution to the avalanche problem. Following the advice the City and Borough of Juneau (CBJ) is presently establishing a buyout plan for endangered homes. CBJ will be working with homeowners to determine the level of interest and then applying for Hazard Mitigation Grant Program dollars from FEMA to fund the buyouts in the priority areas in the order of highest danger [2].

Final remarks

From the previous paragraphs, it can be concluded that every situation needs to be considered individually. In hazard zones, the risk can be mitigated, which is among others depending on the slope angles of the avalanche paths, and the amount of snow present in the terrains. This can be done by measures like avalanche dams, snow supporting structures and wind baffles. In some areas, it can also help to release an avalanche artificially and sometimes only buyouts will give a safe solution. For more detailed information about how the research in Siglufjörður and in Juneau has led to the taken measures, then the articles of Stefan Margreth will give more insight. ◄

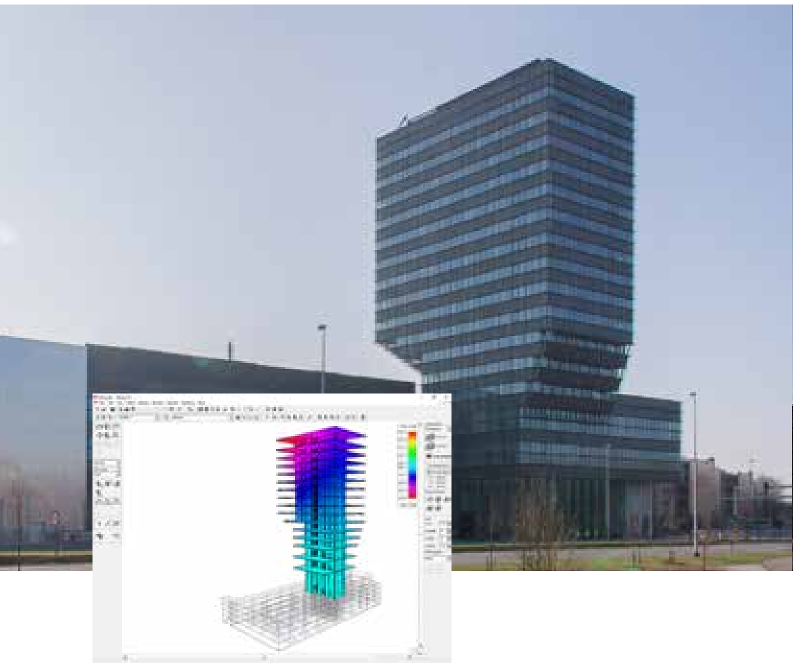
Figures:

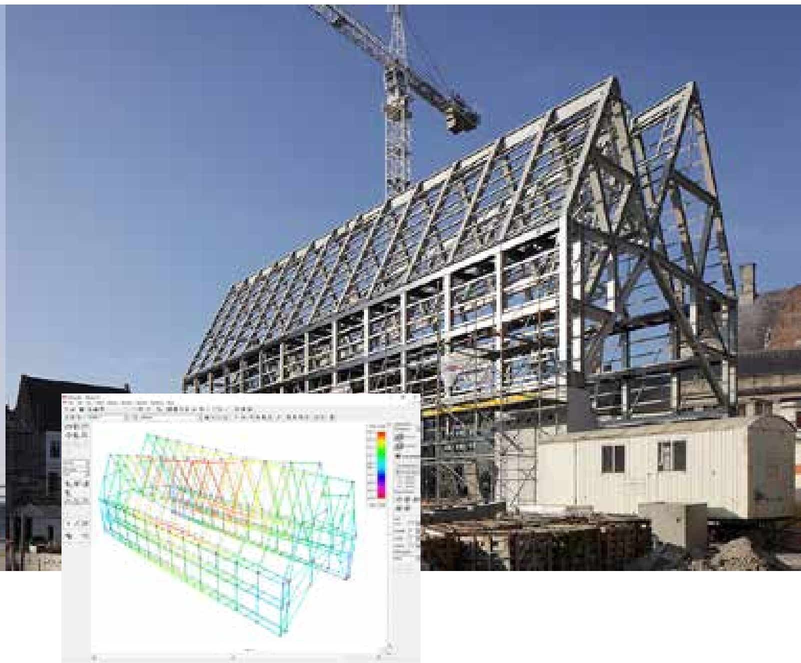
Header	*https://commons.wikimedia.org/wiki/File:Avalanche_Zinal.jpg*
2	*S. Margreth*
3	*Þ. Jóhannes-son*
4	*Alaska Mountain Safety Center*
5	*David Kent, April 3, 2007, www.westjuneau.com*

References:

[1] Margreth, S., Jóhannesson, T., & Stefánsson, H. M. (2014). Avalanche mitigation measures for Siglufjördur - realization of the largest project with snow supporting structures in Iceland.

[2] Margreth, S., & Mattice, T. (2012). Re-evaluation of avalanche mitigation measures for Junea.





Guwahati Smart City

Riverfront design approach

By: Luc Veeger
Architect, urban designer, and project manager Guwahati Smart City at Arcadis

Arcadis, in consortium with a local Indian partner Tata Consulting Engineers, has been appointed as Project Management Consultant (PMC) to design, develop, engineer, and implement the Guwahati Smart City project, India. The various Smart City project components are grouped into subprojects. One module under Area Based Development (ABD) is to develop the six kilometer long riverfront development along the south bank of the Brahmaputra river, between the famous Kamakhya Temple and Raj Bhavan. Ages of Dutch water management experience, state of the art technology, and research in water and river modeling technology can contribute to sustainable design solutions for this important part of the world. The Dutch water sector, including universities with a strong high-tech and innovation attitude, is in a preferred position to share their expertise. This article summarizes the holistic Smart City design approach including major required river modeling and structural design disciplines.

Guwahati, 'The City of Temples' is the capital and gateway to the northeast Indian State of Assam (*Figure 1*), a hub for promoting 'Look East Policy' in India. The state of Assam has over 30 million inhabitants, a strategic position in the region between China, Bhutan, Myanmar, and Bangladesh, produces the well-known Assam tea, and has a strong economic forecast. Guwahati, located on the banks of the Brahmaputra river has been bestowed with a unique wetland ecosystem, a network of hills and basins, rivers and beels that add value to its scenic landscape beauty including wildlife sanctuaries with elephants, tigers and rhinos. At the narrowest spot of the river basin, people settled from the 4th century on the embankments and were able to live in natural circumstances with the power of the mighty Brahmaputra (the son of the creator god Brahma). Today, the city suffers yearly from heavy floods due to poor river infrastructure and heavy monsoons (*Figure 5*). Due to a traditional passive and reluctant attitude, the Indian and Assamese people accepted these natural disasters as their destiny, still till today in 2018. This approach is changing and these people have already taken the first step with low-tech embankment protection (*Figure 4* and *Figure 6*). Their Smart City, ambition is an expression of this development.

The broad context of Guwahati is defined by the Bramaputra valley with its immense power of the river, the delicate unstable seismic landscape, due to the colliding Eurasian (Chinese) and Indian tectonic plates with high earthquake risks, the extreme monsoon climate, its strong cultural heritage and fast urbanization, and economic development.

Figure 1: Assam, Guwahati, and Brahmaputra river

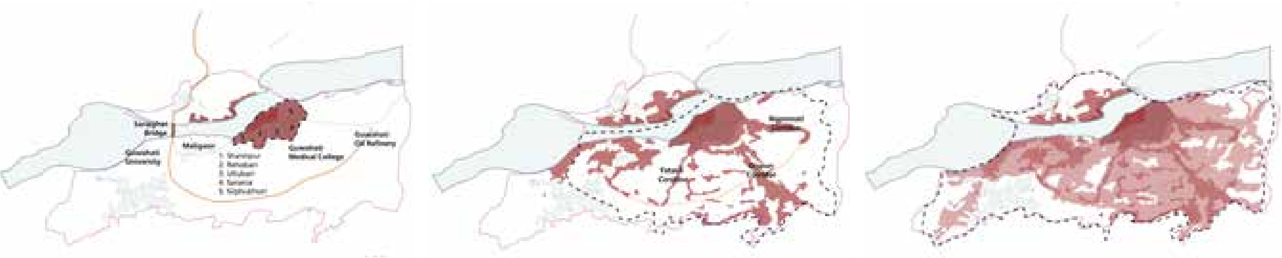


Figure 2: Guwahati's urban development 1890, 1960, and 2015 (from left to right)

This settlement became the natural and cultural habitat and developed throughout the ages into the metropolitan area of Guwahati today with over 1 million inhabitants (*Figure 2*). In general, the riverfront is the zone of interaction between urban developments and the water. The riverfront Guwahati area is considered as a unique and irreplaceable resource where it is the interface between land, water, air, sun, and productive plants. In many cities in the world, riverfront areas began as commercial centers, transportation hubs, and manufacturing centers, as a central focus for them. However, due to uncontrolled urbanization, difficulties in city planning and maintenance, and climate and technology change created a dramatic change in riverfront areas that occurred in the past fifty years (*Figure 3*). Currently, a reunification between the river and the city, and urban renewal is forced by increased environmental awareness and the historic preservation movement.

Figure 3: Guwahati riverfront 1870 (left) and Guwahati riverfront 2017 (right)

Current population of over 1 million is spread over a municipal area of 245 km^2 (approx. 4,000 inhabitants per km^2). The urban sprawl is rapidly growing beyond the planning area and posing serious challenges to the sustainability of its major water and city infrastructure. The challenges, especially identified in the very near future, were that of climate change, water and river management, drainage and sanitation, transport congestion, energy, and waste management for the entire city. Guwahati is among

Figure 4: 'Low-tech' temporarily embankment protection after the first flood and monsoon on June 11th and 12th

Figure 5: Eroded embankment and protection structures flushed away in 2017

the first 20 Smart Cities in India to launch this renewed city planning program. The Smart City concept aims resilient and livable cities which have smart (i.e. intelligent), physical, social, institutional, and economic infrastructure based on sustainable and adaptable planning.

The historic context of Guwahati together with the new Smart City ambition requires an approach to design and engineer with these natural forces of the river and the geological context. Rather than control this extreme natural context in this Smart City, it is our goal to coexist and design with these natural and cultural assets. The design solutions for the riverfront and its protective structures aim and try to sustain and improve this unique habitat (*Figure 10*).

Figure 6: 'Low-tech' temporarily embankment protection after the first flood and monsoon on June 11th and 12th

Engineering for smart water management of Guwahati and Brahmaputra river.

A model of the city is built to achieve a smart and sustainable water management concept, including flood and erosion control, the puzzle of the river, the inland rivers

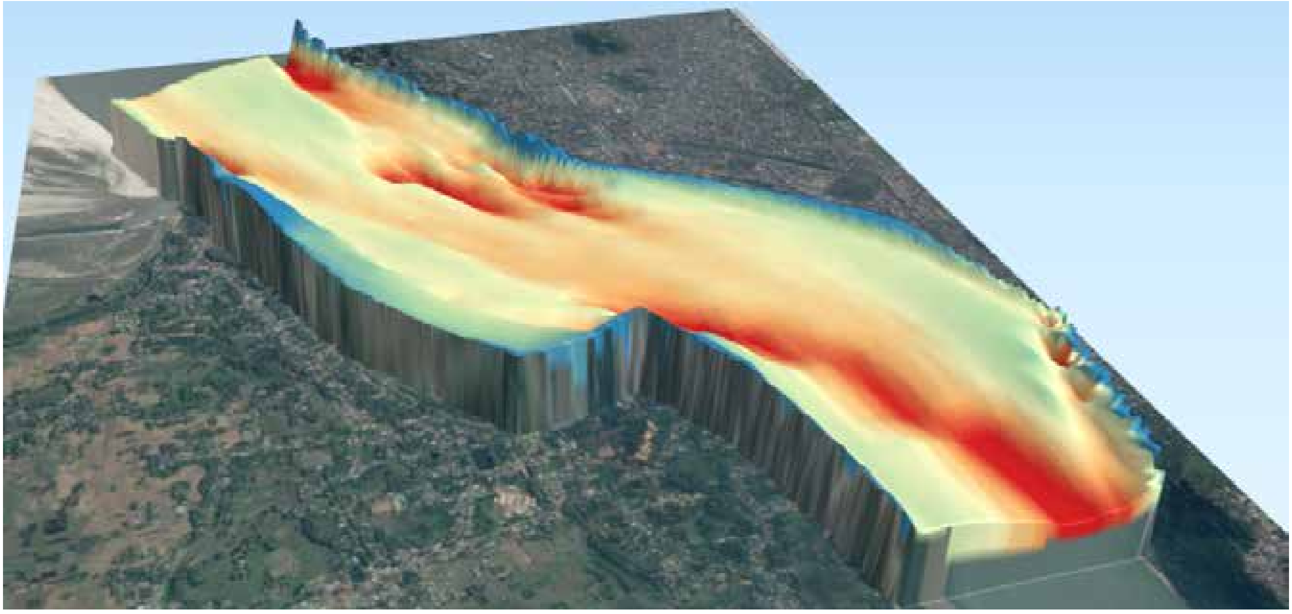


Figure 7: Digital Elevation Model riverbed Brahmaputra made by Arcadis, 2017

and canals, city lakes, ponds, and the topography of the urban landscape. This integrated model is the basis for analysis of water quantities and quality. The Brahmaputra river, termed a moving ocean, is an antecedent snowfed river which flows across the rising young Himalayan Range. Geologically, the Brahmaputra is the youngest of the major rivers of the world.

Figure 8: High water level July 2017 (left), Northbrook gate Guwahati, 8 meter difference between high and low water level (right)

To start the design process within an existing context it is required to define design starting points for topics like topography, geology, seismic conditions, rainfall, climate, waterlevel (danger, design flood, high and low), flow velocities, and a clear urban and landscape design vision. For example, due to the climate change scenarios, Indian Network for Climate Change Assessment (INCCA) has estimated the country average increase in peak of 100-year floods by 10 to 30%. Similarly, the increase in monsoonal flood at Guwahati for a future projected period of 2071-2100 is circa 20%. Based on these estimates, a 15% increase in the present estimate of 100-year flood is considered for climate change analysis. The top of the embankment has to accommodate the increased flood levels (*Figure 8* and *Figure 9*).

Figure 9: Water high during the monsoon, June 12th-14th 2017

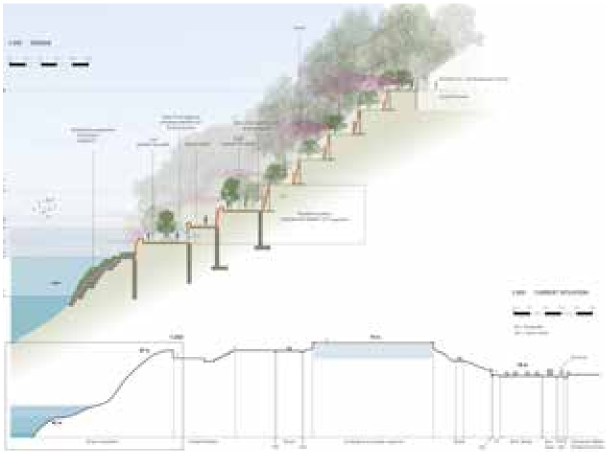


Figure 10: Digital Elevation Model riverbed Brahmaputra made Arcadis, 2017

River engineering is influenced by innumerable factors like catchment hydrology, geomorphology, river hydraulics, hydraulic structures, study of channel braiding through erosion and deposition, etc. To develop any riverfront, the scientific analysis must be required to understand river engineering phenomena. In our era of high computational development, computer based 3D models are a strong tool to analyze river engineering phenomena (*Figure 7*). Fluvial parameters like design flood level, velocity, and shear forces and stress are required and will be estimated by simulation in the model Indian planning, design, and engineering culture requires important and smart skills to collect all required data from all different government departments and institutions.

For the six kilometers stretch, a vast topographical survey has been carried out. Based on this data the riverbed and riverbank will be combined in the Digital Elevation Model which will be used for river simulation as well as structural design simulation. These 3D river models will be extended in the next phase for the whole river bank to be able to design the riverbank protection works in more detail for construction. ◀

Figures:
All *Arcadis*

Pieters
BOUWTECHNIEK

Pieters Bouwtechniek is een toonaangevend onafhankelijk ingenieursbureau in constructieadvies. Zorgen voor de juiste samenstelling van de draagconstructie van een bouwproduct, dat is sinds 1974 ons vak. Van constructieontwerp en advies tot de oplevering van het gebouw aan toe. Met vestigingen in Haarlem, Utrecht, Delft, Amsterdam en Zwolle. Door liefde voor ons vak gegroeid.

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Wil je, tijdens of na je studie, aan de slag bij een toonaangevend ingenieursbureau in constructieadvies? Bij een ervaren organisatie met een open werksfeer waar kwaliteit, dienstverlening en ondernemerschap voorop staan? Pieters is altijd op zoek naar oplossingsgerichte en innovatieve medewerkers.

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An interview about the design of houses able to withstand hurricanes

Floating Homes

Interview with: Pieter Ham
PhD candidate TU Delft

By: Denise Kerindongo
Editor KOersief

In a tropical climate, hurricane seasons are unavoidable. Every year, a lot of homes are destroyed all over the world. Pieter Ham, together with fellow student Joran van Schaik, thought there must be a solution to solve these problems. During his graduation project, together with Joran, Pieter worked on an assignment to investigate the possibilities. Pieter Ham recently returned from the Philippines, where he was working on a project to build floating homes. This was the perfect opportunity for the editorial board of the KOersief to interview him about the design process of these homes.

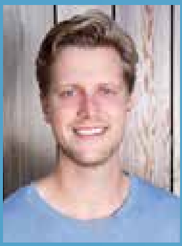
How did you come up with the idea to build floating houses?
While graduating, together with Joran, I made an assignment in which we looked into the possibility to build adaptable buildings in places where improvement is very much needed. This in order to help people who live under severe circumstances due to the hurricane seasons. In addition, I worked at a company named Finch Buildings. Finch Buildings develops and designs modular buildings that adapt to the environment and the circumstances. This was the starting point and inspiration to set up the foundation 'Finch Floating Homes', which develops floating houses for tropical flood areas where adequate housing is very much needed. They develop certain modules, that can be mounted and demounted very easily on the building site, which is a great advantage. We translated the concept of Finch Buildings to a model that could be built in the troubled areas. That was the research we did during our graduation project. Due to the super typhoon in November 2013 that struck the Philippines, a time before we started, we chose the Philippines to establish our project.

Can you explain what you have done there?
When we arrived in the Philippines, we observed that a massive flood problem exists there (*Figure 1*). Not only there, but in a lot of areas in the southeast of Asia. This problem mainly exists, because a lot of water is taken out of the ground and causes ground settlements. Some areas flood daily, due to the high water level. In the Philippines, there is a dry and a wet season. In the wet season during the periods with a lot of rainfall, the floods are more severe. That is why we made designs for floating structures that can withstand floods.

Where did you make the designs, in the Netherlands or in the Philippines?
We made these designs in the period that we visited the Philippines, which was during our graduation project, we made the different design concepts after speaking to the local inhabitants of the area. We asked them what was important for them about their house and how their ideal dream house would look like. Eventually, that was the design on which I graduated. Now, during my PhD, I am proceeding on designing and developing modular buildings. I have the goal to build the first pilot houses in June 2018. This is all in collaboration with Delft University of Technology.

Figure 1: Houses during the flood

What were the thoughts behind the design of the houses?
At first, we did research on the way people build their houses in former times in these specific areas. The native inhabitants developed their own identical building style, which has been improved for centuries. Eventually, they designed the 'Bahay Kubo', which is a type of residence that can be found a lot in tropical climates. It is mainly constructed with bamboo, several grass types, and nypa-leaves. These houses are constructed on piles, risen from the ground. This method has the advantage that when a flood occurs, the residents stay dry and that the vermin cannot reach the houses. Another smart application is the pointed roof; with strong winds, a pointed roof is a smart structure and better than a flat roof. This was the concept on



Pieter Ham is a former Building Engineering student from Delft University of Technology. Since March 2017, Pieter is doing PhD research for the TU Delft Global Initiative. This means that for the next four years he will be optimizing the floating home. The goal of the Global Initiative program is to solve problems in developing countries with technology and thus applying knowledge where it is most needed. This is exactly what Finch Floating Homes does. Thanks to the collaboration with TU Delft, several students have already connected with Finch Floating Homes.

which we proceeded, in combination with the techniques we apply at Finch Buildings. Namely, an innovative and sustainable building concept, which is easily expandable and adaptable.

The design of the house also has a floatable foundation (*Figure 3*). The modular floating foundation consists of a wooden frame with barrels. The foundation can easily be expanded, so that a larger floating platform with more homes can be created. The foundation is held in place by pillars that are fixed in the ground. This allows the foundation to adapt to the water level. It is also possible to let the houses rest on the ground at the moment that the water is low.

This concept is very applicable in the Philippines, because you often see that the families are expanding there. Therefore, the adaptable aspect of Finch Buildings is a good fit. So, the design of the house is a combination of the former building methods combined with what we do at Finch Buildings.

What materials are used for the houses?

The design exists of prefab elements which can be produced by local employees. We aim to build with local wood. Wood as a building material is durable because it grows back. Furthermore, wood is the only building material that stores CO_2 from the atmosphere instead of emitting it. The prefab elements are produced in a dry and controlled environment in a factory, which has advantages as we learned in the Netherlands. This results in high quality products, which we aim for.

Figure 2: Floating homes with foldable roofs

How was the collaboration between you and the people in the Philippines?

The collaboration went very well and was a lot of fun. My last visit was in November to make preparations for the execution of the houses. The goal was to gather different local parties to work with. We needed a building site, so we made appointments with the municipality and I also sat with local construction workers. In these conversations, I noticed that because of the research we did on the ancient building methods, our building plans were more accepted. The design is not just something we came up with, but in collaboration with locals we have come to the best design that suits the location and the inhabitants.

Figure 3: Floating foundation

What makes the houses hurricane-resilient?

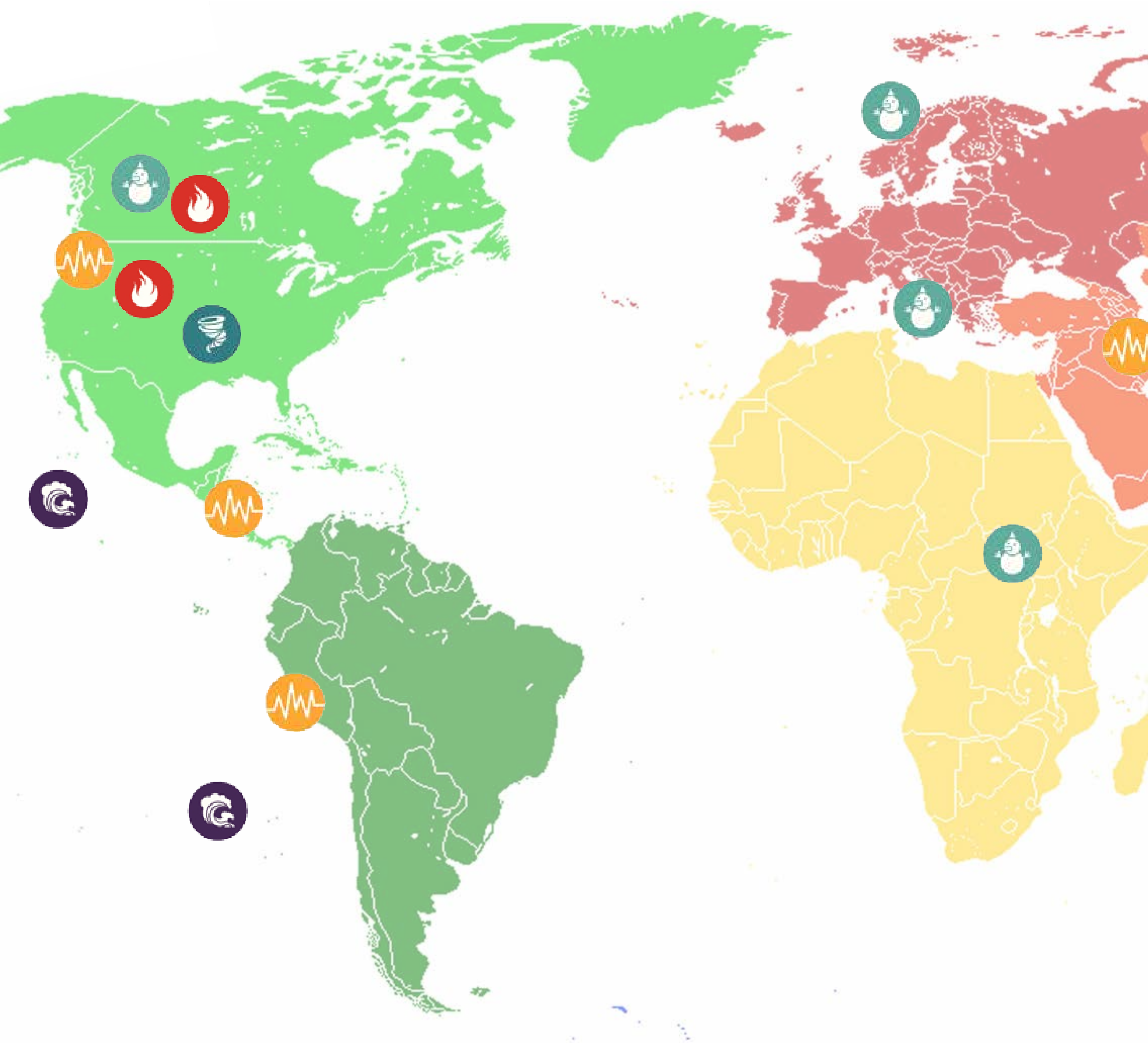
A simple trick is that the houses have pointed roofs. Also, a square floor plan is applied which makes the houses more stable compared to elongated floor plans. The walls that provide the stability are all processed in the prefab elements. So, this makes it easy to construct a stable house. Since the intensity of typhoons has increased over time, some parts of the 'Bahay-Kubo' have been reconsidered. The roofs of the 'Bahay-Kubo' have canting roofs, which are advantageous for rain, but not for wind loads. Therefore, we made a variant in which you can fold the roof which makes the house more able withstand storms (*Figure 2*). Thanks to a clever design of the facade panels, the house is provided with natural ventilation and offers protection against typhoons. However, when there is a super typhoon, there are always small parts of the building that will break. But the fact that the buildings are adaptable, makes it easy for the parts that are broken to be replaced. In this way, the whole house does not have to be built again, but only partly reparation is needed.

If you had only one tip for the ultimate hurricane-proof house, what would it be?

To build a perfectly well hurricane-proof house is not difficult at all. When you build a concrete bunker, for sure it will withstand such extreme loads. However, the goal is to design a livable place where ventilation, comfort, and daylight are present. The houses must be affordable and made with sustainable materials, which makes the design process more interesting. However, if hurricane-proof is your only requirement, it will not be that hard. ◀

Figures:

Header, 1-3 Pieter Ham / Finch Floating Structures



Often, weather circumstances provide the most extreme load cases. The map shows these extreme weather loads on their most common locatio

Snow in a desert

January 7th, 2018, Ain Sefra, a desert town in Algeria known as the 'Gateway to the Sahara', experienced a substantial amount of snow for reportedly the third time in 40 years. Some reports say parts of the area got nearly 38 centimeters of snow, but Ain Sefra officially reported less than one inch. It is not uncommon for the temperature across even the hottest of deserts to plunge tens of degrees Celsius at night, meaning any unusual snow could stick around for a while. However photographers at the scene said the snow actually stayed intact for a good portion of the day.

Hail on a bounty island

Samoa has been hit by a hail storm so rare that it was believed to be a hoax by many of the island's inhabitants. The tropical nation of Samoa lies in the Pacific Ocean, where the average temperature at this time of year is 29°C. On September 16th, 2016, a hail storm struck the eastern side of the island of Savai'i, accompanied by heavy rain and strong wind gusts. It was only the second time since records began that hail has fallen on Samoa, the first was in 2011. The storm lasted 10 to 15 minutes and produced hail stones roughly 2 centimeters wide.

Not one, but two tornad

On June 16th, 2014, a rar
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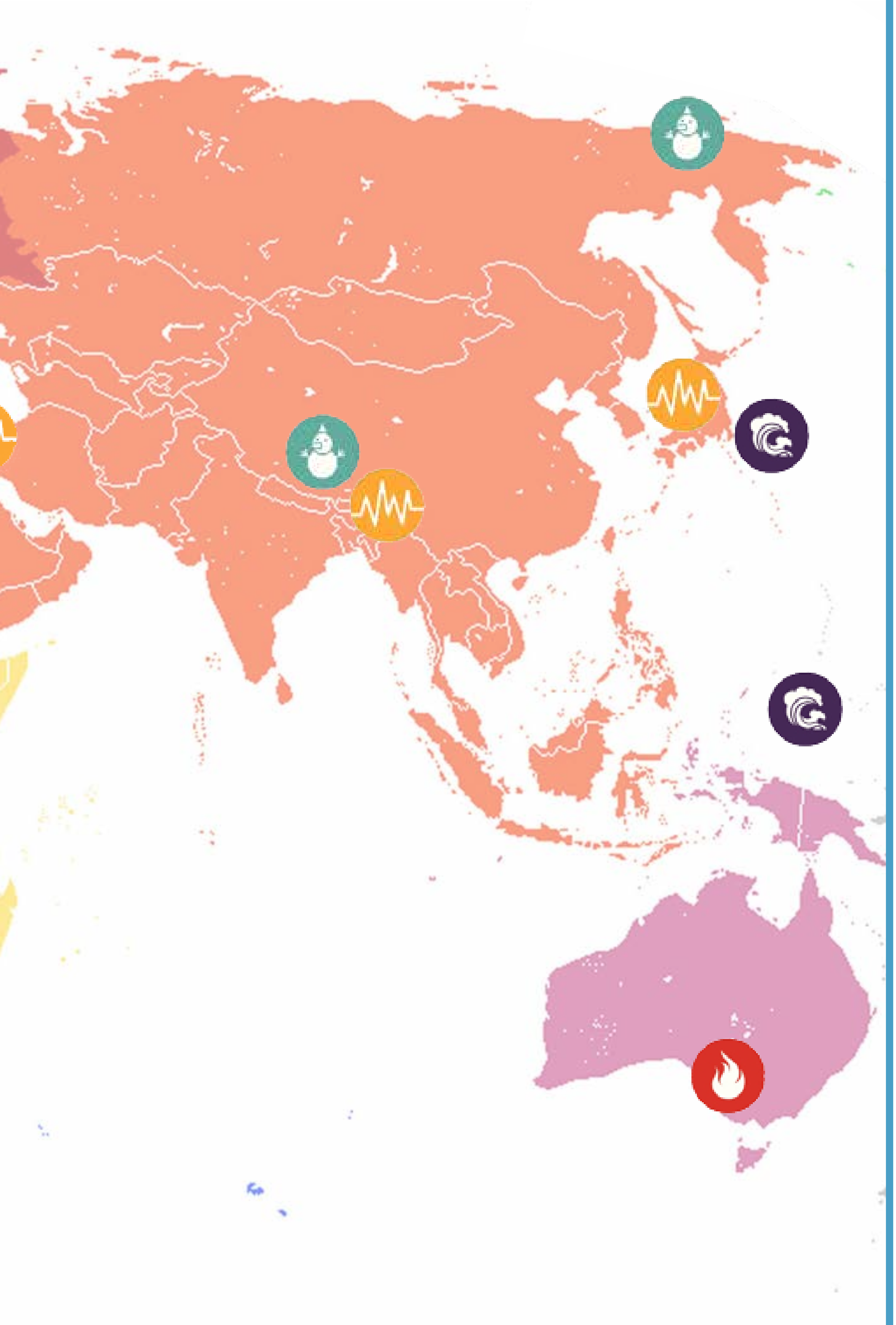
every 10 to 15 years.



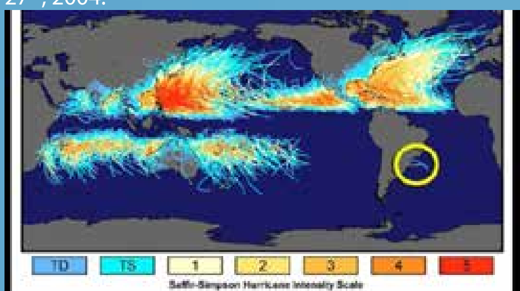
ns. But what if these weather circumstance occur at the most unexpected places?

does

e double tornado mowed Pilger, Nebraska. Double, nusual and occur perhaps

Unexpected hurricane

Until 2004, no hurricane had ever been confirmed in the South Atlantic Ocean. In late March 2004, however, wind shear was low off the eastern coast of South America as an upper level low pressure system was sprouting thunderstorms near its center. Making the transition to a tropical cyclone, what was later called Hurricane Catarina turned back westward, making landfall in the Santa Catarina province of Brazil as a Category 1 storm on March 27th, 2004.



Wildfires

The west of the USA, Canada, and Australia have had the largest wildfires in history. The latest wildfire in California destroyed almost 5,000 residential properties and 10,000 of them were damaged.

Tornado

The United States is home to the majority of all the tornadoes that touch down around the world every year. After the Joplin Tornado in 2011, it was questioned whether the tornado was that strong or all residential buildings had such weak structures. One of the few buildings still standing was the St. John's Regional Medical Center. However, one of the hospital's towers took a direct hit and was rotated approximately 10 centimeters about its foundation.

Tsunami

The Japanese word for harbor is tsu and nami means wave. Powerful undersea earthquakes are responsible for most tsunamis. Tsunamis occur all over the world, but the most treated zones are around the Pacific Ocean, also called the Pacific Ring of Fire. Several features make a tsunami destructive. The most obvious one is the force of the high-velocity water flow. However, stationary objects like houses often resist these forces and the water will go through and around the structure. On the other hand, it is often the debris in the water that causes damage to structures. This debris can even be on fire, which then spreads among combustible materials. After water rushes onto land, it retreats back to sea and wears away soil around foundations creating erosion.

Avalanche

An avalanche is a sudden flow of snow down a slope, such as a mountainside, and occur all over the world on tall mountains. Natural disasters that can be triggered by ourselves and can be deadly. A deadly avalanche quickly reaches a speed of 130 km/h.

Earthquake

Earthquakes are felt by people somewhere on the globe just about hourly. They can range in size: from those that are so weak that they cannot be felt to those violent enough to toss people around and destroy entire cities. According to building codes, earthquake-resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location. So, earthquake resistant designs may differ around the world.

The earthquake of 2017 in Sarpolzahab, Iran

By: A. (Akbar) Shahiditabar and H.H. (Bert) Snijder
Guest researcher and professor of Structural Design at TU/e, resp

According to the Geophysics Institute of the University of Tehran, on November 12th, 2017, at 18:18 GMT (21:48 local time), an earthquake with a magnitude of 7.3 on Richter's scale occurred in Iran. Based on International Institute of Earthquake Engineering and Seismology (IIEES) of Iran, the epicenter of the event was located at 34.48° N and 45.84° E, 37 kilometers - southeast of Sarpolzahab (in Kermanshah Province in Iran) and its depth was about 18 kilometers deep. The record obtained in Sarpolzahab shows a maximum Peak Ground Acceleration (PGA) of 0.7g and 0.4g for the horizontal and vertical components respectively. The population of Sarpolzahab and its nearby villages is about 85,000 of which 55% is living in urban areas and the rest in rural area. On the basis of field evidence, this strong earthquake killed about one thousand people and left thousands homeless[1].

Seismicity of the affected area
In the seismic code provisions of Iran, seismicity is categorized into four levels: low, moderate, high, and very high. The region concerned is categorized as having a high level of seismicity. The existing records on seismicity history indicate no earthquake greater than 7 on Richter's scale. In the previous century, no strong earthquake has taken place and the only earthquake recorded in this city in the history with magnitude greater than 6, refers to about 1,000 years ago (958 AD) [1]. Although previous studies have excluded the probability of occurrence of an earthquake greater than 7 for this region, this event proves that the level of seismicity of this region needs to be upgraded.

Building performance in the Sarpolzahab earthquake
All existing buildings in the region are categorized into two classes: non-engineered buildings and engineered buildings. Non-engineered buildings include adobe houses and masonry buildings, and engineered buildings include concrete and steel structures.

Figure 1: Soft story on ground floor (left) and global buckling of braces (right)

Figure 2: Inappropriate performance of structures with two different lateral displacement resisting systems in two orthogonal directions

Although the number of adobe houses was limited, they were ruined completely in the earthquake and the associated number of casualties was high. Masonry buildings showed a weak performance in the earthquake as well. The conjunctions of the vertical wall and the roof are the weak points of these kind of structures. They turned out not to be able to transfer lateral forces to the ground. Since there were many masonry buildings, both in urban and rural areas, most of the casualties were related to this building type. Other masonry buildings, in which horizontal and vertical tie beams were applied, showed acceptable performance during the event and a limited number of casualties were associated with these buildings.

Steel structures were affected by the earthquake as well. The problems observed in steel structures were as follows: a too soft story on the ground floor (*Figure 1, left*), global buckling of braces (*Figure 1, right*), incomplete penetration welds in connections, inappropriate performance of structures with two different lateral displacement resisting systems in two orthogonal directions (*Figure 2*), and non-designed connections between stairs and structures. Problems also occurred due to poor design of stairs: the load path to transmit the stair load is not paid attention to and the stair stiffness and loading are not taken into account in the global structural design (*Figure 3*).

[1] At the time of writing this report, no official statistics were published about numbers of casualties and homeless people.

Figure 3: Collapsed stairs due to poor design

Concrete structures were also damaged due to the earthquake. The main weak point of these structures is in the beam-to-column connection. The lack of transverse rebars to provide confinement and transmit shear force is the main reason for the observed damages in concrete structures (*Figure 4*).

Figure 4: Lack of transverse rebars

Performance of non-structural components

One of the main problems observed in the affected area was damage to non-structural components. The improper connection between non-structural components and structural elements is the main reason for this damage. The lintel has a fundamental role in increasing the strength of unreinforced masonry walls. Under lateral loading, if the lintel is not braced to structural elements properly, it separates from the structure and wall and the openings, such as doors or windows, become disengaged and topple. In this earthquake, most of the damage to non-structural components occurred for the following reasons:

- improper connection of the wall and the structural elements (*Figure 5*);
- no bracing of the lintel to the structure;
- no tying and bracing of parapet walls to the roof;
- no buttressing of boundary (yard) walls (*Figure 6*).

Figure 5: Improper connection of wall and structural elements

Lessons learned from this earthquake

To prevent similar disasters and to reduce the loss of life and property in the future, it is essential to study this destructive earthquake and to correct existing structural weak points. By investigating the recent Sarpolzahab earthquake, the following lessons could be learned:

1. The adobe houses and the masonry buildings without tie beams should be replaced by new earthquake resistant buildings. If these buildings are located in rural areas, since most of the buildings in rural areas are one or two stories and the quality of fabrication is low, masonry buildings with tie beams are proposed for replacement. And if these buildings are located in urban areas, steel or concrete structures are suggested as replacement.
2. The construction accuracy of steel and concrete structures needs to be increased. To achieve this, it is necessary to limit steel structure construction to factory construction (it is not allowed to fabricate on site). For concrete structures, more attention needs to be paid to the detailing of the beam-to-column connections.
3. The damage to common structures due to the Sarpolzahab earthquake was more than expected and the amount of loss of life and property was more than predicted. This is also due to underestimation of the level of seismicity of the region.
4. The intensity of the earthquake proved that the seismicity level of the region must be increased from high to very high, also to ensure that the most important structures, such as those of hospitals and essential facilities, can perform well immediately after the earthquake.

Figure 6: No buttressing of boundary (yard) walls

To summarize, in order to create sustainable earthquake resisting structures in the region, the higher level of risk based on the recent Sarpolzahab earthquake needs to be recognized and reflected by upgrading the seismicity level of the region to very high. Apart from that, replacement of existing structures by better earthquake resisting structures is needed and construction needs improvement.

Also, the earthquake in Bam, Iran, in 2003 had the strongest intensity in the seismicity history of Bam [2]. The earthquakes of Bam and Sarpolzahab are evident examples of the necessity to reconsider the seismicity level and to improve the structures to guarantee the future safety against earthquakes of these regions. ◀

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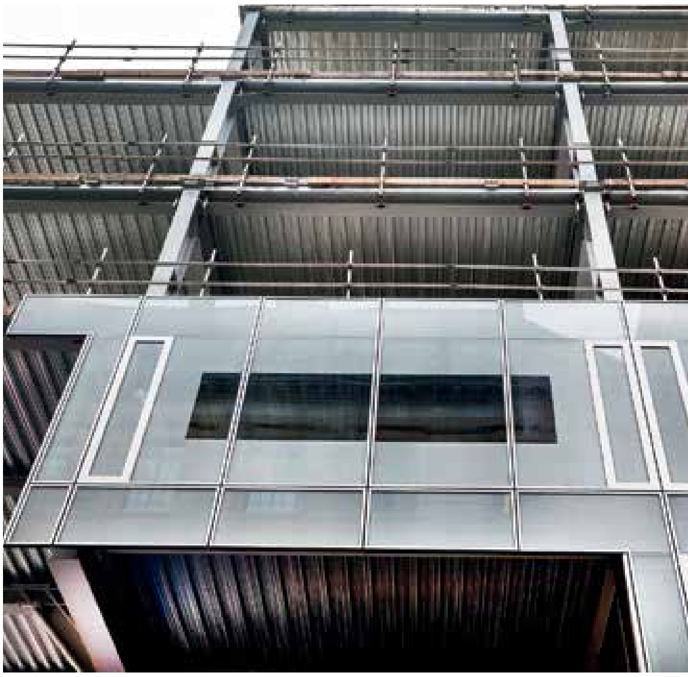


Forensic engineering MPB Eindhoven Airport in Structures Laboratory Eindhoven

Eindhoven Airport

By: Simon Wijte
Adviesbureau Hageman and professor at TU/e

In the evening of the 27th of May, a part of the Multi Purpose Building (MPB) at Eindhoven Airport, that was still under construction at that time, collapsed. The MPB should consist of a public bus station, a fast food restaurant, and a four layer parking garage. In the Structures Laboratory Eindhoven, tests have been performed for the forensic engineering after the cause of the partial collapse.

The structure

The building of the MPB is consists of two almost symmetrical parts, which are separated by an expansion joint (*Figure 1*). The four layer concrete structure is created by flat slabs, columns, and three bracing elements in each part. The flat slabs are constructed with a so called BubbleDeck floor, that is created by precast concrete planks with a thickness of 70 millimeters on which weight-saving bubbles with a diameter of 360 millimeters are placed. On site, the construction of the floor is finalized with a layer in situ concrete of 380 millimeters.

Figure 1: Structural plan

Critical detail

On commission of BAM, the contractor, a research was performed by Adviesbureau Hageman after the cause of the collapse. After studying the available design documents, such as calculations and drawings, it was concluded that in the middle of the span of the floor system a critical detail (*Figure 2*) was present.

The detail is found at the location where the positive bending moments are relatively large, at a seam between two precast plates. In the detail, tension forces in the reinforcement in the plank on one side of the seam should be transferred to the reinforcement in the other precast plank. This is performed by the bond between the reinforcement and the concrete of the plank. Next, the force should be transferred through the interface between the plank and the in situ concrete. From there, by bond, it can be transferred to the coupling reinforcement, which brings the force over to the other side of the seam.

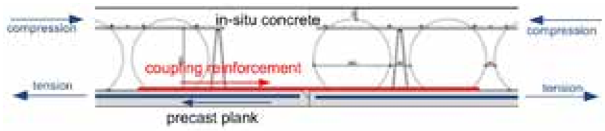


Figure 2: Detail at a seam between two precast planks

In this detail two critical aspects are present:

- the anchorage of the coupling reinforcement on the plank;
- the capacity of the interface between the precast plank and the in situ concrete.

It is known that in common construction practice the coupling reinforcement is placed directly on the plank. So, the connection between the reinforcement bars and the concrete is not optimal. In addition, the coupling bars, consisting of Ø16-100 at the critical location which, due to the bubbles, should be placed concentrated or bundled at every 400 millimeters (4Ø16-400). This can also have a negative effect on the anchorage length. Especially the influence of the lack of cover on the bars due to the placing on the plank is not well known.

The precast planks are made of self-compacting concrete. From literature it is known that the bond between self-compacting concrete and traditional concrete can be poor. Also, the placing of the lattice girders in the plank, 400 millimeters away from the seam, is so that the contribution of these reinforcement bars, passing the interface, is debatable. Also, it was known that the contractor chose to temporally remove the props below the floor at a time where the compressive strength of the in situ concrete was limited to approximately 18 N/mm^2 while the supplier of the floor suggested that this should be 34 N/mm^2.

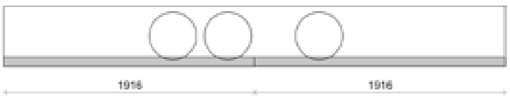
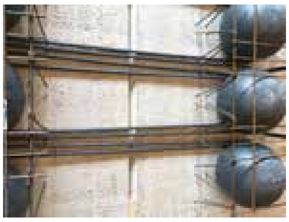
Code	Description	Code	Description
V	straight 3Ø16 + 1Ø10 first bubble direct adjacent to seam 	K	with a chamfer 4Ø16 first bubble at 450 mm from seam 
L	coupling reinforcement spread 	A	coupling reinforcement bundled 
18	limited strength of in situ concrete	34	higher strength of in situ concrete

Table 1: Overview of variables tested

Due to these arguments, it was decided in an early stage of the research to perform experimental research after the moment resistance of the detail.

Experimental research

For this research in the Structures Laboratory Eindhoven, two parts of the floor were reconstructed. The floors had a length of 6 meters and a width of 5 meters, that represented two critical locations of the detail. Here, precast planks were used that were identical to those in the actual structure. An overview of the differences between the two critical locations is given in *Table 1* by the codes V and K.

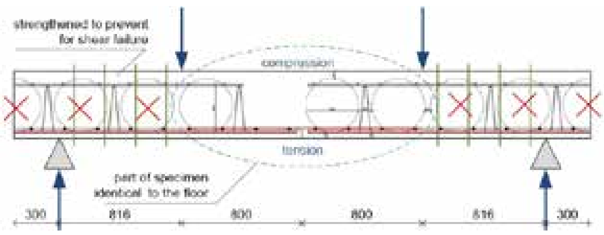


Figure 3: Specimen in the four-point-bending-test

In the experimental research, a four-point-bending-test was performed (*Figure 3*). In the middle of the specimen, a large moment is achieved while the shear force is limited. The specimens, with a width of 0.8 meters, were sawn from the constructed floors. In total, ten specimens were available. Four of these have been tested when the compressive strength of the in situ concrete which was limited to approximately 20 N/mm^2. The behavior of these four specimens was kind of similar.

The load on the specimen could be increased up to 100 kN with a slight increase of deflection. After that, the deflection increased rapidly while the force could be increased marginal. During the test, a crack occurred in the interface between the plank and the in situ concrete. Also, the width of the seam between the two planks increased with an increase of load. The width of the crack at the interface was measured. It could be noted that the crack appeared already with a limited load. At the point where the deflections started to increase rapidly, also the width and the length of the crack at the interface increased rapidly. In the failed specimens, the crack in the interface continued over the length of the coupling reinforcement and after that continued in a vertical direction (*Figure 5*).

With the limited strength for the in situ concrete in all four specimens, failure occurred due to failure of the interface between the precast plank and the in situ concrete. The way the reinforcement was placed, the amount of coupling reinforcement, the presence of a bubble close to the seam, and a chamfer at the seam, seems not to influence the failure mechanism.

After further increase of the concrete strength, three tests have been performed. These three tests behaved the same as the

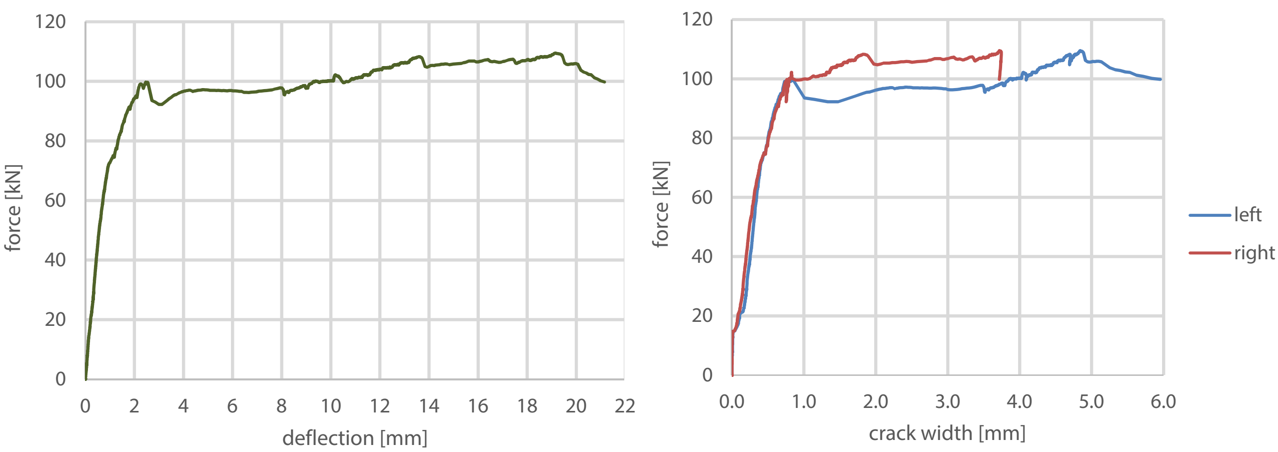


Figure 4: Specimen KL18 relations between load displacement and load-crack width at the interface

previous test with the limited concrete strength. The same failure mechanism was found and also the failure load did not vary. Therefore, it is concluded that the compressive strength of the in situ concrete does not influence the failure load. A summary of the test results is given in *Table 2*.

Specimen	Strength in situ concrete [N/mm²]	Maximum load [kN]
VL18	22,7	110
VA18	24,6	118
KL18	22,6	110
KA18	24,7	113
KL34a	33,3	107
VL34a	36,3	120
KL34b	37,8	94

Table 2: Results of four-point-bending tests

Cause of the partial collapse

The average moment resistance found from the tests is equal to approximately 128 kNm/m. This is far lower than the moment resistance that was expected. Depending on the amount of reinforcement present this should vary between 325 to 375 kNm/m.

In the area where it is supposed that the partial collapse has started, the moment due to the effect of the permanent load is equal to 120 to 140 kNm/m. It is believed that due to the limited resistance of the detail due to the permanent load in the structure already a redistribution of internal moments was already present. This also could be derived from the fact that prior to the collapse, that particular part of the floor showed large deflections and significant cracks were present on the top of the floor above the middle columns. On the 27th of May, the weather was beautiful and there was a lot of sunshine. Due to this, additional moments and curvatures occurred in the top floor of the structure. At that time, due to the lack of moment resistance and rotation capacity in the detail considered, the floor failed.

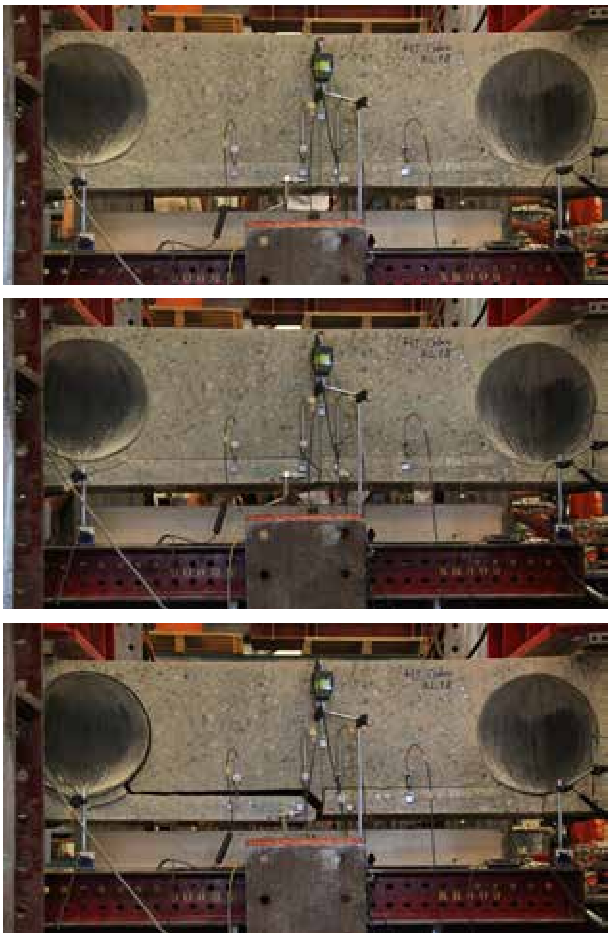


Figure 5: Failure mechanism of the test specimen

Effect of strengthening

After seven tests where performed, the focus of the experimental research shifted to the question whether it is possible to strengthen the detail. Therefore, the three remaining specimens where strengthened with threated studs. These studs were applied in the anchorage zone of the coupling reinforcement and prestressed and anchored with plates and nuts at the top and the bottom. In other specimens, injectable adhesive anchors were applied from the bottom and anchored in the in situ concrete.

Both strengthening measures were successful. With the strengthening measures it was possible to reach the expected failure load and failure mechanism: being the rupture of the tension reinforcement. A comparison of the load-deflection behavior of some regular specimens and two strengthened specimens is given in *Figure 6*.

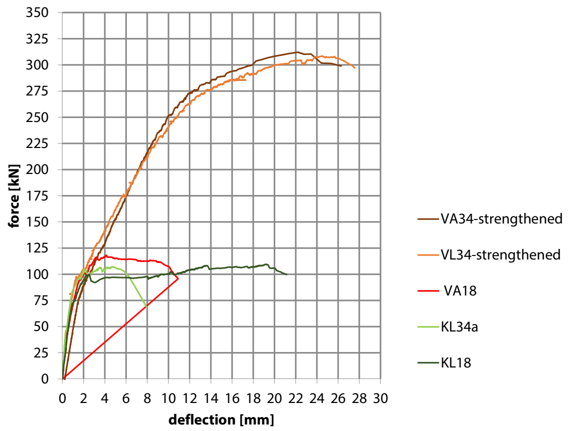


Figure 6: Comparison of the load-deflection behavior of strengthened and regular specimens

Conclusion

The findings of the research after the cause of the partial collapse of the structure of the MPB at Eindhoven Airport are mainly based on the experimental research performed in the Structures Laboratory Eindhoven. I would like to thank my TU/e colleagues from the laboratory for their effort and the nice work that they have performed.

From the research is learned that there is a problem with this particular detail of plank floors and that the structural reliability of several other structures in the Netherlands have to be reassessed. Therefore, the research on the behavior of this detail, used in other configurations of plank floors, will be continued in this new year. The aim of this research is to come up with design rules by which the structural reliability of these kind of structures can be assessed ◀

News

By: Cement
Knowledge platform about concrete structures

Second chamber for lock Eefde
Rijkswaterstaat is working on a better accessibility of the Twente canals, among which the expansion of the lock at Eefde with a second lock chamber, allowing more ships to pass through the lock. A, for the Netherlands, unique type of door was used for the lower lock head: a segment door. This is a door with a circle segment in the vertical plane. The door can turn up and down and is closed in vertical position. The choice for this door and other components followed from a consideration of various variants in a trade-off matrix. For the chamber, a variant with a sheet pile structure was chosen. Non-linear elastic calculations were used to deal with the special loads on the lock heads and doors, like contact with vessels, wind, and translation waves.

Figure 1: 3D overview with the new lock of Eefde

Parking garage in Delft sandwiched between railway tunnel and existing buildings
A new parking garage has been built underneath the old railway viaduct in Delft. On one side, it borders on the west tube of the new railway tunnel and on the other side, it is close to historic buildings. This required a sophisticated construction phasing that also influenced the design. In contrast to the tunnel, which has been built top-down with the wall-roof method, the parking garage is constructed bottom-up in an open construction pit. The garage consists of diaphragm walls, in situ cast deck and precast concrete intermediate floors. The diaphragm walls support both deck and floor; thus the diaphragm walls also serve as the foundation of the parking garage. Initially, deck and floor would be fixed into the diaphragm walls. With double-layer fixation reinforcement, of Ø50 in the outer layer and Ø40 in the inner layer, it was feasible. However, the connection was ultimately optimized to a hinged support or else the execution process would be violently disrupted.

The parking garage was partly built simultaneously with the west tube of the railway tunnel. At these locations, the wall between the garage and the tunnel was constructed with separate diaphragm wall panels (berets). A layer of stamps alternately supported these berets and the diaphragm wall behind them (from the eastern tunnel tube). The space between the berets is closed, after completion of the floor, with an in situ cast wall.

Figure 2: Stemps in parking garage, Delft

Wide plank floor problems
As a result of the collapse of the parking garage at Eindhoven Airport, it became apparent that the adhesion between the wide plank and the in situ pored pressure layer does not always meet the requirements in practice. In some cases, this can lead to insufficient shear strength of the connection area and thus overestimation of the capacity of the entire floor. For this reason, many new and existing buildings have to be reassessed. Various studies are running to the exact capacity of wide plank floors, depending on the connection area, and the possible solutions. ◄

Figure 3: Wide plank floor

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Let's digitize structural engineering

By: Gijs Schalkwijk
Structural Engineer at B-invented

What a relief to see the digitalization of the building industry continuing. Models, instead of drawings, are used more frequently for coordination among contractors, engineers, and other parties. And on building sites we see tablets appear. Big steps are taken by connecting modeling and structural engineering and using this information to control assembly lines. These developments make me happy and I hope it is just the beginning of even bigger leaps.

So, when I see 'regular' structural reports coming through, I tend to be a little bit disappointed. They are usually an accumulation of sketches and manual calculations that resemble the work of a generation of engineers long gone. It does the job, but we can make our lives so much easier and more fun!

Often, I ask structural engineers how they see their working process, how they handle recurring standard calculations and alterations. It strikes me that they are not looking into that at all. They are just working very hard to finish the work, preferably on time. At best, they are willing to give it some thought, but are not given any time to improve things.

This strikes me. Especially because in the same conversation, they are moping and moaning about the continuous alterations that are dumped on the structural engineers plate, last-minute and under a great deal of stress. And I get that: adjustments are often no fun, you already thought it through.

So basically, we are still working according to the same principle as we always have: a principle that is stressing us and does not make us happy at all. Of course, all kinds of software help to speed up parts of the calculation job, but these optimizations are too fragmentary. Clearly the challenge lies in the overall process. How to keep track of all those shreds of numbers? How to oversee all the consequences of alterations? And how to ensure the structural engineer is actually working on the structural design (and not copying values from one program to another)?

These questions motivate me to think about how I do want to work. Only to find out that this way of structural engineering does not exist yet, or not in an effective way. But the spot on the horizon is clearly there. And although it is unsure how we will get there, I will not believe this goal is unattainable if you take into account the way 'digitalization' is changing the rest of the world.

I am sure I am not the only one with this motivation. And I am convinced that we are able to change the backlog we have into a front-runner position. Structures will become more comprehensible and the job even better. We just have to make it happen. ◄

A trip to the limestone quarry in Maastricht

KOers excursion

By: Caroline Koks
Editor KOersief

In the first week after the Christmas break, we visited the eldest factory of ENCI B.V., ENCI Maastricht. For KOers, this was the last opportunity to see the quarry and the factory in production, because in July 2018, ENCI will stop with the commercial mining of limestone. Knowing that this was the last chance, we were very curious to see it with our own eyes.

We were welcomed by Marcel Bruin, who began with an introduction about ENCI Maastricht, which was founded in 1926 and was situated along the river 'Maas'. He also explained to us the production process of cement. In this way, we obtained some knowledge and a good overview of the actions that are performed on the factory terrain.

Figure 1: Group picture at the limestone quarry

Next, we visited the factory terrain and the quarry. ENCI Maastricht produces clinker and various cements. The factory terrain has a cement rotary kiln, a roller press and ball mills to grind cement, a shipping department, and a quay, which are spread out over an area of 33 hectare. The quarry has an area of 135 hectare. We saw the process from extraction up to the final product.

In July 2018, ENCI will stop with the extraction of limestone and will continu with the production of clinker up to July 2019. Hereafter, they wil import semi-finished clinker to keep producing cement.

Together with the government and the society for the Preservation of Nature, ENCI developed a plan of transformation for the quarry. In the summer of 2017, the nature reserve was open for swimming, but for now, the area is only accessible to hikers. ◀

December 2018: Lustrum VIII

Do you have a marvellous input for this week?

Send an email to KOers@bwk.tue.nl or visit us at the KOerscorner at Vertigo floor 2

Ventur, the building around the wind tunnel

TU/news

Interview with: Bas van der Zanden
Project manager Engineering department at Huybregts Relou

By: Eline Dolkemade
Editor KOersief

One and a half year ago, Eindhoven University of Technology (TU/e) wrote out a tender for a simplistic building that would function as a shelter for a new wind tunnel. The tender was very limited and consisted of five questions that needed to be answered. Soon, Huybregts Relou was chosen as the contractor. They proposed to define the project in Current Engineering (CE) sessions, in which all parties involved brainstormed about the project in the initial phase. This method should ensure that the preparations take weeks instead of years.

The idea of a wind tunnel on the TU/e campus has been around for a long time. Since 2014, there have been speculations about it and the location where it would be built has also changed several times. Construction began on the east side of the TU/e site in 2017 and the new wind tunnel was opened on December 14th of the same year.

The assignment was to build a simple building where the wind tunnel could be accommodated, which had to meet a few architectural requirements of the TU/e. Actually, it had to be a black box, without windows, with a front door, and a few escape doors. In order to meet the architectural requirements, the building had to be placed on a concrete cantilever.
For security reasons, the building has no windows: test measurements are taken with blinding lasers that may shine outwards. In the roof, there are some roof windows that can be shielded, so they cannot let the lasers through.

Figure 1: Ventur

After accepting the contractor, the TU/e decided that an ICT facility should also be present in the same building. So, two completely different functions are housed within the building and additional choices that had to be made. These choices were discussed in the CE sessions with the various parties. During these sessions, it is important that the client knows what he wants. For example the fire separation between the two functions: is it only a wall or a whole fire-resistant box, how many minutes of fire resistance, fireproof in every direction, etc.

During the project, the original design turned out to be too expensive due to a heavy cavity wall on the concrete cantilever among other reasons. The TU/e was asked again what needed to be explicitly present in the building. This was the concrete cantilever and a masonry facade. To stay within the budget, the design was optimized and materials were saved.

Especially in the structure there was a lot to be gained. The final design consists of two independent steel structures, for both building functions, with steel cladding. Despite the TU/e's requirements, the cantilever has been shortened. The masonry wall functions only as facade and ensures that the building looks as a whole from the outside. Within the ICT function, an extra floor has been created with hollow core slabs. The building is supported by a reasonably strong foundation. Not because of the building itself, but because of the vertical load coming from the self weight of the wind tunnel. The vibrations caused by the wind tunnel are absorbed directly by vibration dampers, causing the weight of the wind tunnel to be governing.

From the outside, the building looks like a simple black box, but it had its problems. Mainly, due to the two completely different functions new solutions had to be conceived than originally planned within a limited budget. Despite the CE sessions, the preliminary phase did not always run smoothly and it took more time than expected. When designing a building, the client demand is very important. Comparing the construction industry with the car industry, many clients ask for a luxury Porsche Carrera with the price of a simple Ford Focus. Each building is different and comes with a different price, which is difficult to establish in a preliminary phase. In joint sessions, client should be specific about the content of the building, instead of asking what it costs, as done in the car industry where models and additions are fixed. ◀

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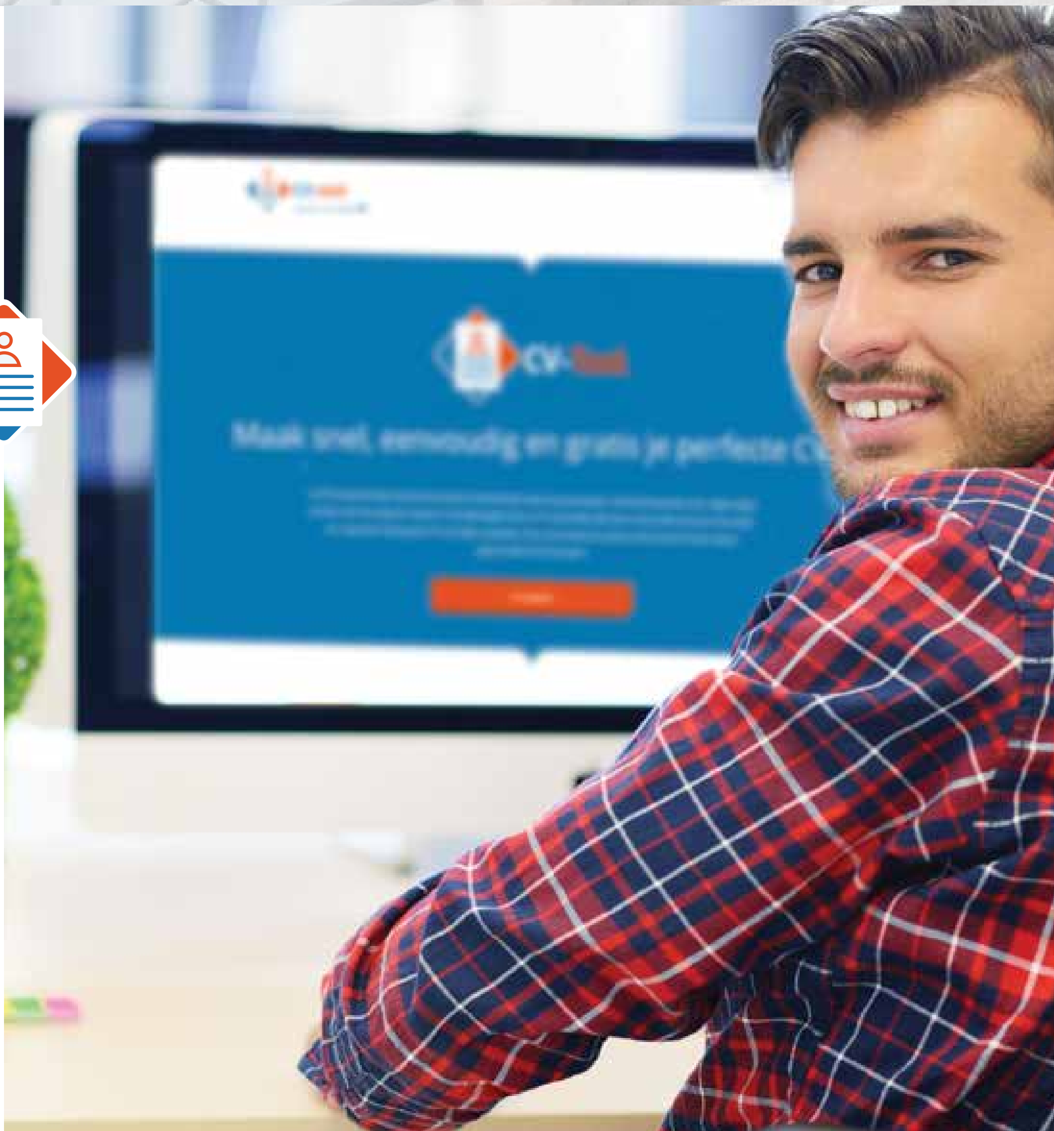

Master's thesis

Reuse of concrete floor slabs derived from a monolithic floor

By: Eline Dolkemade

Raw material sources are decreasing, but we still throw away many materials and products that did not yet reached the end of their technical lifespan. Often this waste is burned and the raw materials in these products disappear from our economy. A solution for the depletion of raw materials and the growing demand for new products is a circular economy. To realize a circular economy, the Dutch government mentions sectors that need a specific approach of which the built environment is one. There is no clear definition yet of how a circular building should be constructed. One of the aspects many people agree on is that structural elements need to be reused.

Concrete is the most used material for construction of structures. Reuse of concrete structural elements is not a new phenomenon. Already since the 1980s practical examples of reusing concrete elements are executed and also several researches into this topic are conducted. Most of these studies are done on prefabricated elements since the disassembly of these elements is less energy and cost consuming than sawing of monolith structures. However, the current building stock also contains many in situ cast concrete structures. These structural elements will also be released in the future and cannot be ignored during the search for circular solutions and reuse of concrete elements.

Figure 1: Sawing a concrete floor (Wijma bv)

The research starts with the general benefits of reusing structural concrete elements. Subsequently, the structural feasibility for the reuse of floors slabs, derived from a monolithic concrete floor, in a new structure will be examined. These floor slabs will function in the future as precast floor elements that operate differently than the monolithic floor they came from. The moment capacity, new supports, transfer of vertical loads, and the diaphragm action to resist horizontal loads are the aspects that are going to be considered. ◄

Impact of seismic strengthening/mitigation methods on a steel structure

By: Stijn van Kuijk

In 1959, the first gas field in the province of Groningen was discovered by the 'Nederlandse Aardolie Maatschappij' (NAM), a Dutch petroleum company. The gas field has been in production since 1964 and since the 1980's seismic activity is registered (*Figure 1*).

In 2012, an earthquake with a magnitude of 3.6 on the Richter scale occurred in Huizinge (*Figure 2*). This earthquake caused major damage to buildings compared to earlier earthquakes in Groningen. Although the gas production in Groningen has been reduced in the last years, the number of earthquakes is still relatively high. Hence, it may be clear that Groningen is a seismic area, and therefore the buildings should be designed to resist seismic loads.

There are several ways to design an earthquake resistant building. A distinction is made between strengthening the structure and mitigating the effects on the structure. Strengthening can be achieved by providing the structure with sufficient flexibility, strength, and ductility. Seismic mitigation, on the other hand, can be obtained by seismic isolation, energy dissipation, or a combination of both.

The goal of the master's thesis is to design the steel structure of an 120MW datacenter showing the impact of different seismic strengthening/mitigation methods for the Groningen seismic activity. The preliminary design is based on gravity and wind loads. Thereafter, different seismic strengthening/mitigation methods will be applied, including buckling restrained moment resisting frames, elastomeric base isolators and sliding isolators. The impact of the applied method on the structure will be examined and compared to the other methods. ◄

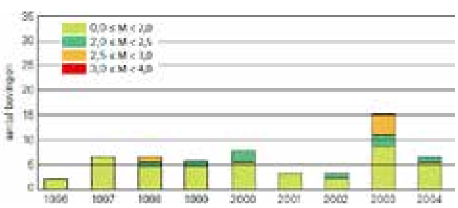

Figure 1: Earthquakes in Groningen 1996-2004 (Bouwen met Staal, 2015)

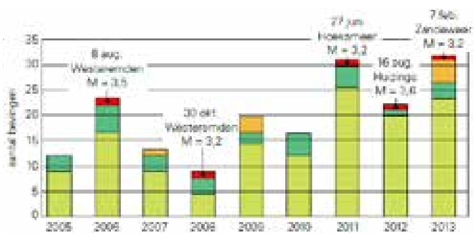

Figure 2: Earthquakes in Groningen 2005-2013 (Bouwen met Staal, 2015)

Properties of fresh and hardened reinforced self-compacting lightweight concrete

By: Lia de Mooij

Concrete and steel are the most used building materials in the Netherlands and have a large impact on the CO_2 emission in the built environment. The combination of those two materials, reinforced concrete, is a very suitable building material, unfortunately it is also very environmentally harmful. For this reason, research is being done to investigate the reuse or a more efficient use of those materials. One way of realizing a more efficient structure is the use of lighter elements, which leads to a lower dead load on the underlying structure and foundation. In this way, material, transport, and assembling costs can be saved.

Last year, a graduate student worked on the development of a lightweight concrete balcony in cooperation with the company Geelen Beton (*KOersief 103, page 36*). My project is a follow-up of this research. This project contains research about material related aspects, bond behavior of the reinforcement, and cracking behavior of lightweight aggregate concrete.

A new lightweight concrete mixture will be developed and compared to the mixture as used last year. The mixture will contain expanded clay aggregates (*Figure 1*), while the existing mixture contains natural expanded silicate.

After this material related experimental research, the best performing mixture will be chosen and further optimized.

Figure 1: Lightweight concrete with expanded clay aggregates

In the final part, the lightweight concrete mixture will be used in larger scale elements which will be tested in a cantilever set-up. The element will be attached to an Isokorb (a structural thermal break) to simulate a balcony. In this test, and in additional pull-out tests with varying reinforcement thickness and bond length, the bond strength and cracking behavior will be determined and compared to rules given in Eurocode 2. ◀

Analysis of plastic failure in case of a (fatigue) crack

By: Jan Hermus

For the past few years, failure of structural components due to fatigue cracks is a hot topic. In the past, there was less knowledge about fatigue which can result in failure of structural components in the present. A structural component can fail due to brittle fracture or plastic collapse. This thesis is focused on failure due to plastic collapse. It has been found that there is an excessive margin of safety in the methods to access cracks. One of the reasons for this conservatism is that the equations in the standards are based on a uniaxial state of stress, but for a specimen with a notch/crack in uniaxial tension it is possible to develop a triaxial stress distribution, even if the external load is uniaxial. Just inside the root of the notch, the axial stress is high and the sample tries to shrink in the y- and z-direction. At the surface and near the notch root, there is no axial stress, so the material experiences no strain in these two directions. The contraction of the region inside the notch is constrained by the lack of contraction outside the notch. This uneven strain in the y- and z-direction induces stresses. However, the stress in z-direction depends also on the thickness. If the thickness in the z-direction is small, then the magnitude of this stress is relatively low compared to the stresses in x- and y-direction. When there is a significant thickness, the strain in the z-direction is constrained, which results in zero stress at the surface with a maximum stress in the mid-thickness. Thus, the notch induces a biaxial or triaxial state of stress which depends on the thickness of the specimen. This increases the yield surface or yield condition because the hydrostatic stress increases, resulting in a higher limit load than the limit loads calculated with the British Standard. ◀

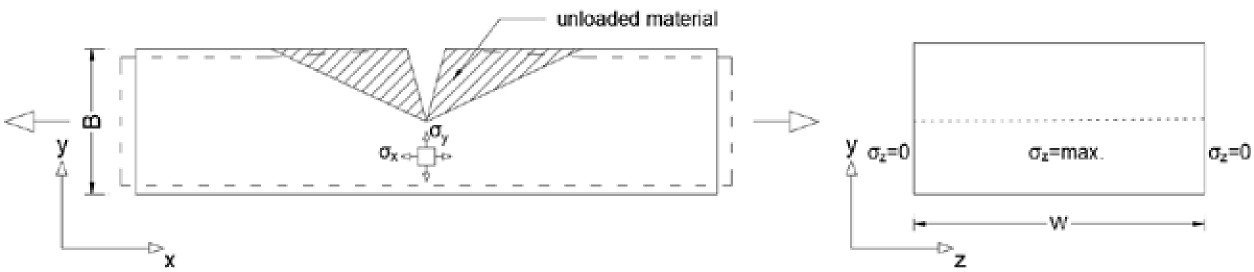

Figure 1: Developing a triaxial stress state

Master's thesis

3D concrete printed sandwich panels

By: Floor Vermue MSc
Supervisors: prof. dr. ir. T.A.M. (Theo) Salet, dr. ir. F.P. (Freek) Bos, ir. H.M. (Hans) Lamers

The way buildings are constructed is always evolving; new techniques have to be faster, cheaper, and more efficient. Sandwich structures are used in the built environment because of the insulating properties of the core material and the efficient mass-stiffness ratio. By using a 3D concrete printer to make sandwich panels, a structure can be produced that is both energy and material efficient.

The main goal of this study is to prove the structural capacity of sandwich structures with 3D concrete printed faces, and secondly, to make a numerical model of this structural sandwich element so it can be used to optimize a sandwich structure in shape.

In existing structural sandwich panels, different core materials and shapes, such as polyurethane foam and honeycomb structures, are used. For this study, three main different core materials are applied all in solid shape. Since it is favorable to print the material together with the concrete faces (*Figure 1*) and no shear connectors are used, the core material must preferably be printable, easy to shape, adhere to the concrete, able to transfer shear forces, and have a low thermal conductivity. These preferences were taken in consideration when choosing core materials and with a trail-and-error based strategy every next step was determined.

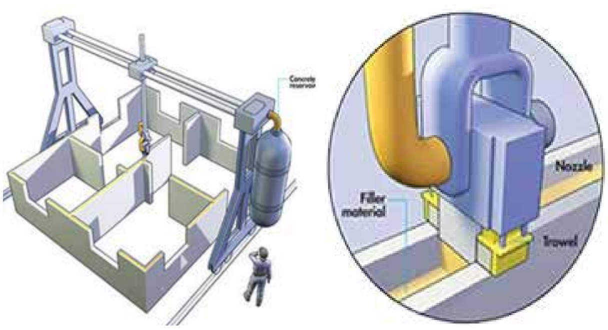

Figure 1: Printing concrete sandwich panels

Figure 2: Four-point bending test on a sandwich beam with an ultra-lightweight concrete core

Experimental research

Sandwich beams with different core materials and on different scales were manufactured to examine the composite behavior with the concrete faces both in the production process as in a simple bending experimental test. The structural and composite properties of the different core materials, ultra-lightweight concrete, polyurethane foam (PUR), and expanded polystyrene (EPS), were obtained by experimental tests on the material and the sandwich. First, small scale bending tests were executed on sandwich beams without reinforcement and with different core-to-face-thickness ratios. *Figure 2* shows the test setup of a sandwich beam with an ultra-lightweight concrete core. Next, a bending test was performed on a larger scale sandwich beam with reinforced faces (*Figure 3*). By using different core-to-thickness ratios, the amount of composite action of the sandwich beam could be seen.

First, ultra-lightweight concrete was chosen, because the production process is similar to the concrete faces, so it might be possible to make this material printable as well. When testing the ultra-lightweight concrete core sandwich specimens, the material showed poor formability, resulting in a partial connection with the concrete faces which caused a debonding of the faces during the test. Ultra-lightweight concrete proved to be difficult in production, but the stiffness of the material was sufficient to ensure partial composite action with the concrete faces. With an increase in core thickness, the ultimate load capacity of the beams increased as well.

Figure 3: Four-point bending test on a sandwich beam with reinforced faces and an EPS core

Secondly, polyurethane foams were chosen because they proved to have many advantages over ultra-lightweight concrete; a low thermal conductivity, an excellent formability, a sufficient connection with the concrete, a low density, and different stiffnesses available. Unfortunately, the production process of sandwich panels with polyurethane cores also proved to be difficult. The use of polyurethane in large voids gives rise to a significant production of heat and after expansion it is possible that the foam will shrink before it takes its final shape. Two different polyurethane foams were tested: sprayable foam and 2-component foam. The sandwich beams with a sprayable foam showed no composite action with the concrete faces and acted as two independently working concrete beams. This is shown in the results by no increase in ultimate load capacity when the core-to-face ratio increases (*Figure 4*). The sandwich beams with 2-component PUR foam, which have a higher stiffness than the sprayable PUR, did show a significant post cracking strength and composite behavior.

Lastly, a sandwich with an EPS core was tested, which eliminated some of the production problems of the other materials but has insufficient structural properties. Also, to connect EPS with the concrete faces an adhesive had to be used, which was in this case sprayable PUR. The core material of the two sandwich beams with an EPC core failed in shear, proving the structural capacity of the reinforcement. Two different types of reinforcement were used: steel cables that are printed together with the concrete, and steel reinforcement bars put in by hand. The test showed a significant post cracking strength for both sandwich beams which can be explained by the reinforcement.

Numerical model

A numerical model, created in Abaqus, is used to get better insight into the comparison between the design rules and the actual material behavior. This model was verified using the load-deflection graphs of the experimental tests. The numerical model simulates the nonlinear behavior of reinforced concrete by means of a concrete damaged plasticity concept, which can simulate the damaged behavior of concrete, and uses crushable foam hardening behavior, which can simulate the increase in stiffness of foam when compressed.

When verifying the numerical model, the model demonstrates the elastic behavior of the sandwich beams with an Illbruck PUR core accurately (*Figure 4*). However, the load-deflection curves of the test specimens show the presence of initial cracks by a slight plastic curve, which is not accounted for in the numerical model. The verification of the nonlinear numerical model of the sandwich beams with an EPS core also showed an accurate elastic curve. However, the model showed dissimilarities in failure mode load, which could be explained by different definitions of boundary conditions. The resistance between the roller supports and the concrete in the experimental test was not accounted for in the numerical model, but this can be accounted for some catenary action in the reinforced concrete, resulting in a higher ultimate load.

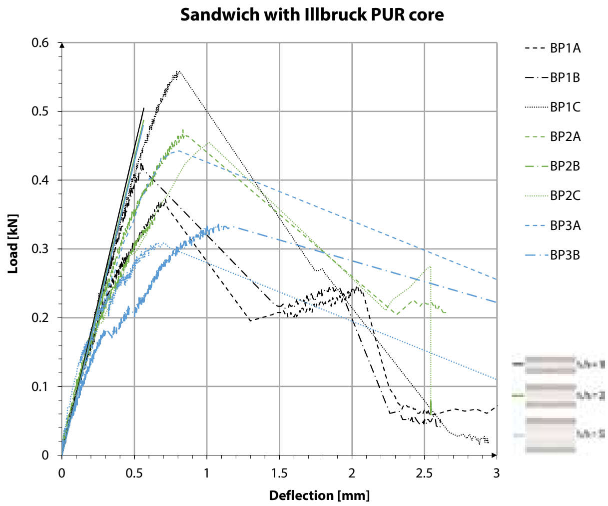

Figure 4: Load-deflection curve of sandwich beams with a sprayable PUR core. Different core-to-face ratios were tested, with a ratio of 1 (black), a ratio of 2 (green), and a ratio of 5 (blue)

Conclusions

This study is the first step towards the production of structural 3D printed sandwich elements. However, a large difficulty still remains in finding a proper core material. The experimental findings indicate that the two component PUR is the most promising material for structural, formable, and adhesive properties and also prove that both methods of reinforcing the concrete faces work. ◄

Internship experiences of a KOers member

By: Victor Hjelmgren
Master student Structural Design from Sweden

The Master-phase of your study is the perfect time to explore your possibilities and to broaden your experiences. Throughout the years, several master students from the TU/e have visited a university abroad and students from abroad have visited our university in Eindhoven. This article will give an insight about the experiences of an exchange student. Below, you can read how Victor Hjelmgren thinks about our small country and our education.

I was born and raised in Gothenburg, a city that you have probably never heard of. When I moved to the Netherlands last August, I was surprised that barely anyone had heard about the second largest city of Sweden. Even before I started to consider moving to Eindhoven, I could easily name at least ten Dutch cities from the top of my head. However, I guess Swedes hear more about Dutch soccer than Dutch hear about Swedish soccer. That is probably the reason.

Gothenburg was built by the Dutch, back in the 17th century. A predecessor of the city, also named Gothenburg, was inhabited only by Dutchmen, although that town was destroyed by the Danes. Apparently, the Dutchmen were hired because they were recognized as excellent civil engineers, especially in wetlands like those on the Swedish west coast. Downtown Gothenburg still has several moats and canals, although some of them have been filled because they smelled too bad!

Being a master's student in structural engineering and building technology, I found the reputation of the Dutch as skilled civil engineers a good reason to go to Eindhoven for an exchange. And as far as I can confirm, the Dutch are good at steel structures, aluminium structures, vibro-acoustics, and structural dynamics. These subjects are what I am studying this semester and the academic level is high. I was also working on a design project for a while, although I quit that halfway through the semester. Taking it chill during the first quad is not a very good idea. Especially not if you are trying to perform your structural calculations using Excel, while your – really talented – classmates are using professional FE software. Moving from a Mac-friendly country to a Mac-unfriendly university, where the IT helpdesk crew takes cover when seeing a Macbook, has its disadvantages.

However, I have come to realize that dropping a course is just a way of embracing the Dutch way of life. Nobody, among all the Dutchmen I have met here, have taken a full 15-credit quad. A funny thing I have noticed is that no one asks you which courses you are taking; they ask you which ones you are following. Apparently, that is related to how it is said in Dutch. However, there seems to be a subconscious attitude, that you may follow a course for a while (attend the lectures and do the assignments), but you might not really take it. That is, you might not finish it and get it on your record, but quit it just before the exam weeks when you realize that time is not on your side.

Being said that the academic quality of the TU/e is high, one could learn even more by spending more time with the teachers. A few hours per course are scheduled for asking questions about assignments. Back at Chalmers University of Technology in Gothenburg, where I used to study, several hours each week are dedicated to working on assignments, with a couple of PhD students available for help. The same concept would help a lot even in Eindhoven. Sometimes, civil engineering bureaus even volunteer by lending us their engineers as supervisors. The reward the companies get is a good insight into the new generation civil engineers, being able to find talented and nice people at an early stage. Considering the big extent of cooperation between the TU/e and the industry, this should be doable.

However, there is a good teamwork between the students. I did not expect the Dutch students to care a lot about me as an outlander, but I do feel welcome here. To be honest, I did not put any effort into involving the exchange students in student life back in Gothenburg. Now, I am an exchange student myself and I am glad that people do care about me.

After this fall semester, I am moving back to my hometown to do a master's thesis on the dynamic behavior of footbridges made of fiber-reinforced polymers. I am going to miss the friends that I have met here in Eindhoven and the laid-back atmosphere that I characterize the country with. Things that I will not miss are the littering, the lack of decent lunch on campus, and the tiny beer glasses. ◀

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The experience of...

By: Jelmer Feenstra
Graduate Fire and Structural Engineer at Holmes Group

In 'The experience of...' a person from the business community tells his or her story about the experience in and around the Built Environment. This time it is Jelmer Feenstra, who graduated Cum Laude in 2016 from the TU/e, with a master Structural Design. With his thesis, he won the IFV VVBA thesis award 2016 (*article in KOersief 101*). Currently he is working as a Fire and Structural Engineer for Holmes Group in Auckland, New Zealand.

Yes, before you ask, everything is upside-down in New Zealand, and yes, you get used to it. With that out of the way I hope to give you a glimpse into working abroad and the life of an expat.

Opportunity

Let's rewind: after I graduated in September 2016, I started job hunting and part of that job hunting I did through Sentijn (recruiter) who sent my resume to various companies. Through BAM Advies & Engineering, my resume ended up on a desk in New Zealand. Holmes Group, in collaboration with BAM, is currently working on the induced earthquake challenges in the Groningen area. Fast-forward a couple of interviews and Skype Calls later, I had a job offer to work as an engineer in Auckland. In a way, chance (or luck) played a role in this, but personally I think it is also important to think about how you present yourself prior to an interview. Everybody applying for an entry-level job has a degree, so I realized that my main selling points were my thesis and extracurricular activities. I included these on my resume and LinkedIn, which I made accessible in both English and in Dutch. During the interviews, I emphasized my interest in parametric design and the experience I have gained in programming and specific engineering software I used during my master thesis. This resulted in Holmes creating my current combined fire and structural engineer job for me. In summary, it is about triggering an interest, presenting yourself well, and building your professional network to maximize opportunities.

HOLMES—ENGINEERING EXCELLENCE

Holmes is a talented and passionate group of engineering, design and compliance specialists. With more than 420 people on the Holmes team worldwide, we provide creative and practical solutions to our clients' most exacting challenges. Holmes delivers expert structural, civil, and fire engineering, product development and testing, and building code compliance services.

Founded over 60 years ago in New Zealand, and now spanning Australia, the Netherlands, and the USA, we solve new and age-old problems with design artistry and scientific endeavour. Holmes people share a culture of curiosity and inspired practicality. Our common bond is the desire to explore brilliant, intelligent solutions—and share the delight in engineering excellence.

Experience

Sunday March 12th, my plane left for Christchurch, New Zealand, allowing me to arrive just in time for the graduate workshop organized for all new grads at Holmes Group. To be honest this was the easy part; the real challenge was the decision to go. The main reasons to go were the uniqueness of the opportunity and the chance to develop myself both personally and professionally. I typically like to compare this opportunity to when I started university and the associated personal and professional development from studying and living on my own. Living on the other side of the world for work feels like the 'grown up' version of moving to a different city to study. And hey, your friends and family are just one Skype call (and 12 hours) away.

As this is my first job as an engineer I needed to learn working as well as working abroad simultaneously. New Zealand uses the New Zealand Standards as prescriptive design documentation, which is similar to the Eurocode we are taught in university. This design documentation, like all design documentation, is based on international research and therefore very similar to what we are used to. Alternate designs and other recognized standards are allowed for some aspects of design as well. Long story short: do not worry about your educational background, if you can read design standards and solve problems you are all good. As for the difference between me and the other grads; they know a lot more about earthquakes than I (currently) do, but I am quickly catching up. Given you need to learn how to work as an engineer anyway, why not do it abroad?

Figure 1: The Pod in Sylvia Park

First project

My first project was The Pod in Sylvia Park. The Pod is a sculpture that can open up to form a performance stage as well as a wind barrier. Working in close collaboration with the architect on the design allowed me to work as both engineer and designer. A unique and challenging opportunity which taught me a lot about engineering, responsibility, and collaboration. ◀

Royal HaskoningDHV
Consultancy, Engineering & Management

Passion for a brighter world

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

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The future of concrete?

3D Printing of Concrete Structures

By: Rob Wolfs MSc
PhD candidate April 2015 – April 2019

From medicine and prostheses to cars and jet engine turbines, and even your chocolate pie at the Albert Heijn: 3D printing, or additive manufacturing, has rapidly spread into various industries and the daily life of consumers. The potential of the technique is clear: a high speed production, less waste, and an enormous freedom in design comes with the use of 3D printing. Can such a technique be applied in the construction industry as well? And if so, how do we guarantee the safety of printed structures?

Across the globe, 3D printed concrete case studies are being presented in a rapidly increasing pace over the past two years. While they showcase a promising new technique, they also raise questions on the structural integrity of the printed elements and buildings. Since concrete printing is essentially stacking layers of concrete filament on top of each other, a weak interface may occur in between these layers. Moreover, printed concrete – just like its traditional counterpart – can sustain high compressive forces, but has a much lower tensile capacity. Should these printed structures be reinforced, and if so, how to include it into the automated manufacturing process?

The 3D Concrete Printing (3DCP) research group of the TU/e aims to understand the fundamental structural processes of concrete printing. For this purpose, a large-scale 3D concrete printing facility was designed and established at the Structures Laboratory Eindhoven in 2015. The printer consists of a four axis gantry robot, a concrete mixer and pump, and a numerical control unit to control both the robot movements and concrete supply (*Figure 1*). Using this setup, this PhD research aims to develop experimental procedures and numerical models to analyze the structural behavior of printed concrete.

Figure 1: The 3DCP Setup at the TU/e Structures Laboratory Eindhoven

One path of research focuses on the properties of hardened printed concrete products, including the influence of the printing process. Here, the bond strength between layers is of most interest, which may be expected to reduce as the time interval between layers increases. Experimental tests are being developed, like a direct tension test, to characterize this bond strength (*Figure 2*). The results of such tests can be used in discrete FEM models, to predict if and where a printed product may fail.

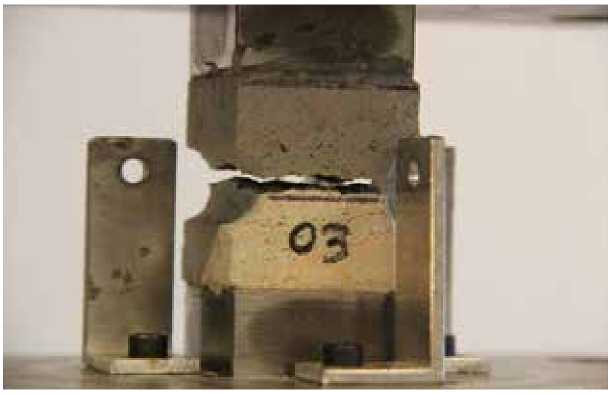

Figure 2: Direct tensile test on printed concrete

However, an additional phase of concrete has to be taken into account in case of 3D printing. Due to the absence of formwork in the printing process, the fresh concrete has to be sufficiently strong and stable to carry the weight of the subsequent layers. The strength of the fresh concrete may be exceeded, or the printed objects may fail due to instability during the printed process, because of the relatively low material stiffness (*Figure 3*). Experimental programs are being developed, based on geotechnical tests, to characterize the very early age properties of printed concrete. The results are used in a FEM based transient analysis, simulating the printing process.

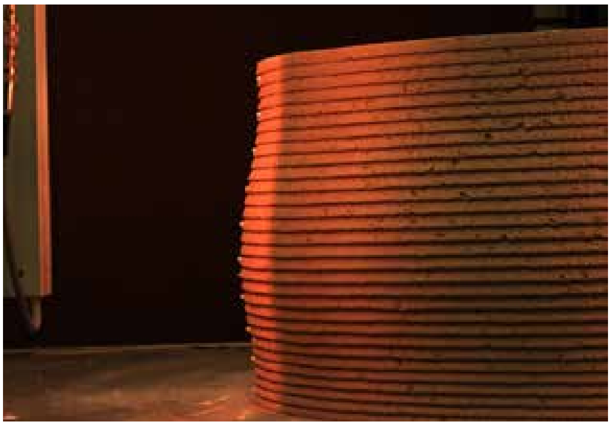

Figure 3: Instability failure during the printing process

Currently, the focus of the PhD project is on further development of the aforementioned test program, and deriving correlations between their results. Subsequently, optimization studies will be performed using the FEM models, which will be validated using the 3D Concrete Printer setup. ◄

Column

Full-size test

Faas Moonen

For over 10 years, Hans Lamers shared his critical and humoristic view on structures, our department, and other issues in this column. However, due to his absence, the editorial board asked me to give it a try to stand in for Hans in this edition. From this last page, I wish Hans a very speedy recovery and I look forward already to reading Hans' typical comments on my column in the next KOersief.

I was recently involved in two innovative projects requiring timber connections: the People's Pavilion (at the Dutch Design Week) and a station for boarding on a new roller coaster (built this spring at a Belgian amusement park). The unique concept of People's Pavilion is using borrowed or recycled materials, without glue, screws, or nails, in order to promote the value of a circular building. ARUP solved this challenge by using tie-down straps to make a solid beam out of 19 small timber elements[1]. The roller coaster station is inspired by typical architecture of Bali, with the elegancy of small timber logs only connected by ropes wrapped around the logs. However, the large span of this station required logs with large diameters, resulting in hidden steel connections covered by ropes.

For both projects, TU/e was asked to check structural assumptions by full-size laboratory tests. Both performed only weeks before construction had to start and both with a striking discrepancy between digital drawings and reality of materials. Timber for the People's Pavilion was thought to be stacked rectangular elements with perfectly fitted surfaces. Reality in our lab showed unplaned timber with largely warped and twisted surfaces and small contact surfaces. The drawing for the roller-coaster station showed straight and regular cylinders. However, logs we tested were largely bend and curved. In fact, we could not find a single diameter matching the digital drawing. Although we were only asked for structural testing, our laboratory tests provided valuable practical information, both resulting in important reconsiderations and redesigns regarding the connection.

Both projects revealed today's improvements to understand complex structures to a very detailed level. However, both proved that practical checking in a laboratory set-up is more needed than ever.

[1] https://www.dezeen.com/2017/10/27/peoples-pavilion-dutch-design-week-low-ecological-footprint-bureau-sla-overtreders-w/

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