STUDIEVERENIGING KOers
CONSTRUCTIEF ONTWERPEN

Kersief

EDITION 111
July 2020

Concrete Giants & Timber Towers

PATCH22, Amsterdam | Image: Luuk Kramer

Editorial

Dear reader,

The last few months were strange times for all of us due to the coronavirus. The University decided to give all courses online and KOers had to cancel all activities. Therefore, we had to adapt to a new situation that resulted in a lot of new initiatives: KOers goes Digital. This also meant that the Editorial board was forced to work online. Nevertheless, we were able to make a very nice new edition with the theme 'Concrete Giants & Timber Towers'.

For this theme, we were looking for giant concrete structures and high-rise buildings made out of timber all over the world. We were able to make a nice collection of articles with, for instance, a piece on the timber high-rise building in Norway, the Panama Sluice in which the mechanism of the enormous sluice doors is elaborated, and some research on concrete done by the Eindhoven Technical University.

The initial idea was to make a group picture together at the 'Bunker Tower' in Eindhoven. The Bunker is one of the most iconic brutalist concrete buildings of the modern Dutch architecture. Due to the coronavirus regulations, this was not possible anymore. Instead, each of us took a picture at home with something related in the theme 'Concrete Giants & Timber Towers'. From left to right; Olaf Vens, Pamela Schippers, Laura Dings, Pieter van Loon, Leonie van der Molen, Tom Diks, Bart van der Born, Maikel Brinkhoff, Evelien Dorresteijn, and Femke Hermans.

In this edition, also the 51st candidates board of KOers will be introduced, the online activities of KOers will be highlighted, and it is the 40th time Hans Lamers, from the structural lab, did write a column for the KOersief!

On behalf of the Editorial board,

Evelien Dorresteijn
Editor-in-chief KOersief 111

Chairman's note

Dear KOers members and relations,

First of all, I hope that everybody is well and healthy.

At this moment, Monday 23th of March, we are right in the middle of a crisis. It is hard to write this note, not knowing how things will develop in the upcoming weeks. This KOersief should be released during the end of the year barbeque, and therefore I will assume we are all eating excellent ribs in the sun behind Vertigo when this comes out.

This has been a great KOers year so far. In the first semester, we have been very active and made lots of new contacts with companies, universities, and study associations in the Netherlands and in Spain. This did not change with the start of quartile three. We organized a really cool design challenge, had our first GMM, and can look back at a some beautiful collaboration with CHEOPS, which led to a welding class.

After Carnaval, things started to change, and we had to adapt to the situation. Therefore we are currently busy organizing some online activities and rediscovering our calendar, which has changed day by day.

Although our normal life, with plenty of KOers activities, has stopped, we have managed to carry on by starting online activities and meetings. In this manner, we kept contact with our members and friends and shared some special moments online, like the stay at home bingo, Online KOKO, and KOers online workout. We also

found the 51st candidate board of KOers, which will be inaugurated in September. I want to wish them success in the upcoming year.

To end this note, I would like to wish everyone a good holiday season, in which going on vacation is possible, and otherwise, I would recommend taking the bike and go discover how excellent the Netherlands can be.

Have a good time reading this edition of the KOersief about concrete giants and timber structures, and I hope to see you in the KOershoek soon.

Stay well and stay healthy
On behalf of the 50th board of KOers,

Hidde van Wezel
Chairman of the 50th board of KOers

KIST to Taiwan goes online!

Agenda

ABT Design Challenge *February 5^{th}*

MDE Madrid - Flamenco Course *February 16^{th}*

GMM *February 19^{th}*

SCIA Workshop *March 9^{th}*

Digital concrete

July 6^{th} - 8^{th} TU/e

The first conference on digital concrete was held in Zürich. The second edition of the "International Conference on Concrete and Digital Fabrication" will be held at the Eindhoven University of Technology! Due to the coronavirus it will be an online conference where key innovators and top researchers from all over the world will exchange insights digitally.

International Study Trip

July 14^{th} - 28^{th} Taiwan

The committee did everything they can to look at all the options and possibilities to go to Taiwan or another location on this beautiful planet, but for everyone's safety they decided it was better to cancel the whole International Study Trip this year. At this point the committee is still looking for some options to maybe give a nice twist on experiencing Taiwan online.

Inauguration drink

September 7^{th} Skybar! Underground, Eindhoven

After the general members meeting, in which our new board will be installed, it is time to congratulate them and wish them good luck during this drink. Everyone who wants to support the new board and celebrate this with a drink is welcome!

National Steel Construction Day 2020

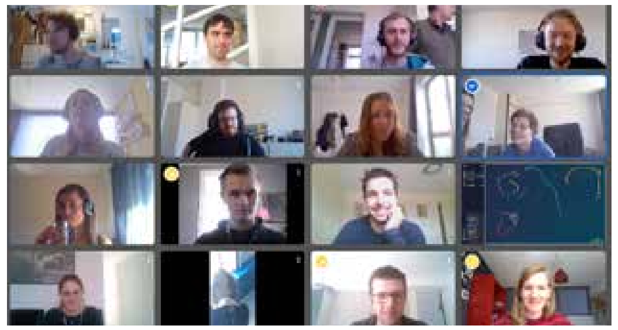
October 13^{th} Van Nellefabriek, Rotterdam

The National Steel Construction Day is the event for the Dutch steel construction industry: from suppliers to designers and from builders to producers. As every year, KOers will be there, so join us! Various projects are highlighted and seminars will be given. Furthermore, the Studentenstaalprijs and the Nationale Staalprijs will be rewarded again.

Beton Experience 2020

November 13^{th} Van Nellefabriek, Rotterdam

The Beton Experience is the same as the National Steel Construction Day, but different. This event is the event for everyone who is connected to concrete in some way. This event will also take place in the Van Nellefabriek in Rotterdam and always has special interest in innovation on a more green reputation for concrete. ◄



KOKO goes Digital *March 26^{th}*

Note: due to the coronavirus and its developments it is possible that the information above is not up to date anymore. For the latest news on activities, check the KOers website!

Introducing the new candidate board of KOers

Monica Suijs - Chairman

Where are you from? Do you intend to return after you finish your study?
I was born in the city of lights, Eindhoven, and I have lived there ever since. I would like to stay close to home if possible, but I will also go wherever the job takes me.

What did you want to be when you were younger?
I first wanted to be a zookeeper, then a dentist, and after that an architect.

What is your favorite KOers activity?
The study trips, of course, because I like to travel a lot.

What is your biggest fear?
Since I am too short to see anything, I am afraid to be stuck in a big crowd where I cannot find anyone.

What is an ideal weekend for you?
Joining the scouts on Saturday. Having fun with the kids there in the afternoon and afterwards enjoying a nice beer at the campfire.

What is your favorite beer?
I have no favorite beer yet, because I am still trying out a lot of beers.

Paul Otterspoor - Secretary

Where are you from? Do you intend to return after you finish your study?
I have always lived in Eindhoven. If I can find a job in the vicinity of this city, I will probably stay here, and also because several friends and family members live here.

What is your favorite KOers activity?
The Concrete Canoe Race. It is a great activity to enjoy the summer weather in a chilled-out atmosphere.

Are you a morning person or evening person?
Evening person.

What is on your bucket list this year?
Attend as many fun activities as possible, but also to finally start my graduation project.

What is an ideal weekend for you?
One day chilling at home without obligations and taking a relaxing walk or bike ride if the weather is good. The other day I like to spend with friends or family.

What can we wake you up for at night?
A good pizza. Or a few extra hours of sleep.

Femke Hermans - Treasurer

Where are you from? Do you intend to return after you finish your study?
I am from Helmond. I actually have already returned back home since living in Eindhoven for two years, after I came back from studying abroad for half a year.

What did you want to be when you were younger?
I wanted to be a painter, writer, musician, or architect.

Are you a morning person or evening person?
A morning person, but not a too early in the morning person.

What is on your bucket list this year?
Walking the Nijmeegse Vierdaagse, driving the NC500 road in the top of Scotland, and first time Lowlands, which are all (hopefully still) going to happen in the summer.

What can we wake you up for at night?
Concerts, festivals, and drinking 'Witte Trappist' in the sun with friends.

What is your favorite beer?
I do not have one favorite beer, I do prefer to drink IPA, blonde and white beers. But I am trying to drink as many different beers as possible.

Mike Veenhuis - Commissioner of Public Relations & Vice-Chairman

Where are you from? Do you intend to return after you finish your study?
I am from a beautiful area of the Netherlands, called 'de Achterhoek'. Which just might become my retirement home, after I have worked everywhere.

What did you want to be when you were younger?
At a very young age, a lawyer. However, I quite quickly turned to the Built Environment.

What is your biggest fear?
Heights and zombies.

What is your favorite beer?
Grolsch kruidige tripel.

What is on your bucket list this year?
To conquer some of the largest roller coasters of Europe with my little brother.

What is your favorite KOers activity?
All the activities where we get to know companies, with whom we can build connections.

Bart van der Born - Commissioner of Education

Where are you from? Do you intend to return after you finish your study?
I am from Schoonhoven, near Gouda. I really like this area, and it still feels like home, but I think I will not go back since proper connections to major cities are lacking.

What did you want to be when you were younger?
As a small kid, I wanted to become a firefighter and, after that, a teacher, because of the many holidays.

What is your favorite KOers activity?
The drinks, I like relaxing with friends and enjoying some beers.

What is an ideal weekend for you?
I do not set an alarm, enjoying nice weather at a terrace or in the park, and ending the day with a barbeque.

Are you a morning person or evening person?
Depends on the amount of coffee available.

What can we wake you up for at night?
Skiing with fresh powder snow.

What is your favorite beer?
Cornet Oaked.

Anke Leemans - Commissioner of Activities

Where are you from? Do you intend to return after you finish your study?
Born and raised in Dongen near Tilburg. Not necessarily, I will go where my job will take me, even abroad.

What did you want to be when you were younger?
Firefighter or be like Bear Grylls.

What is your favorite KOers activity?
Dies Natalis drink, because there was a ball pit.

What is your biggest fear?
Failure.

What is on your bucket list this year?
More traveling.

What is an ideal weekend for you?
City trips, hiking in nature, and doing scouting activities.

What is your favorite beer?
All Russian imperial stouts, especially Loc 84.

Are you a morning person or evening person?
Evening, for sure. ◄

Mjøstårnet

Timber high-rise tower in Norway

By: ir. Niels Castelein
Structural engineer at Sweco

In Norway, the tallest timber building in the world opened its doors in 2019. What were the challenges when building this tall in timber, and how is the structure designed? Niels Castelein, a structural engineer at international engineering firm Sweco, tells all about it.

Let us start with some facts. Mjøstårnet is in total 85,4 meters high, with the highest occupied floor at 68 meters. The full height is reached by topping the building with a pergola structure. The tower is houses offices, a hotel, and apartments. The primary structural material is GluLam, but in the overall design CLT, LVL, concrete, and steel can be recognized. To built the structure, roughly 2600 m^3 of timber was used, with the bulk of it being used for the GluLam bearing structure, as can been seen in *Figure 1*. It is the tallest timber high-rise in the world up to this day.

The main bearing structure is positioned in the facade by constructing huge timber GluLam trusses, combined with beams and columns in the interior. The dimensions of the structural elements vary, from the smallest floor supporting beams (395x585 mm^2) to the larger corner columns of the building (1485x625 mm^2). A benefit of this design is that it results in a torsional stiff structure. A centrally placed core shaft usually needs additional elements in the facade to resist torsion. In the case of Mjøstårnet, the CLT-shafts do not contribute to the horizontal stiffness of the structure. A similar design approach was used in Treet, a 49 meters tall timber building in Bergen. For that building, the structural engineering was performed by Sweco as well.

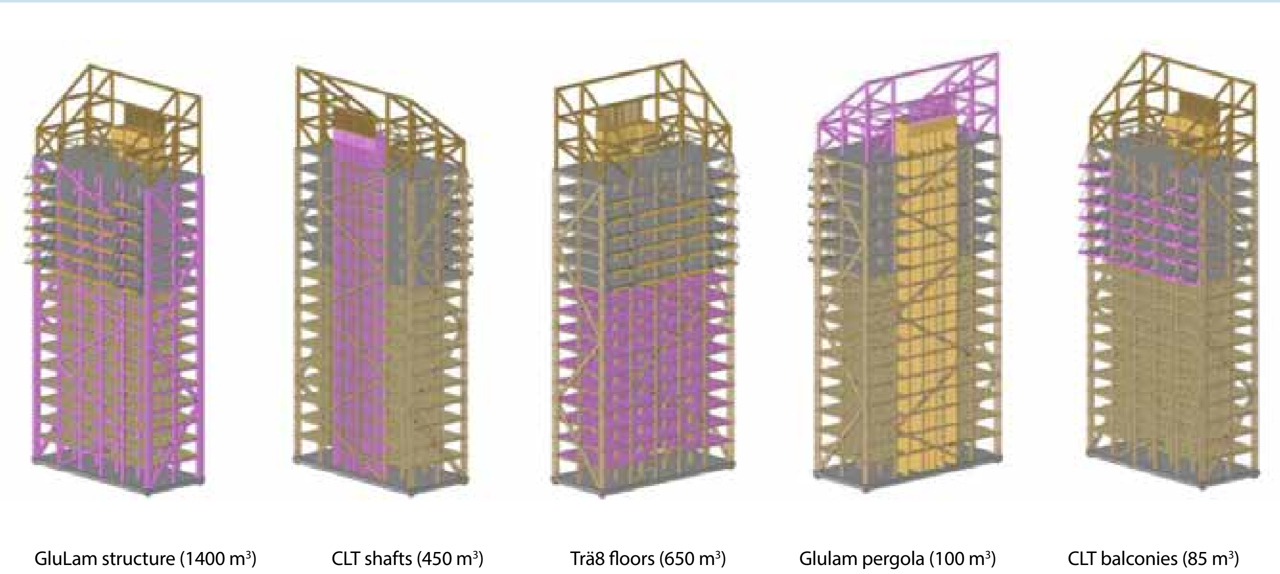


Figure 1: The use of timber in numbers for Mjøstårnet

Challenges in timber high-rise

General difficulties in high-rise buildings are fire safety and dynamic characteristics as resonance and accelerations. Because timber was used as the primary structural material, these aspects were even more challenging. Accelerations due to the wind are close to the limits of comfort, for which two reasons can be appointed: timber being a lightweight material and the tower being rather slender. Mjøstårnet has a slenderness ratio of approximately 1:5. These aspects will make it challenging to go even higher with timber structures in the future, as slender structures are often a necessity (e.g. due to daylighting rules). Concrete and steel high rise structures manage different magnitudes of slenderness (factor 2 to 4), but also those slenderness ratios are being pushed. Sometimes making use of additional measurements, for example, mass dampers.

Figure 2: above: the site in October 2017 [1], below: March of 2018

The exact design parameters (e.g. damping) for the dynamic behavior of tall timber buildings are unknown, as there is no reference. The characteristics of Mjøstårnet are measured in-situ and analyzed by the Dyna-TTB consortium (The Dynamic Response of Tall Timber Buildings under Service Load), aiming to develop design rules. First indications for Mjøstårnet lead to believe that it is stiffer than assumed.

Another design criterium influenced by timber as a lightweight material are the building physics. The top floors are occupied by apartments, resulting in demanding requirements for acoustics and vibrations of floors. To meet the acoustic and dynamic requirements, the top floors are constructed from reinforced concrete, helping the structure in twofold, as the mass also influences the dynamic behavior positively. A total of 1100 m^3 of concrete is added.

Due to the height of the building, the fire department is not able to reach higher floors from street level, making extinguishing impossible. Sprinklers can be a solution; however, these mechanical systems have a (low) probability of failure. For these reasons, a well thought fire safety design is a necessity in every tall timber building. Creating compartments, firestops in facades & shafts, and aiming self-extinguishing within compartments are part of this design.

Self-extinguishing can be achieved by limiting the exposed timber surface. In this structure, the GluLam columns and struts are exposed. The resistance comes from charring, where for a minimum of at least 120 minutes the structure should keep its capacity. The steel plates connecting the GluLam elements are protected by being embedded in the timber, and additional detailing in the form of expending material (strips) in the event of a fire (*Figure 2*). Test set-ups simulating the actual physical situation in the building during its lifespan have proven that withstanding 120 minutes of fire is not a problem and that self-extinguishing is in fact occurring.

Legalization in the Netherlands

Aside from technical challenges, building tall in timber is challenged by legislation as well. Obviously, the design needs to satisfy the Eurocodes, but additional national building codes can compromise projects. All buildings in the Netherlands need to meet the requirements set in the Bouwbesluit. Up to 70 meters tall the Bouwbesluit is valid in its published form. Going higher, the principle of equality is used regarding the level of safety. Together with the local municipality, the required level of risk mitigation for the design is set and translated to concrete measurements. Similarly to the dynamic response, the lack of reference and knowledge causes boundaries to be pushed.

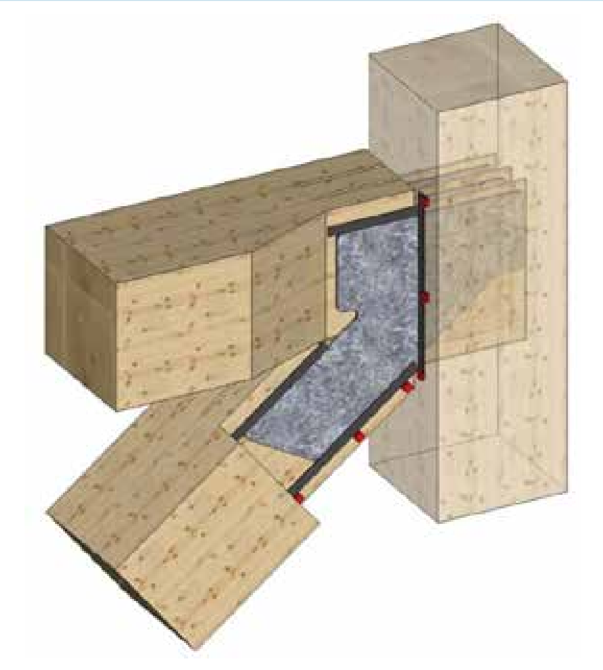


Figure 3: Connecting steel plates embedded in timber and finished with heat protecting strips (expanding in the event of a fire) [1]

Going taller than the earlier mentioned 70 meters involves risk-mitigating measurements that most likely affect the net floor area negatively and endangers economic feasibility (e.g. due to additional firefighting stairways). To regain economic feasibility, the net floor area needs to be increased. Often only possible by going higher, this results in increasing sizes for structural components, but also challenges the structural engineer since it requires upgrading the slenderness ratio to fulfill strict daylighting rules in the Netherlands (also set by the Bouwbesluit). As mentioned earlier, the slenderness ratio is an important tool for the dynamic behavior; stability systems in the outer perimeter of the building, as applied in Mjøstårnet, can be the solution.

Related to economic feasibility, the higher material costs for timber structures are often heard. When the use of engineered timber becomes more common, the material costs are expected to reduce. Additionally, the structure costs compose a certain amount of the total costs of a building. The type of structural system and type of building determine the exact percentage. As an example, residential building blocks could be mentioned, where lots of infills are used in open-plan type structures. Using essential infills in the structural system (shafts, walls) can economically be attractive, but at the same time, limits future changes. This results in the conclusion that costs of structures highly depend on (material driven) design and function, and is therefore difficult to generalize.

Benefits

Benefits that advocate for building tall timber structures should not be forgotten. The carbon stored, it being renewable as raw material and the possibilities for circularity, are huge beneficial factors, especially when these aspects are taxed in the future. For the nitrogen emission crisis in the Netherlands, the low mass of timber for transport (vertical and horizontal) and the incredible construction speed could be an answer, while simultaneously cutting on construction costs. Prefabricating and digitalizing the manufacturing can keep failure costs under control. Cleaner construction sites and reduction of construction periods reduce safety risks that construction workers face.

Figure 4: Detail Timber connection (photo Øivind Haug)

As a timber enthusiast, I strongly believe in the potential of timber as a structural material. A building as Mjøstårnet is a great ambassador for timber and its possibilities. Great examples of proper integration of timber in our Dutch building industry are already present (e.g. HAUT, Patch22). Aiming for taller timber buildings might require a hybrid approach regarding materialization, due to timber's characteristics. However, there is definitely no shame in that. The last thing we should aim for is an inefficient use of materials when trying to reduce our carbon footprint. ◀

Project data:

Owner:	*AB Invest A/S*
Architect:	*Voll Arkitekter*
Contractor:	*HENT*
Subcontractor timber structure:	*Moelven Limtre*
Engineering:	*Sweco*

Acknowledgments:

For being able to write this article, I would like to thank my colleagues Magne Aanstad Bjertnæs MSc. & ir. Onno Walta RO. 2017

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[1] Abrahamsen, R., Mjøstårnet - Construction of an 81 m tall timber building, Internationales Holzbau-Forum, 2017

A concrete giant existing out of 23000 defensive works

The Atlantic wall

By: Hidde van Wezel
Student Structural Engineering and Design

In September 1939, Germany invaded Poland and started the Second World War. in succession, also the Netherlands, Belgium, France, and Scandinavia were invaded and controlled by Nazi Germany. The war began as a success, yet gave a big responsibility to the Germans since they had to defend the invaded territory from allied forces. In 1942, Adolf Hitler saw this responsibility, and therefore gave the command to build the Atlantic Wall, the world's most extensive defensive line.

The Atlantic Wall is a 2,500-kilometer long line of fortress along the coast from Norway to the border between France and Spain (*Figure 1*). The idea was to protect the harbors and beaches from landings by the allied forces. Hoping this would prevent a war on two fronts, with the allied troops from the West and with the Russians from the East. There were plans for a total of 23,000 defensive positions, of which 2,000 in the Netherlands. The Germans never finished the wall due to the lack of building materials and the invasion in France.

Figure 1: Atlantic wall (yellow line)

The defensive line consisted out of separated ensembles that were in contact with each other. The free beaches located between the ensembles, for which the priority of protection was less, were protected with minefields and obstacles. The more robust ensembles were placed at ports and canals. The wall was built in a systematic order. For starters, low-risk areas were protected with small light-armed bunkers called Widerstandsnest (*Figure 2*).

On more strategically important locations, the Germans placed the so-called 'Stützpunkte', which are bunkers with a solid reinforced concrete core. At ports and estuary, where the allies could easily land and unload heavy material, Stützpuntgruppe are placed. This is a group of bunkers with heavy gunnery. Essential locations were defended by a fortress called 'Festung'. In the Netherlands, Hoek van Holland was an excellent example of how a Festung was organized (*Figure 3*).

Figure 2: Widerstandsnest 60

To speed up the process for building all these positions, the German engineers came with the idea to standardize the process. Each bunker, the so-called 'Regelbau', had a code, for example A1. This code defines the thickness of the concrete walls and ceiling. To elaborate: A equals 3.5 meter, A1 equals 2.5 meter, B New equals 2.0 meter, B Old equals 1.5 meter, and so on. The code also defines what kind of gunnery was used in the Regelbau and what shape it had. In the end, over 100 different types of Regelbau were built. The standardization of the Regelbau types made it easy to estimate how much materials were needed and how much labor was required to build the structure.

In the design of a Regelbau, the most import loads are a load of impact and explosion. Depending on how high the risk of heavy impact was, determined by the location of the bunker, the Germans chose a bunker type. The Regelbau were smart designs, equipped in such a way that ammunition could be quickly brought to the guns. For example, rails were implemented in the ceiling. Most bunkers were built in groups, to enable different functions for each shelter. There were bunkers for defensive purposes, as shown in *Figure 4*, but also bunkers in which soldiers could sleep or where supplies were stored.

Not all the bunkers looked like bunkers. All defensive works had the risk of being mapped by air photos, which could be taken by airplanes. Therefore, some bunkers were camouflaged which made them look like farms or normal houses. On the outside, masonry was placed against the concrete walls and sometimes even windows with people drawn on it. The roofs were covered with roof tiles.

The construction of the Atlantic wall had a big influence on the Dutch coastal areas (*Figure 5*). In the Netherlands, many cities are located in these areas. Parts of these cities had to be removed to make place for bunkers and other military facilities. As shown in *Figure 3*, part of the cities turned into Festungs. In The Hague, 132,000 people evacuated knowing their homes would be demolished and defensive works would be constructed. Also, high structures, like water towers, were removed to ensure that the allied forces could not use them for navigation purposes. The materials extracted from the demolished buildings were transported to Germany, where they were reused in the construction due to the scarcity of materials at that time.

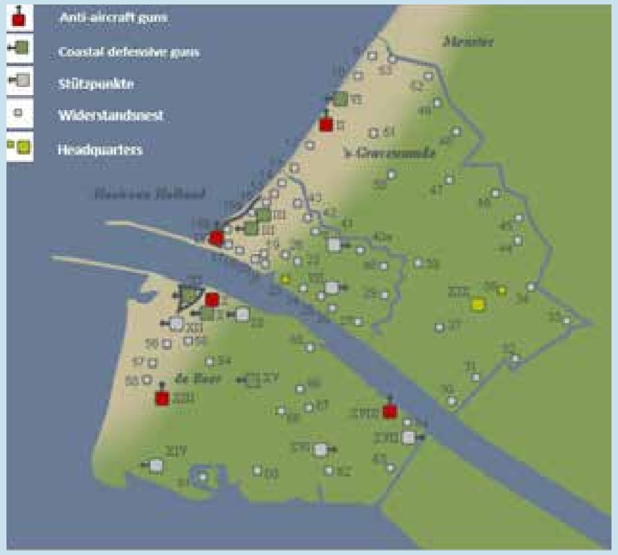

Figure 3: Festung Hoek van Holland

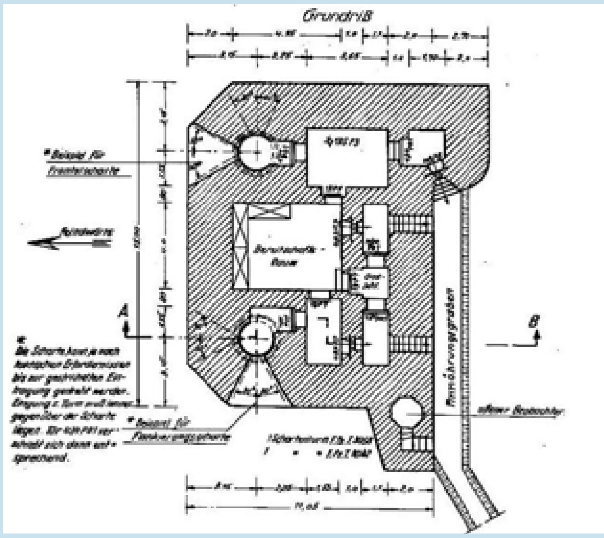

Figure 4: Regelbau 653

For the building of the Dutch part of the Atlantic Wall, the Germans came up with a clever idea. From 1942, when the occupiers started the construction of the wall, they ordered a building stop. This led to big problems for the Dutch contractor companies that needed assignments or they would go bankrupt. The only assignments left were those for constructing the Atlantic Wall. So, large parts of the Dutch wall are made by Dutch contractor companies that were specialized in concrete.

This was not the only measurement the Germans took. The labor required to create the wall was partly done by forced workers. These were deployed by the Germans or by the Dutch contractors in collaboration with the Germans.

The Atlantic wall had a significant influence on the life of many during the war but did not seem very effective in the end. Due to mistakes made by the military top during the invasion and the lack of resources and men, the wall fell on the 6th of June 1944 on multiple places. First in France, but later also in Zeeland to secure the Port of Antwerp. ◄

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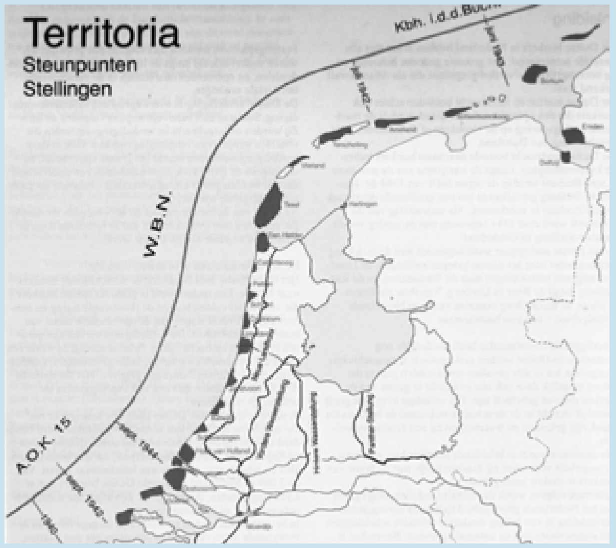

Figure 5: Dutch part of the Atlantic wall

Panama Canal expansion

Innovative lock design

By: Jeremy Augustijn, and Léon Tuunter
Senior project manager/register designer, and senior project manager/MT member at Iv-Infra

In 2009, Iv-Groep signed a contract to design sixteen new lock gates as part of the Panama Canal Expansion project. The contract also covered the design of the drive mechanism and the control systems for the gates, an integrated RAMS analysis of the entire locks complex, and QA support during the construction and installation phase. This has certainly been a 'mega' undertaking, and not only in terms of the physical dimensions of the immense lock gates. At the peak of the Panama Canal Expansion project, Iv-Groep literally worked around the clock worldwide.

Expanding the Panama Canal
The Panama Canal expansion project involves the installation of a third set of locks in addition to the existing complexes at Miraflores and Pedro Miguel. Each complex consists of three chambers, which lift vessels 27 meters from sea level to that of lake Gatun. The new locks are 60% wider and 40% longer than the existing locks. Each has three chambers separated by double gates, whereupon a total of eight new gates were required for each lock. In 2009, Iv-Groep began working on the design of those gates as a member of the CICP consortium, alongside MWh Global and Tetra Tech. The contact with Tetra Tech dates from 2006 when Iv-Groep worked on the tender design for the new storm surge barrier in New Orleans. At the time, Tetra Tech was a member of a competing consortium. They were impressed by our expertise in steel structures, and therefore were keen to involve Iv-Groep as a partner in the Panama project consortium.

Extremely stringent requirements
The requirements to be met by the design of the lock gates for the modernized Panama Canal were extremely stringent: the gates had to be able to withstand enormous water pressures, collisions, and earthquakes. In addition, it had to be possible to open and close the gates within five minutes with only a small amount of water being let through and they needed to be available 99.6% of the time, a requirement with major design and maintenance implications.

The new lock gates
The lock complex walls are made of concrete and are up to 33 meters in height. On the outside they taper down to a width of 30 meters at the base. The new locks include double doors: in the event of an emergency, the first door turns the ship, the second turns the water. The double lock doors are made of steel and are 31 meters high, 57 meters wide, and 10 meters thick. Each door contains an average of 3,500 tonnes of steel. The new locks have roller gates, which on opening and closing will move horizontally at right angles to the direction of navigation. The difference in water level on both sides of the gates is significant, and the design calls for innovative usage and configuration of water saving basins to reuse 60% of fresh water.

Figure 1: Arrival of the first 4 lock gates

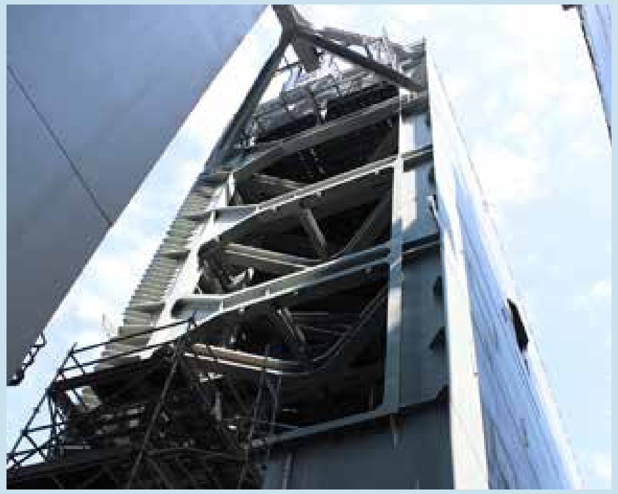

Figure 2: Close-up of lock gate

Due to the enormous dimensions of the lock gates, conventional design methods were not up to the job. Iv-Groep took on the challenge and started looking for alternative and innovative methods to meet the requirements and fulfill the functions, such as turning and sealing on this scale.

A number of innovations explained
99.6% availability of the canal
The high requirements for the availability of the canal called for an intelligent design of the locks drive mechanism. Each time, only four hours will be available for replacing the upper and lower carriages of the gates. The drive mechanism of the Post-Panamax lock gates can withstand single failures of steel wire ropes, electric motors, gear boxes, couplings, etcetera. Components can be replaced without the need to halt shipping traffic. The system is also capable of absorbing both static and dynamic rope elongation. It must be possible to replace components quickly because of the limited time available for scheduled maintenance. For example, the upper and lower wagons must be capable of replacement within four hours. The durability of components is also an important factor and careful wear, tear, and fatigue calculations are therefore essential.

Figure 3: Building of Panama canal expansion

Figure 4: Aerial view of new lock gates (photo by: the Panama Canal Authority)

Load Limiting Device
On the Pacific Ocean side, the complex is located right above two fault lines in the Earth's crust that can cause severe earthquakes. The wagons could be subjected to extremely high vertical loads during an earthquake or when a ship collision results in a leak in a buoyancy tank. Since the wagons cannot be designed to withstand these high loads, Iv-Groep has developed a special Load Limiting Device (LLD). When the load on the wagons becomes too high, the spring of the LLD will be compressed and the vertical load is redirected through the 'feet' of the gate. Since the LLD consists of a set of pretensioned springs, compression will not occur during normal operation. Thanks to the LLD's self-correcting properties, the gate will return to its original position following an earthquake so that the lock can be taken back into operation immediately.

Limiting leakage of fresh water
Gatun Lake is a fresh water lake with a surface elevation of approximately 27 meters above the Pacific and Atlantic Oceans. The lake not only serves as a reservoir for the lock system, but also is a water source for Panama City. Therefore, the design minimizes leakage. Average leakage may not exceed 5 l/m/min while the leakage at any point on the lock gates must remain below 10 l/min. The seals used to prevent leakage must have a service life of at least 15 years. During that time, the gates must be designed to be opened and closed 135,000 times. The seals must not wear out during that time. A solution is provided by an innovative seal that is activated by water pressure differences. Iv-Groep has applied for a patent for this system.

Future proof
Another special feature is that the design takes into account the future expansion of the capacity of the Panama Canal. This leaves enough space 'over' for yet another double set of locks. The doors are designed to last 50 years. The unique challenges in this project have led to important innovations that may be relevant in their application to other lock complexes in the Netherlands, but also far beyond. ◄

Recent research done on the Eindhoven University of Technology

Eindhoven as a Concrete Giant

By: Maikel Brinkhoff, Evelien Dorresteijn, and Karsten Nefs
Editors KOersief and PhD candidate

Eindhoven University of Technology (TU/e) was one of the first that started experimenting with 3D printing of concrete. From that moment on, a lot of research is performed to be able to print, for instance, the first houses (project Milestone), the first bicycle bridge in Gemert, and the longest printed bridge in Nijmegen. 3D concrete printing (3DCP), is not the only research that is carried out on concrete at the TU/e. Several research topics will be briefly mentioned in this article. So, the TU/e is quite a Concrete Giant in the structural world.

Geopolymer Concrete
Some common waste materials can be used as an alternative for cement in concrete; geopolymers is one of those combinations. Since geopolymer is made out of industrial waste, the binder is more sustainable and environmentally-friendly. Yet, a lot of research still has to be done in order to use it on a large scale. Three recent papers on geopolymer research from the TU/e will be briefly elaborated.

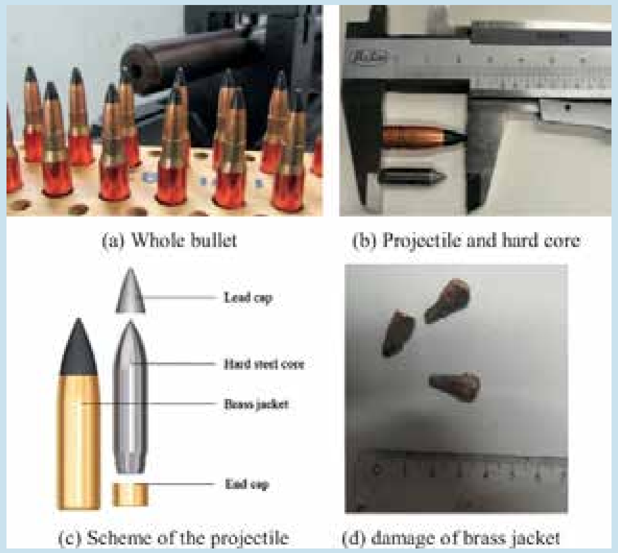

Figure 1: 7.62 × 51 mm NATO armor-piercing bullet

Geocon bridge geopolymer concrete mixture for structural applications
The main goal of this paper is to develop a geopolymer concrete mixture and upscale it to structural use. With the optimization of the geopolymer mixture, a reinforced geopolymer bench is made. A lot of tests were done; the results show that the geopolymer beams were quite similar to the ordinary portland cement (OPC) concrete beams. The four-point bending test shows that the flexural capacity, crack spacing, and crack width were comparable. However, the stiffness is lower and is decreasing over time and, therefore, shows larger deflections. When designing with a geopolymer concrete structure, this should be taken into account, and focusing on a prestressed structure will be more interesting. [1]

Design and performance evaluation of ultra-lightweight geopolymer concrete
Geopolymer, or also called an alkali-activated material, is based on a composition of a reactive material and an activation solution. The activation solution is needed to activate the pozzolanic properties of the reactive waste material. To achieve an ultra-lightweight geopolymer concrete, waste glass as aggregates are applied. The tests done in this research show excellent performances for the mechanical property, thermal property, and durability. [2]

Evaluation of hybrid steel fiber reinforcement in high performance geopolymer composites
In this paper, two lengths of steel fibers are tested in a geopolymer concrete mixture. The results show for the addition of steel fibers a slight decrease in the slump flow and increase in the porosity, but effectively inhibits the drying shrinkage and improves the stress-strain behavior. The right mixture of long and short fibers shows a synergetic effect and leads to optimum strength.

Impact resistance concrete
Research done on the impact resistance concrete is to investigate and predict the influence of several parameters on the impact of the penetration depth on concrete.

Influence of key design parameters of ultra-high performance fiber reinforced concrete on in-service bullet resistance
This paper addresses the influence of critical parameters on the bullet impact resistance on ultra-high performance fiber reinforced concrete (UHPFRC). The effects of steel fiber type and dosage, coarse basalt aggregates, matrix strength, and target thickness are researched by subjecting the concrete to a 7.62 millimeters bullet shooting with velocities of 843–926 m/s, see *Figure 1*. Short straight fibers show better anti-penetration results than the longer hook-ended fibers, and the optimum volume dosage is approximately 2 %. When the coarse basalt aggregates have a particle size up to 25 millimeters, the results show a slightly higher mechanical strength and a significantly increased bullet impact resistance with a 14.5 % reduction of the penetration depth. To withstand the bullet impact under a velocity of 843 mm/s and 926 mm/s, a slab thickness of approximately 85 millimeters and 95 millimeters respectively is needed. [4]

A nonlinear rate-dependent model for predicting the depth of penetration in ultra-high performance fiber reinforced concrete (UHPFRC)
The reason UHPFRC is most of the time used for protective structures because of the ultra-high compressive strength and excellent toughness material properties. In this research, it is found that the depth of penetration (DOP) is affected by the compressive strength of the concrete, while the tensile strength influences the cracked region radius. In this paper, a model is proposed for the analytical prediction of the DOP for UHPFRC, whereby the Hoek-Brown criterion is used to account for the nonlinear response of the UHPFRC. [5]

3DCP
3D concrete printing has become one of the main research areas in the department of structural engineering and design at the chair of concrete structures, with close collaboration with many other chairs. The concept of 3D printing is not new anymore, much research has been done in the last five years, however, the research field is still expanding. Still, a lot of goals have to be achieved in this relatively new field. Form freedom, reduction of intensive labor, and material efficiency are a few of the driving forces behind research in additive manufacturing methods. A recent paper which provides an overview of the current state of additive manufacturing with cementitious materials is:
Extrusion-based additive manufacturing with cement-based materials – Production steps, processes, and their underlying physics: A review [6]

Mechanical performance of wall structures in 3D printing processes: theory, design tools and experiments.
3D concrete printing is a complex process of extrusion of layers in a fresh state on top of each other. During a print session a lot of things can go wrong, not only the printing process (mixing, pumping, and transporting of concrete) but also the failure of the printed object itself. In this paper, a mechanistic model for two important failure mechanisms, plastic collapse, and elastic buckling, is described. The model makes use of only 5 dimensionless variables to describe the two above mentioned failure behaviors; three dimensionless parameters for elastic buckling and two dimensionless parameters for plastic collapse. While the derivations behind the model are quite complex, the use of the model with the provided design graphs and the dimensionless parameters is relatively straight forward. [7]

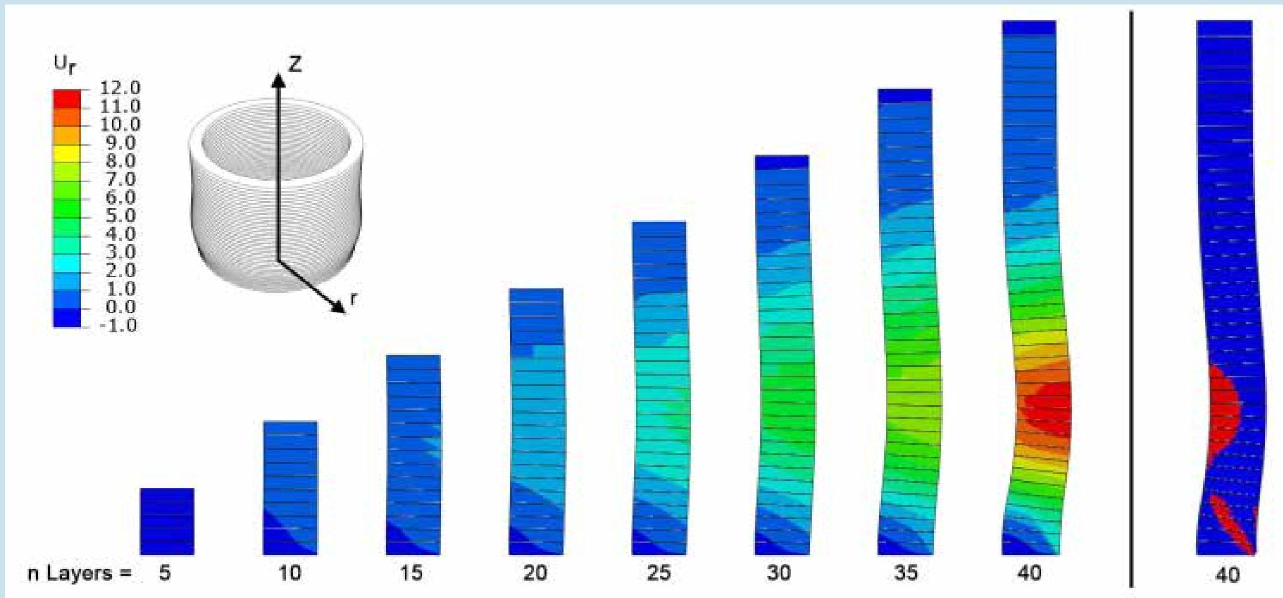

Figure 2: FEM model - buildability of fresh concrete

Structural failure during extrusion-based 3D printing processes

This paper gives a validation of the previously mentioned model [8] to calculate failure behavior in 3D printed objects, with both numerical and experimental research. A sophisticated FEM model is created, in which the buildability of fresh concrete can be predicted, see *Figure 2*. The main advantage of the use of this FEM model is the wide range of structures, without geometrical restrictions, the model can be used for. Both the analytical [7] and the numerical model are in good agreement with the experimental test results. [8]

Hardened properties of 3D printed concrete: The influence of process parameters on interlayer adhesion.

The previous papers mainly describe the fresh state of the concrete, however, the printing process itself also influences the hardened properties of concrete. This paper focuses on three main process parameters; the height of the nozzle above previous layers, the time between sequent layers are printed on top of each other, and dehydration of the surface. Which are all tested on compressive and tensile strength for the three independent directions in the hardened state. For all these variables an extensive test series was performed, in which more than 170 specimens are tested, see *Figure 3*. A longer interval time between printed layers, which is normally a function of print speed and print path length, has a significant negative effect on the bond strength between layers. This effect is enhanced if the layers are not covered during long intervals times, due to dehydration of the surface. Also, a clear direction dependency of strength properties is found. [9]

Sustainable concrete

Valorization of waste baby diapers in concrete

The construction industry is infamously known for its raw material use and pollution [10]. Sustainability can be reached through several ways. One, rather out-of-the-box, approach is the use of shredded baby diapers as a viscosity modifying admixture (VMA) [11]. These admixtures are used to alter the concrete's rheology (flow properties). Although having several advantages, i.e. reducing a waste stream and lowering the industry's raw material use, the use of diapers is not straightforward. Used diapers namely contain substances that can deteriorate concrete and corrode reinforcement. The aforementioned study [11] modeled the substance's concentrations in concrete and finds that, with the right dosage, shredded baby diapers can indeed be used as a sustainable and effective VMA.

Smart concrete

Smart concrete covers a broad category of exciting and innovative concrete types. Here, we will discuss two of these.

Study of self-healing properties in concrete with bacteria encapsulated in expanded clay

In this study, bacteria encapsulated in clay are added to circumvent cracking to produce a more durable concrete. The process relies on concrete's high pH to keep bacteria inactive. Water eventually penetrates the concrete through cracks, lowering the pH and activating the bacteria. This induces a chemical reaction, converting calcium lactate to calcium carbonate (limestone). The concrete used consists of ordinary Portland cement, pit sand, the bacteria infused clay, and water. A compressive force of 21.2 MPa (90% F_c) was applied to form cracks. Self-healing is quantified by the following formula:

$$H(\%) = \frac{F_c(control) - F_h(healed)}{F_c(control)} \cdot 100$$

Figure 3: Test Matrices after testing

where the F denotes corresponding compressive strengths. An increase in compressive strength thus translates to healing efficiency. Results show that after 63 days, healing efficiency is 40% which means the clay infused with bacteria contributes to strength recovery. [12]

Multifunctional wall coating combining photocatalysis, self-cleaning and latent heat storage

Another smart application of concrete revolves around developing and studying a mortar that combines energy storage, depolluting, and self-cleaning capabilities. These characteristics are enabled by adding phase change materials (PCM), titanium dioxide (TiO_2), and Rhodamine B respectively. *Figure 4* shows adding the components in a specific ratio (30% PCM and 2.5% TiO_2) does not diminish properties but rather enhances them. Another observation is that titanium dioxide deteriorates quality, and higher PCM values appear to compensate for this. Evidently, this ratio leads to the highest pollution degradation rate and second-highest self-cleaning grade. As for heat transfer, a higher TiO_2 concentration yields better results, which, as mentioned, deteriorates mechanical properties. [13] ◄

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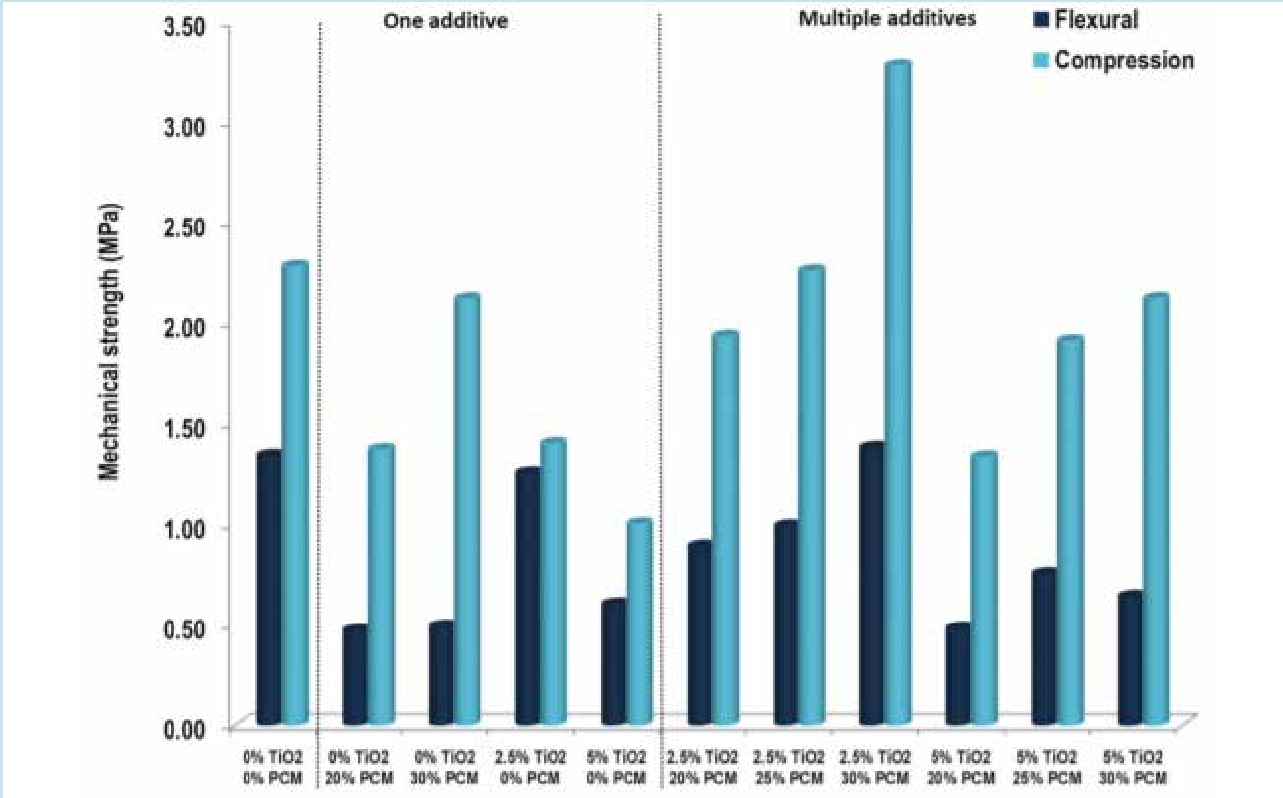

Figure 4: Mechanical strength of the tested compositions

Triodos bank Zeist

The new standard for offices

By: ir. Gert-Jan Rozemeijer RC
Director and senior adviseur at Adviesbureau Lüning

The new central office of the Triodos bank in Zeist sets the new standard for modern office buildings. Nature-inclusive, optimal connection with the surrounding nature, sustainable, and a healthy indoor climate. This all was realized with barely more cost compared to a traditional office. The biggest, fully timber, building of the Netherlands offers a unique balance of nature, culture, and economy.

Estate De Reehorst
What does a bank do that wants to offer a sustainable alternative to other banks if it needs a new office building? Will it add another glass palace to the Zuidas? Triodos bank has chosen to approach things completely different. Their choice was to move into an existing estate: De Reehorst, located in Zeist. This brings the bank back to its roots, where it was once founded. The estate is located at the station of Driebergen-Zeist and is an important link in the Ecological Main Structure (EHS). A conscious decision was made to make the walking distance from the parking longer than the distance to the station. Constructing in such a vulnerable area requires special attention. At the same time, the new use of the estate means a strengthening of its survival. The estate will be restored, expanded and opened to the public by Triodos.

Respect for nature
As mentioned, caution was necessary when developing a building in the middle of nature. The starting point for the design was to allow the building to become part of its environment. On the one hand, by matching the shape of the building to the surrounding nature. With its organic form, the building follows the existing trees and bat routes. Also, the building does not rise above the forest. The highest roof floor is in line with the crowns of the existing trees.

On the other hand, the all-glass facades bring nature inside. Maximum daylight deep into the office and maximum view of the greenery from all workplaces. By locating the timber rafters on the inside and keeping the facade as transparent as possible, your eye is automatically drawn to the spectacular view.

Structural Design
Except for the basement and the foundation, no concrete has been used in the building. The construction of the upper structure is entirely made of timber. The cores for stability, the floors and the rafters together form the construction. Each tower contains 26 characteristic timber rafters per floor, which function as a column and a floor girder. In a flowing form, the rafters bend from vertical to horizontal. They span 6.5 m from the corridor to the facade. Because a cantilever of this length would cause excessive deformations in the

Figure 1: Timber cantilever rafters and core

Figure 2: Standard floor with timber rafters

facade, it was decided to make the facade structural. This was not easy given the desire to give the facade maximum transparency. Placing a column at the end of the rafters was therefore not an option. What did offer a solution were the open parts in the facade. Every 3.6 m there is a window that can be opened by the users. At the location of these windows, frame profiles were provided in the architectural design, and facades in the further profile were empty. And although these frames are not on top of each other and also not directly under the rafters, they have nevertheless been used to create a structural line in the facade. In order to respect transparency, the facade posts are made very slender as steel box profiles (120x60 mm). A steel edge beam takes care of the load transfer from the rafters to the facade posts.

Timber Core
The office building is the first building of this size in the Netherlands that obtains its stability from timber cores. Each tower has a stability core made of CLT (Cross Laminated Timber) walls. The cores that, in addition to the stairwell and elevator, also contain the toilets and pantries, have a curved shape on the outside. The straight walls from the core have been used for stability. Through the rigid floor diaphragm effect in the floors, all three cores are used for the stability of the 23 meters high building. Naturally, the timber core meets the same horizontal deflection requirements as all other buildings (u <h / 500 mm). The CLT walls of the cores, with a thickness of 200 millimeters, are vertical. As a result, the 3.5 meter wide panels were placed over four floors at once. The reason for this is that this allowed the number of joints to be considerably reduced compared to a horizontal division of the walls.

Fire safety
The floors are, just like the walls of the core, made from CLT. The vibration behavior was decisive for the dimensioning of the floors (thickness d = 120 mm). The floor is dimensioned according to the SBR guideline Vibrations in floors due to walking, class D (office functions). Although the entire

Figure 3: CLT-walls of the elevator

Figure 4: CLT-walls of the core of 4 building layers

building is equipped with a sprinkler system due to the compartment size, and there is no requirement for fire resistance under the Building Decree, a requirement has nevertheless been retained with regard to fire safety. This requirement, of at least 30 minutes, applies to the rafters and floors. For the cores, a fire-resistance requirement of 60 minutes has even been met. To prevent the steel facade posts from having to be protected against fire, the rafters are designed for a free cantilever in the event of a fire.

Installation site instead of a construction site
In the view of the architect, Thomas Rau, the circular building is "temporary merging of products, components and materials with a documented identity". A 'material bank' has been created, as it were, in which materials are temporarily stored. The condition for this is that the materials can be reused without damage, which requires dismountable connections. The timber construction lends itself perfectly to such connection details, which can be detached and reassembled. All connections on the construction site are made with screws, pins and timber thread bolts. In total 165,312 pieces. The construction site has thus become a mounting location. Virtually all parts, in addition to the timber construction, for example also the facades, were delivered prefabricated and connected to each other by means of demountable connections. In addition to being suitable for circularity, this has also significantly reduced the nuisance on the estate during construction.

The future
The timber construction in the new office shows the circular and sustainable future of offices. Due to the relatively low requirements for fire resistance and sound insulation, offices are ideally suited for timber. Achieving climate goals increasingly demands different materials. Solutions with biobased and circular materials will largely solve this question. With a construction entirely of timber, this new office is the new standard for this. ◀

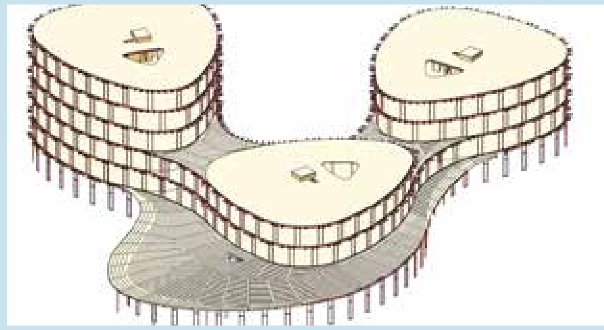

Figure 5: 3D-Revit model of the structure

Programming self-shaping wood

The Urbach Tower

By: Dr. Markus Rüggeberg, ir. Dylan Wood, Dr. Philippe Grönquist, Prof. Achim Menges
Researchers at University of Stuttgart, ETH Zürich, and Empa

Since May 2019, a unique timber tower represents a new landmark in the Remstal close to the city of Urbach east of Stuttgart, Germany. Designed and built as one of 16 architectural landmarks for the Remstal Gartenschau 2019, the manufacturing of the individual curved lamellae of the 14m high tower represents a paradigm shift in timber manufacturing. The curvature of the lamellae has been introduced by a self-shaping process rather than by a mechanical machine-driven forming process. The Urbach tower represents the first building worldwide consisting of self-shaped components.

Wood as a construction material is exposed to ever changing ambient climatic conditions, which inevitably leads to swelling and shrinking due to moisture content changes. This dimensional instability may lead to warping and cracking of boards. In timber manufacturing, multiple rules, guidelines and treatments exist for the conditioning and arrangement of individual wood elements for flat components, in order to maintain the flat state and avoid cracking during service. Curved shapes have so far been achieved by a layered design and brute mechanical force to bend the individual layers into the desired shape, which is then fixed by the gluing of the lamellae. The design and the manufacturing of the Urbach tower manifests a re-thinking of how we deal with the hygroscopy and the moisture-driven deformation of wood. Rather than trying to counteract its inherent behavior, it is taken as a unique property and power, which can be utilized to program-specific self-shaping movements. Opening the design space to more complex, curved wood structures in innovative and performance-driven architecture.

The shape change is solely driven by the shrinking of the wood during a decrease of moisture content. Inspired by the moisture-driven opening of the pine cone with its bi-layered scales [1] and analogous to the well-known bi-layered temperature-driven thermostat, a bi-layer setup of a wood veneer with laminated glass fiber reinforced composite [2] or with two wood layers with differential fiber orientation in the layers transforms the shrinking of the wood into a shape change of the bi-layer [3]. Manufactured at high moisture content in flat state, the standard technical-drying process is employed for the self-shaping of the individual wood bi-layer into a programmed curved shape. In the same way that machines can be programmed to perform different movements, wood parts can be programmed to curve into predetermined shapes when dried.

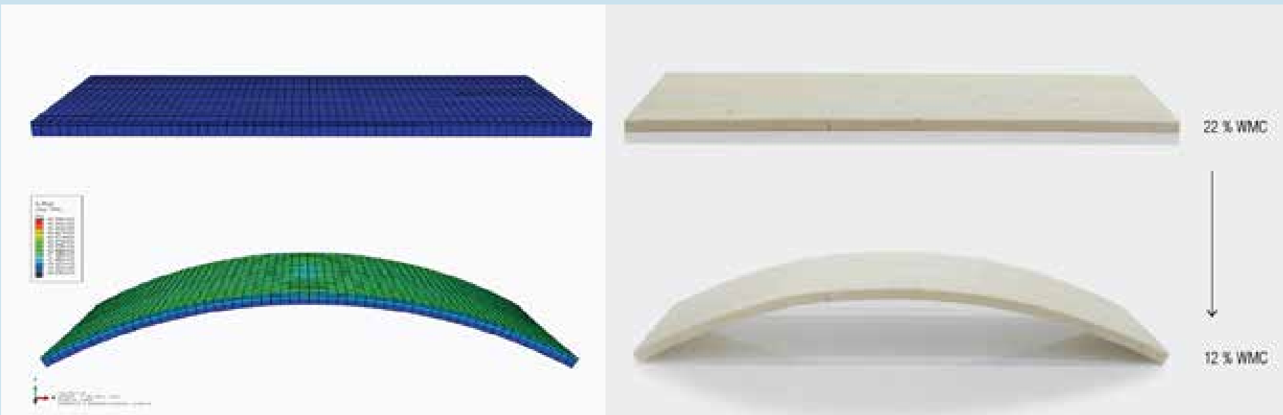

Figure 1: FEM predicting moisture induce curvature (left) compared to the experiment of moisture-induced curvature (right)

Material specific computational mechanics models have been developed and implemented in a Finite Element Method software (see *Figure 1*) to design, predict, and optimize the material arrangement required to produce different curvature types and radii [4,5,6]. Further research effort was required for upscaling such bi-layer components to building scale, adapting the technical drying process to avoid cracking as well as mechanical characterizing the components of the tower.

The Urbach Tower consists of bi-layers of 5 x 1.2 meter size and 40 millimeter thickness from spruce wood. After drying, the bi-layers were overlapped and laminated in curved state to lock the geometry in place. Together with an additional outer 10 millimeter thick layer, this resulted in a 90 millimeter thick cross-laminated timber (CLT) structure with form stable geometry, see *Figure 2*. This new manufacturing technology of curved CLT has been patented [7]. The rapid adaptability of the process to obtain different curvatures opens up new and unexpected architectural possibilities for thin shell wood structures, using a sustainable, renewable, and locally sourced building material. The Urbach Tower is the very first implementation of this technology on building-scale, load-bearing timber parts [8].

The components of the tower are five-axis CNC cut and detailed from half-cylinder blanks with a length of 15 meter and pre-assembled into building groups of three components for transport, including water barrier and external wood cladding. Each component is cut and detailed in just 90 minutes of machine time. A custom-made protective cladding layer consisting of glue-laminated larch wood is added on the outside. This also includes the application of a newly developed transparent and durable inorganic coating, which protects the wood from UV radiation and fungi attack. Instead of ripping and turning silver- grey when exposed to outdoor weathering, the larch wood will take on an even white color over time. The tower was assembled (as can be seen *Figure 3*) in a single working day by a team of four craftsmen without the requirement of extensive scaffolding or formwork, and topped-off by a transparent roof. The Urbach Tower is the outstanding result of building innovation made possible with the joint expertise and practical skills at the interface of material science, digital innovation, and craftsmanship.

The project was financially supported by the community of Urbach, Remstal Gartenschau 2019 GmbH, the German Federal Environmental Foundation (DBU), Innosuisse (Swiss Innovation Agency), Carlisle Construction Materials GmbH, and Scanntronik Mugrauer GmbH.

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Figure 2: Curved CLT panels in final, form stable form

Figure 3: Prefabricated assembly group

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Self-forming Curved Wooden Components Research and Development, Wood Manufacturing and Construction

Project support:
Community of Urbach
Remstal Gartenschau 2019 GmbH

German Federal Environmental Foundation (DBU):
Design, Fabrication and Engineering Methods for the application of curved wood elements in high-performance, resource-efficient wood construction: Project Tower Urbach, Remstal Gartenschau 2019

Innosuisse – Swiss Innovation Agency:
Smart, Innovative Manufacturing of Curved Wooden Components for Architecture with Complex Geometry
Carlisle Construction Materials GmbH
Scanntronik Mugrauer GmbH

Project data:
Dimensions

- 14.20 meter tall timber structure
- 4.0 meter radius bottom, 3.0 meter radius top, 1.6 meter radius middle
- Spruce Wood CLT with 10-30-10-30-10 build-up
- Larch wood façade with titanium oxide surface treatment
- five-axis CNC cut components
- 12 individual prefabricated components pre-assembled in groups of three
- Crossing screw connection detail with wood alignment blocks
- Eight sensors to monitor internal WMC of the structure

Construction System
Curved surface-active tower structure, self-shaped curved cross-laminated spruce timber (CLT) 10 -30-10-30-10 layup, glue-laminated Larch façade with titanium oxide UV protection surface treatment, curved polycarbonate roof with a steel support structure. ◀

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Figure 4: Assembled tower

Online activities with KOers

KOers goes Digital

By: Evelien Dorresteijn
Editor KOersief

KOers is not able to do any activities on the campus of the Eindhoven University of Technology, due to the corona crisis. Because the board definitely did not agree on stopping with everything, and is quite enthusiastic, a lot of new initiatives were born: KOers goes Digital.

KOKO goes Digital
Normally, every Tuesday there is a KOKO (KOers KOffietijd) in the break at the KOershoek in Vertigo. During the KOKO we eat some tosti's, drink coffee and tea, and have a nice talk with each other. In the first half year of this college year, there were also some special KOKO's, like the KOKrOKO (KOers kroketten KOffietijd), ChoKOKO, (Chocolate KOers KOffietijd), Healthy KOKO with smoothies, Hangover KOKO with hotdogs and waffles in the structural lab, KOKO on floor 9 with appelflappen, KOdOKO (KOers dOnuts KOffietijd). To conclude, the KOKO is a social and fun activity for KOers. This is why the KOKO was the first event that went online weekly. For every KOKO, a game was prepared. Games like Curve Fever (*Figure 1*), Bomberman, the KOers quiz (*Figure* 2), Pictionary, a logo quiz with the logos from the partners of KOers (*Figure 3*), and there are still many more to come.

Figure 1: KOKO - curvefever

Stay @ Home Bingo
The second online activity was the Stay @ Home Bingo. Every participant received a bingo card with letters that can

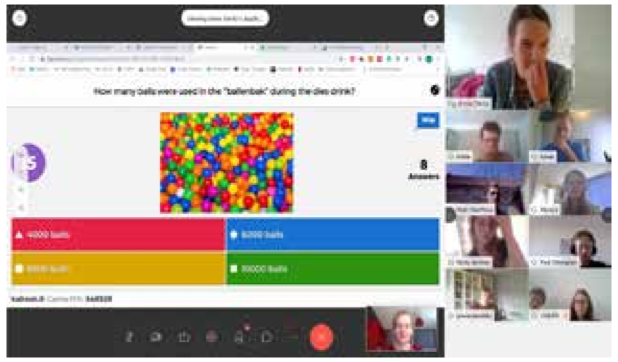


Figure 2: KOKO - KOers quiz

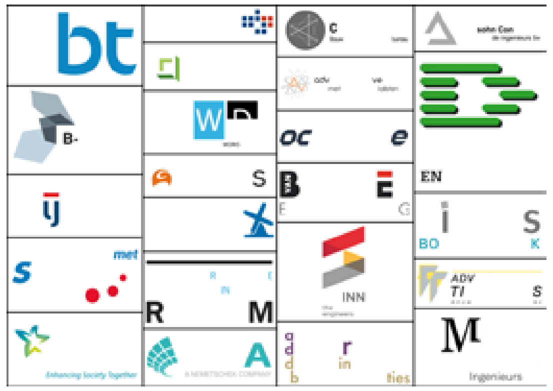


Figure 3: KOKO - KOers logo quiz

Figure 4: Stay @ Home Bingo - challenge B and C

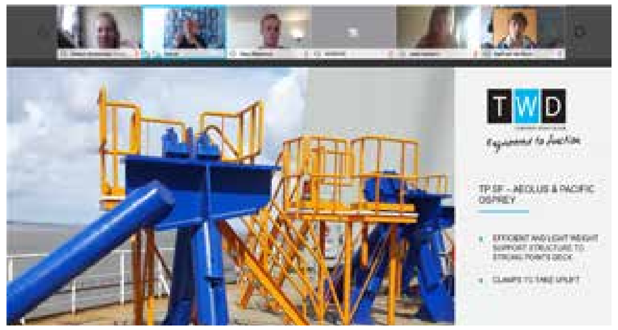


Figure 5: Online Lunch Lecture by TWD

be ticked by doing the challenge with that letter. For nine weeks, weekly challenges were uploaded with a unique letter, see *Figure 4*. If the letter is on your unique bingo card, you have to fulfill that challenge, and if fulfilled well you can tick that box off. The person who has their bingo card full first, wins!

Online lunch lectures
Also the lunch lectures by several companies were given online. KOers was very pleased that the companies were willing to participate in this online experiment. The first online lunch lecture was given by TWD about Offshore Engineering, see *Figure 5*. The second lunch lecture was given by Continu about how to apply for a job online, the third lunch lecture was given by Van Rossum about the Sluishuis, and there are more to come. Although the lunch lectures were online, it was a really nice alternative for the lunch lectures as we know and maybe even easier to ask questions to the speaker.

Online drinks
KOers organizes some drinks every year, and of course these can not be missed in the list of online activities. The first online drink was the pub crawl. Normally, during a pub crawl several pubs are visited, but because this is not possible, everyone changes their background of the webcam to the

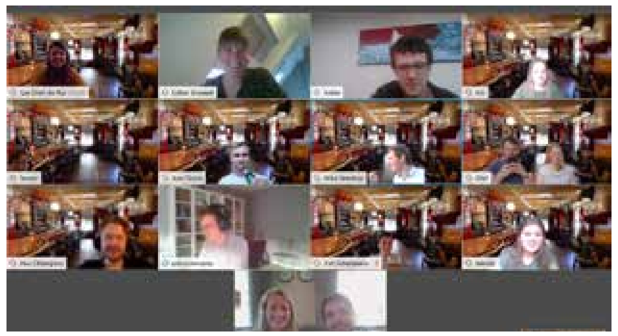


Figure 6: Online Pub Crawl

same picture. In this way, everyone is enjoying their drinks in the same pubs, see *Figure 6*. Also an online Bock Beer Tasting drink and a Beer Pong drink are on the program.

Fit with KOers
Normally, May is the month with a lot of sports activities like, the Batavierenrace, Huizen en Disputen Race, E.S.V.V. Pusphaira football tournament, and so on. Also all these activities were canceled, which is where Fit with KOers online was born. We started the Fit with KOers month with the online Batavierenrace, see *Figure 7*. Together we ran 125 kilometers in 10 hours, 43 minutes, and 46 seconds, with an average speed of 5:08 minutes per kilometer. KOers ended up in de 94th place, which is higher than last year where we ended in the 97th place. Besides, the runners of the Batavierenrace did run very fast, they were also sponsored by KOers. For every kilometer they run, KOers was donating one euro to the Red Cross. In addition, the board of KOers did run the KOers logo.

Figure 7: Batavierenrace

Figure 8: Fit with KOers

Besides the online Batavierenrace, KOers organized weekly fitness workouts. Every week the workouts were done with another object. The first week all workouts were done with a pan, see *Figure 8*, the second week with toilet paper, the third week with a broom, and the fourth and final week with a book.

Another sports activity during the month May is 'Walk May with KOers', a walking challenge. In this challenge, the goal is to reach a minimum of 41,000 steps in a week. 41,000 is because KOers exists this year 41 years. During every weekly fitness workout, a top tree of the KOers members was announced who walked the most in that week. In this way, KOers is staying Fit in the month May. ◀

Integral role of the engineer

De Hoge Regentesse

By: Robbert-Jan Meijers & Brenda Goedhart
Wijcon

'De Hoge Regentesse' is a medium high-rise building located in The Hague in The Netherlands. It consists of a tower with 24 building layers, consisting of 128 apartments, a ground level of commercial areas, and an adjoining building with parking spaces. In total, the building height is up to 70 meters. Due to the chosen building system, it was managed to construct up to one level in three days. The total structure was built within 100 days. Especially in an urban area, with a small construction site and the need of limited nuisance to the neighborhood, a shorter construction time lowers the burden on social environment and failure costs.

To construct 'De Hoge Regentesse', Wijcon chose a structural building system that combined traditional with a prefab construction method. Due to the interaction between forces, it was not possible to construct the first three floors with prefabricated elements. From the fourth floor, the layers were suitable for the use of prefab elements, and therefore the structural system was manufactured prefabricated. Wijcon, the engineering company of Van Wijnen, made this decision because of the repetitive floors in this project. In addition, prefabrication of structures influences construction time in a positive way. On the other hand, the challenge of a prefabricated structure lays in the alignment and coordination of different elements. The prefabricated elements, which are produced by different suppliers, such as floors, facades, and inner walls require a high quality and well-coordinated engineering. For this project, Wijcon was responsible for the main engineering of the building, as well as the detailed engineering of prefabricated elements. As the main engineer, Wijcon was responsible for the stability of the structure and for providing calculations that determine the amount of reinforcement for the elements that are poured in-situ concrete. Another responsibility was making the essential structural design decisions in the early phase of building development. Due to the experience of Wijcon, in the combined and integral role of main constructor and detail engineer, as well as the involvement in the design phase, requirements for a prefabricated structure were already taken into account. This lead, for example, to the detail presented in *Figure 1*, which shows the connection between the inner wall, the load bearing facade, and floor. In this detail, multiple elements have to fit together, which is only manageable with expertise in prefabricated structures and with a fluid cooperation between the involved companies.

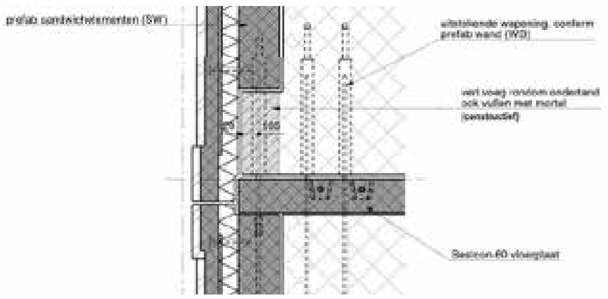


Figure 1: Facade wall detail

Eventually, the choice of Wijcon to combine prefabricated structures, to be involved in the design phase, and have the integral role in engineering resulted in a reduced building time, failure costs, and probably most important, a limited burden on social environment. ◄

WIJCON

By: Cement
Knowledge platform about concrete structures

Options CO_2-reduction for cement
Reduction of the CO_2-footprint is one of the most important current themes in the concrete industry. The production of cement makes a significant contribution to the total CO_2 emissions, mainly due to the enormous demand for concrete. However, reducing the CO_2 footprint of cement or making use of alternatives is not that easy.

The easiest step to take is replacing part of the Portland cement clinker by alternatives like blast furnace slag and fly ash. However, blast furnace slag is already for 90% worldwide applied in cement and concrete, but the total volume of blast furnace slag is only 8% of the total demand of cement. The share of suitable fly ashes is of the same magnitude. One alternative is a cement type based on unburnt calcium silicate or the clay type kaolin, both of which are practically unlimited available worldwide.

There are also a couple of developments with regards to alternative binders:

- Belite-rich Portland cement: Portland cement containing belite, where the burning temperature is lower. The strength development is also lower. The CO_2 reduction is about 10%.
- Calcium Sulfoaluminate-belite cement. This is comparable to belite-cement, but it has a lower burning temperature and a faster strength development. However, this needs an aluminium rich addition, like fly ash, or (when upscaling) bauxite. This makes it very costly. The CO_2 reduction is about 25-30%.
- Wollastonite. An alternative clinker material that is common in nature. It leads to a lower burning temperature and during hardening about 30% of the CO_2 is absorbed. The dimensions are limited to about 200 mm. It has a pH of about 9, which is too low for application as structural concrete (risk of corrosion of reinforcement). CO_2 reduction of 60%.
- Hydrated calcium silicate. Based on the usual raw materials like calcium silicate and sand. It has a complex and costly production process that is still in the laboratory phase. It does not have a high pH, and is therefore not applicable as structural concrete. CO_2 reduction of 50%.
- Geopolymers: Alkaline activated binders, currently often based on fly ash and blast furnace slag, which means there is (netto) no CO_2 reduction. Possible alternatives for slag and fly ash are an artificial produced slag and other secondary material flows.

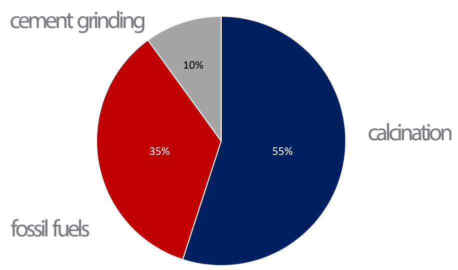


Figure 1: CO_2-emissions during the production of Portland cement (CEM I)

More about the possibilities of CO_2 reduction are in the Cement-article 'CO_2-reductie: opties voor cement.' You can read this article on: www.cementonline.nl/co2-reductie-opties-voor-cement

Figure 2: Depot Boijmans van Beuningen in aanbouw, mei 2019, foto: Hans Wilschut / BAM

Safe execution due to construction phase analysis
In a lot of cases, construction safety during the execution is underexposed. The project Depot Boijmans van Beuningen in Rotterdam, shows the importance of an extensive analysis of the construction phase.

The Depot consists of a double-curved concrete shell in the facade, steel-concrete columns in the building, and concrete floors. Due to the cantilever behavior of the walls, a 500 mm thick concrete wall and two 390 mm thick concrete floors needed to be temporarily supported from outside the building. On the one hand, this demanded heavy supporting structures and on the other hand an extra foundation with foundation piles to take up the loads from the supporting structure. From the construction phase analysis, it became clear that the activation of the supports was possible, which meant that the forces on the supporting structures reduced by half. This resulted in a lighter supporting structure with a foundation of prefab concrete plates. This resulted in a large cost reduction with still a safe execution.

More about the construction phase analysis of the Depot Boijmans van Beuningen is, together with the analysis of the project 'Forum Groningen' available to read in the Cement-article 'Veilige uitvoering dankzij bouwfaseanalyse.' You can read this article on: www.cementonline.nl/veilige-uitvoering-dankzij-bouwfaseanalyse ◄

1,300 tonnes of steel in the main load-bearing structure of Nhow Amsterdam RAI

Special interaction of forces between concrete and steel

By: Patricia van der Beek
ASK Romein

"The job gave us headaches both in the engineering and implementation phases," says Oostingh engineering manager Kees Oudshoorn. "It already started with the construction of the main load-bearing structure. This is a hybrid construction of concrete and steel, most of which also extends outwards. We worked out the detailed engineering of the main load-bearing structure in BIM, with a great deal of attention to the interaction of forces inherent in such a complex concrete-steel connection. We did this in close collaboration with Van Rossum consulting engineers, Red Betonbouw and Pleijsier Bouw."

Supporting and monitoring overhangs

An issue for concern with the overhanging parts was that they had to be supported during construction. The overhangs of the bottom building block were supported by scaffolding. 'We could not do this for the two superjacent blocks,' says KeesJan Nieuwenhuis, director of Oostingh. 'The facades underneath had to be kept clear. That is why we opted for an overhanging support structure, which was braced against the concrete core'. Oudshoorn adds: 'We had to take account of the fact that the overhangs were slightly lowered because of all the loads. However, the glass facade, which hangs on the structure, only allowed minimal tolerances. We had to, therefore, closely monitor those settlements and make adjustments where necessary. That was exciting until the end, but it went well. The facade consolidation proceeded without major modifications'.

Welding on site

Oostingh delivered the structural members and steel girders ready-made at the building site as much as possible. 'Some parts were too big to transport,' says Nieuwenhuis. 'We had to bring those in parts to the building site and weld them together on-site.' Oudshoorn: 'We also had to weld part of the structure to the underlying structure. We devised a connection for this so that the parts fit into each other like Lego blocks. In this way, we gave the construction the necessary rigidity, and we built in enough tolerance'. We post-treated the welds on-site with a fire-resistant coating.

BIM Award

'A special project' reflects Nieuwenhuis. 'Despite the various headaches, we have made it a success together. The way we tackled the complex structure even earned us a BIM Award. A great recognition for our work, of which we are naturally proud'. ◀

Figure 1: RAI hotel close-up

The looking glass

Transposing a facade

By: Iris Rombouts and Jet Sennema
Structural engineer & project manager at Octatube, communications at Octatube

Challenge accepted: three curved glass boxes, each no less than 8 meters long, entirely held together by a structural sealant (no bolts used), to be assembled horizontally, and mounted vertically on site.

The famous P.C. Hooftstraat in Amsterdam was recently adorned with this show stopping glass facade designed by UNStudio, named 'The Looking Glass'. Three curved glass boxes descend from the upper floors, resembling the flow of billowing fabrics. The glass boxes start flush with the adjacent buildings and cantilever outward while moving upward. This gradual movement emanates a fluidity you would not associate with glass.

Octatube was responsible for the pre-engineering, technical design, production, and assembly. The boxes are entirely bonded by means of structural silicone, thus no bolts were used. Slender stainless steel profiles in between the panels define the glass box shape.

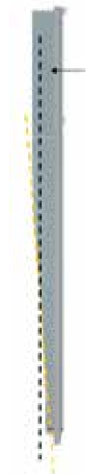


Figure 1: UN Studio, PC Hoofdstraat (Photo: Eva Bloem)
Figure 2: Cantilevering facade (right)

The upper panel slightly cantilevers outward, creating a tensile load on the silicone bonding. The lower pane is pushed in the direction of the sealant joint by the mass on top of it.

Custom steel auxiliary frame

We designed a custom steel auxiliary frame that functioned as a stiff mold around the glass boxes to make sure that the structural sealant did not experience too heavy loads during transport and hoisting. The structure surrounds the glass boxes on all sides and is mechanically linked to the main steel of the glass boxes.

The glass boxes were transported horizontally in their auxiliary frames to the P.C. Hooftstraat. On site, they were rotated and vertically mounted into the facade: one of the most spectacular challenges of this project.

The deflections of the glass boxes and the steel auxiliary frame had to be kept to a minimum, and therefore all stages of the assembly were calculated.

On site, two cranes handled the rotation of all three boxes with an elaborate pulley mechanism at the top and bottom of each box. In the first phase of the rotation, the box is carried by both cranes and pulley mechanisms, whereas in the last phase of the rotation (when the box is in full vertical position), only one crane and one pulley mechanism carries the load.

The rotating had to be done slowly to gradually control the self-weight of the glass box: going from a horizontal load to a vertical load before being mounted in the superstructure. Before the trucks arrived, the brackets attached to the steel in the superstructure were pre-installed and positioned. Once the glass boxes were connected to these brackets, the auxiliary frame was removed.

After months of preparation, the entire assembly was done in just 1.5 days. It all came down to the exact millimeters, from the silicone bonding, the curved glass and steel connections, and rotation on site: everything had to come together perfectly – almost a job for a Swiss watchmaker. ◀

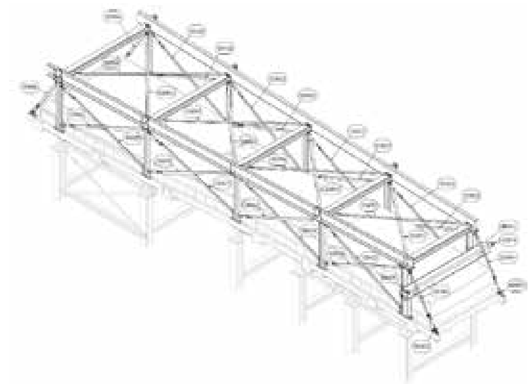


Figure 3: drawing of the auxiliary frame

Figure 4: lifting the auxiliary frame

Quality assurance in structural design engineering

Effects of the new Dutch law on quality assurance in construction

By: Jack van Hoof
BouwQ

On May 14th, 2019, a new Dutch law on quality assurance in construction ('Wet kwaliteitsborging voor het bouwen') was approved. This law is scheduled to come into force in 2022 for Consequence Class 1 (low-risk constructions). The main changes as a result of the new law are:

- **the transition of municipal construction supervision to private quality assurance organizations**
- **compulsory documentation by a contractor that the delivered construction meets regulatory and contractual requirements**
- **contractors remain liable for attributable defects after project completion**

Consequences for structural design engineers

Under this new law, contractors are responsible for checking and demonstrating that regulatory and contractual requirements are met, both in the design and in the realization phase. Contractors will pass on these increased responsibilities, and the afore-mentioned increased liability to their subcontractors and suppliers. As a consequence, many design and construction engineering organizations will need to improve their internal quality controls to meet these additional requirements from contractors and to limit their liability. Known solutions for this are first- & second-line supervision (Eurocode DSL 1 & 2) and employee qualification or certification (e.g., 'register constructeur'). But this is not yet common practice at many design and construction engineering organizations.

Verification of structural designs and calculations

Municipal building inspection departments will no longer be responsible for checking if a construction meets regulatory requirements when this new law comes into effect. This role will be taken over by private quality assurance organizations. These organizations will perform independent verifications in the design and realization phase to check that the construction meets not only regulatory but also contractual requirements. When the completed construction meets the requirements, the quality assurance organization will issue an official statement. This statement from the quality assurance organization together with the documentation collected by the contractor to demonstrate that the building meets regulatory requirements is sent to the responsible competent authority. The responsible competent authority has ten days to check the quality assurance statement and documentation. If they have no objections, the completed construction can be used by the owner. BouwQ is such an independent quality assurance organization with an extensive track record for all types of constructions, ranging from infrastructure, high-rises, residential and non-residential buildings. Our Structural Design Supervisors verify the designs and calculations of crucial parts of a structure, such as foundation, pile plan, main supporting structure, linkages, overhangs, floors, and balconies. For this, they use various tools, such as AxisVM and Technosoft. Due to the broad range of construction types that are verified by BouwQ, its Structural Design Supervisors are all-round structural design engineers with expertise in the different structural design approaches used for steel, concrete, and timber frame constructions. Since BouwQ is responsible for verifying if the regulatory requirements are met, the Design Supervisors are also experts in the applicable laws and standards.

Opportunities for students and graduates

BouwQ offers unique opportunities for students and graduates to become all-round structural design experts. Through an extensive training program with mentoring from senior experts, combined with diverse and increasingly challenging projects, you gain hands-on experience with different types of structural designs and applicable regulatory requirements. Next to this, you will gain experience with the challenges in the realization phase. Check www.bouwq.nl/over-bouwq/werken-bij-bouwq for vacancies, internships, and student jobs. Or contact us via info@bouwq.nl. ◄

What it is like being an Engineer at TWD

By: Charlotte Focke
Temporary Works Design

TWD develops the methods and designs the equipment contractors need to efficiently realize major construction projects. Through the years, we have built up a track record full of engaging projects. We are, amongst others, active in the heavy civil industry. A project we are proud of is the 'walking piling gate,' a piling solution which autonomously skids forward, significantly shortening the project lead time. TWD's core market is the offshore wind sector. One of our most recent finished projects is the monopile gripper on DEME's heavy lift vessel Innovation, which was deployed to realize one of the largest offshore wind farms in Belgium.

The Innovation gripper

In 2018, after Chris finished his Civil Engineering study at the TU Delft, he started working at TWD as an Engineer. "The first project I worked on was the monopile gripper for DEME's heavy lift vessel Innovation. The challenge was that the gripper had to be lightweight since these types of vessels have limited capacity in carrying heavy loads. The gripper, of course, also had to be strong enough to hold the monopile while being installed withstanding wave and wind forces."

The revolutionary 'pendulum design' has the gripper ring suspended in tension rods, resulting in such a logical and optimal load path that the systems' stiffness could be maximized while keeping the overall gripper weight down. The unique combination of gripper stiffness with the slenderness of the structure enables DEME to maximize the useful payload on their vessel.

"The great thing about this project was that I experienced it from start to finish, which meant that I was also involved in the fabrication and even went offshore to see the gripper in action. Last January, the gripper successfully installed 58 windmill foundations in record speed, something I am extremely proud of".

"Every design is created from the collaboration between engineers and designers. For this project, I worked in an energetic team guided by experienced technical advisors. I highly appreciate the collaboration within TWD. Difficult problems are always tackled together. This results in a large variety of activities and a strong social element in our work. At TWD there is a 'work hard, play hard' mentality, which means there is always time to celebrate a successfully finished project with a cold beer at our recurring Friday night drinks."

Figure 1: Chris and his colleague, Yuri, offshore

My learning curve

"TWD offers multidisciplinary services, ranging from structural, mechanical, and installation engineering to specialist disciplines and marine engineering. The initial challenge, when I started working at TWD, was that I was specialized in hydraulic engineering. I had to learn and familiarize myself with mechanical and structural engineering. I did learn the basics of TWD's engineering work during my bachelor's, but that was already a while ago. Luckily, the structural competences came back relatively quick and I felt ready to further develop myself. After talking to my coach, I started to learn about planning and client communication, and in less than a year, I became a Project Engineer."

Working at TWD

"Working at TWD gave me the opportunity to do what I am most passionate about. The projects are challenging and diverse; you get to work in a young and energetic team, and the options to develop yourself seem endless. I look forward to the engineering challenges ahead."

Do you also see yourself working as an Engineer at TWD? Apply now and engineer your future, just like Chris, at TWD! Please send your letter of motivation and CV to hr@twd.nl or contact HR via +31 10 294 03 74. ◄

Figure 2: TWD's gripper design on DEME's vessel Innovation

The (un)changing field of structural engineering

Previously on the KOersief

By: Inge Eekhout & Jet Sennema
Octatube

You might have seen it on television: the tent of the popular TV show Nederland Muziekland. This show, broadcasted in the mid-eighties, showed Dutch musicians performing in different locations in the Netherlands. Everywhere the tent was set up, the party started.

Yet nobody wanted to make this portable tent structure, certainly not for the available budget. For Mick Eekhout however, the words 'can't be done' did not exist. This marked the start of Octatube in 1983. Octatube designed and built the innovative tent structure in-house and within budget. The traveling canopy was meant to last for a few years, but still continues to flourish during music festivals throughout the Netherlands.

This can-do mentality, with which Octatube was founded, runs as a common thread through the company. From a handful of people, a number of drawing tables, and a workshop with rented machines to a company with over 110 employees. They design and build complicated and challenging concepts for bespoke glass and steel constructions, roofs, and facades.

Figure 1: Lifting glass fins in place | Van Gogh Museum (photo © Hajar Elouarrat & NUfoto.nl)

Octatube's (structural) engineers have never been averse to experimentation. It contributes to the learning curve and courage of our organization. As every project is unique with its own complexities, it requires you to look at and think differently about the structural application of materials such as steel, aluminum, glass, composite, and cardboard.

Luis Weber has been working as a structural engineer for Octatube since 1999. Among many other projects, he worked on the cardboard bridge designed by Shigeru Ban in 2007. "Nobody dared to work with cardboard tube construction," says Luis, "so we decided to jump in and take up the challenge. If we weren't a hundred percent certain about something, we would try it out anyway". As there was no readily available structural data from the manufacturers, the structures were designed by testing. Design, development, and research were integrated into the search for a suitable structural concept. Cardboard turned out to be an excellent material for standardized space frames.

Figure 2: Paper bridge by Shigeru Ban (photo Theo van Pinksteren)

Figure 3: Markthal in Rotterdam (photo Ossip van Duivenbode)

Octatube's timeline now includes more than 1100 projects, most of them bespoke and never done before. The bigger the challenge, the better. Some examples include: the Glass Hall in the Beurs van Berlage (the first large frameless glass construction in the Netherlands, realized in 1990), the Floriade Pavilion (one of the first examples of cold-bent glass in the Netherlands, realized in 2002), the roof of the Victoria & Albert museum in London (thermally hardened structural glass beams that span up to 11 meters and cold-twisted glass panels, realized in 2011) or the Markthal (the largest cable net facade in Europe showcasing maximum transparency and minimal construction, realized in 2014).

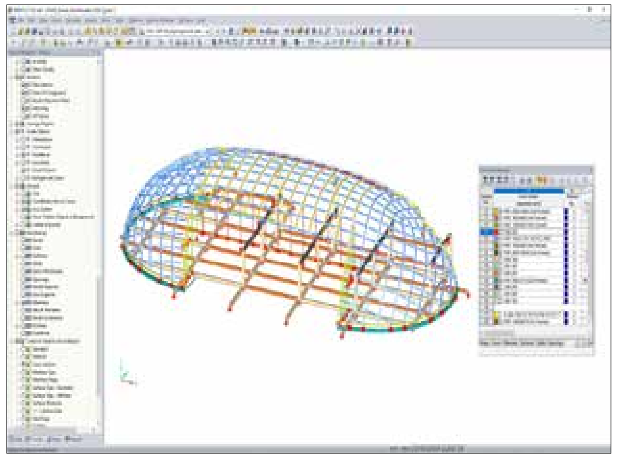


Figure 4: Diamantbeurs model RFEM

Surely, over the years, our way of working has changed and can not be compared to the past. From big A0 drawing tables and humongous computer screens seemingly weighing 200 kilograms, to desks with slender screens connected to computer beasts that run software enabling us to create high-quality 3D details in a fraction of time. What's more, parametric design software, for example, allows us to generate structural alternatives and easily implement optimizations. We did this for the Diamantbeurs in Amsterdam, designed by Zwarts & Jansma Architecten, and realized in 2019. The shape of the gridshell was determined with the help of a parametric computer model. Because of the free form of the design, all parts (steel beams, glass panels, etc.) are different. They also come together in different geometric ways. This meant that with one adjustment in the design, all parts changed. This led to the idea of developing a parametric tool that could convert the complex basic geometry into a detailed production model. From this model, the productions were controlled. By designing the project parametrically, the structure not only proved to be technically feasible, but also more cost-efficient. The solutions that we developed for the Diamantbeurs can be applied in new projects. An example is the gridshell canopy for the C30 building of Shell in The Hague, that we are currently working on.

However, what would blow the mind of the structural engineer of 30 years ago is the way we work together within Octatube today. We have stepped away from top-down management. The traditional structures of decision making, in which the management has the last word, have been let go. We are working in self-directed and self-organizing multidisciplinary teams.

Michele Akilo, who started working as a structural engineer at Octatube in 2018, was introduced to this new way of teamwork in his first project: the Blackrock Shopping Centre in Dublin, a gridshell canopy: "Organizing teams in this way allows you to solve problems in a short amount of time".

Figure 5: Construction is underway for the Blackrock Shopping Centre in Dublin

Every member of the team has their own role and responsibility for the project as well as for personal growth and development. Problems are solved within the team, and team members are free to make decisions. This has facilitated a company culture in which we stimulate and challenge each other to become better and more creative.

We are curious to see what the future holds. One thing is sure: the can-do mentality with which Octatube was founded has not changed and will never change. If you would ask us, a project is most fun when it does not seem feasible. Realizing challenging architecture. ◀

Kickstarting your career as a structural engineer at a contractor

Getting your feet wet?

By: ir. C.R. (Caroline) Koks
Structural engineer at Heijmans

Working at a contractor can be an exciting way to start your professional career in the construction industry. At Heijmans, there are great opportunities for young structural and building engineers to become involved in all aspects of design and construction. In this article, recent graduate and old KOers board member, Caroline Koks, describes her first steps into the world of structural engineering.

Heijmans is one of the largest construction companies in the Netherlands and combines activities related to property development, construction, technical services, and facility management. Heijmans' project portfolio ranges from traditional residential developments to large office complexes, and from infrastructures such as roads and bridges to museums and datacenters.

The company does not only develop, build, operate, and maintain these projects: it also has a full in-house engineering department called Design & Engineering. Within this department, designers and engineers from different building and construction related backgrounds collaborate on the technical aspects of these projects.

One of the main advantages of working in such an in-house consultancy department is the opportunity to have a direct connection with the full breadth of knowledge the company has to offer. If you are an engineer or designer who likes to collaborate in a multidisciplinary environment, this might be the place for you.

The Design & Engineering department has close ties with the colleagues on-site to make sure anything that gets engineered is buildable. The engineers are involved within the whole process, from tender to design and from realization to maintenance and re-use. For example, as an in-house structural engineer, you would work on a concept design for a tender, collaborating closely with the design team and communicate your ideas through sketches and models with the architect, planner, cost-expert, etc. Later in the process, during detailed design, you might review the work of an external structural consultant on some of Heijmans' biggest projects, ensuring the structural safety is guaranteed. Working closely with colleagues from the planning and logistics department and realization, you also check whether a buildable, sustainable, and feasible design is being delivered.

In the execution phase, you will deal with challenges that were discovered during construction preparation. For example, we had to design the connection between the foundation piles and foundation beams that were both designed by different companies. The rebars 7Ø32 in the piles need to be anchored 1100 millimeter in foundation beams with a height of only 600 millimeter. The beam itself was heavily reinforced, so it was not able to anchor the rebar under an angle in the beam. We designed a solution with a higher quality of the concrete and steel plates at the end of the rebars. Due to a higher quality of the concrete, approximately half of the stress could be transferred into the concrete. To anchor the rest of the stress, steel plates are applied at the end of the rebars that result in an equilibrium between the tension stress in the steel plate and the compression stress in the concrete.

The department Design & Engineering also pays attention to the use of new technologies and innovation. The BIM team is constantly improving our digital workflow. We now first build a 3D digital "prototype" for many of our projects before we construct the design in the real world. A digital prototype, also known as the digital twin or BIM model, contains all the elements and specified information. Teams that are specialized in making point clouds scan our projects to obtain 3D data, and we use Virtual Reality for the review of designs.

Parametric design and engineering is another technology that is now finding its way into our office. We use these tools to optimize our structures, automate workflows, and find ideal building configurations. For example, it is used in the development of a residential tower.

Furthermore, we are looking into ways to implement these tools into, for example, project planning. Circularity is another topic within Heijmans that is getting a lot of attention. Our strategy is to build 100% circular in 2023! Among other things, we now start to measure circularity within various projects, we are developing our own circular office concept, and we are implementing material passports into the internal BIM processes.

Working for a construction company also means many of your projects actually get built. Your design and reviewing activities will be interspersed with site visits and inspections. This makes your workweek very diverse, and every day gives you new insights and new energy. Except for the design projects, we do not plan more than two weeks ahead, since we do not know what is coming. In one week, you can work on a tender of a residential complex, checking whether PV panels are possible on an existing building and design a solution for a problem on one of the large projects that Heijmans is constructing.

Figure 1: Slipform system at European Medicines Agency (EMA) (Photo: Rob Acket - Piktsjers)

Figure 2: New Amsterdam Court House (NACH) (Photo: KAAN architecten)

Projects
One of Heijmans' largest and most ambitious projects is the European Medicines Agency (EMA) new office building, which was just finished on the Amsterdam Zuidas (Header). EMA is responsible for the scientific evaluations and supervision of medicines for the benefit of public and animal health in the European Union. Heijmans formed construction consortium EMA with Dura Vermeer, to whom the Central Government Real Estate Agency awarded this Design, Build and Maintain project, to create a new conference center and office for the employees of this leading European Institute. This BREEAM "excellent" office with a gross surface area of 39,000 m^2 and a height of 81 meters, contains approximately 1300 workplaces. The major challenge was to construct this building in 18 months, where a building of this size and complexity would normally take around 38 to 40 months.

Piling works started in May 2018, and the building was delivered in November 2019. Since a regular design phase would take too long, it was cut into three parts; the core, facade, and finishing/furnishing. This way, it was possible to put piles in the ground and simultaneously work on the final design of other parts.

In order to meet the tight deadline, the concrete core was built using a slipform system, which operates on a 24 hours per day basis (*Figure 1*). This method ensured that the concrete core was finished before winter. In the meantime, the technical details of the steel structure were finalized. The slipform core grew approximately ten centimeters per hour, i.e., a floor per day.

After topping out of the core, the steelwork and facade commenced. During the final phases of the project, over 700 people were working on site.

Another interdisciplinary project is the New Amsterdam Court House (NACH) and is currently under construction. The former complex of the Amsterdam Court House was very outdated. That is why the largest court house in the Netherlands will have a completely new accommodation at the same location on the Zuidas with an office area, courtrooms, interrogation rooms, and an attached area (*Figure 2*).

The project is characterized by a goal-oriented approach with a focus on quality, but also by the special design: striking and functional with a suitably authoritative appearance. The open building offers employees and visitors a view of the city and allows passers-by a look inside the building.

The structural design has been devised from the user's point of view. Large spaces for the meeting rooms at the bottom and above the smaller spaces such as work and meeting rooms. From a structural point of view, the other way around would have been easier, but it is about functionality. In addition, large voids are designed, and this makes it challenging to construct the structure. Floors are carried by the walls on top of it, and in order to construct this, a lot of temporary structures are needed. Hundreds of scaffoldings are constructed to carry the loads of a structure that still has to be built (*Figure 3*).

Starter at Heijmans

At Heijmans, everyone starts their career as a Trainee. Based on your ambition, it will be determined whether you start immediately working in a specific position, or whether you will change your position three times over a period of a year. For me, it was clear that I wanted to work in the field of structural engineering, and since December, I am part of the team Method & Structure. However, I want to gain more practical experience, so in the upcoming months, I will visit several building sites to see how the projects that I have reviewed or designed so far are being realized. As a trainee, you get the opportunity to develop the skills you want and to work on projects / within departments you normally will not be able to. If you do not exactly have in mind where you want to start your career, you can rotate within one business unit or between different business units. For example, it may be that you first work on the realization of a project at a project location or regional office, followed by gaining experience at the head office in Rosmalen for six months during the acquisition phase of a project and at last get to work at one of our specialist business units.

In addition to a specific work field, you will also get the opportunity to develop your soft skills as a trainee. Together with your fellow trainees from the various business streams, you follow an educational training program that is spread out over one year. To ensure that you make a good start, you will be offered a combination of job-specific courses combined with training in areas such as project management, contract management, and communication. In addition to knowledge and skills, the traineeship pays a lot of attention to personal development. You have a mentor who guides you and who you can turn to for questions and advice. You have a lot of contact with other trainees within Heijmans during the training days and peer review meetings. You will also visit several projects together, so you can see live what your colleagues are doing. Through these contacts and various colleagues within Heijmans, you get to know the company and experience what suits you best.

You can start as a Trainee all year round. The Traineeship's training program starts twice a year: in February and in September. ◄

Figure 3: Scaffolding at New Amsterdam Court House (NACH) (Photo: David de Jong Photography)

Lynn Rietveld

Internship

By: Lynn Rietveld
Student Structural Engineering and Design

During the first quartile of my Master's, I decided that I wanted to do an internship. This plan became clear to me by noticing the knowledge of students that did do an internship. My search began at the educational office of the Built Environment, who directed me to the responsible teacher for internships. I learned that I had to find an internship by myself, so I started searching the internet.

This search led to a few possible companies. Because I did not adjust my résumé since the first year of my Bachelor's program, this needed an update. After I did that, I send an email to a company called Vericon. The next day I already received a phone call from Vericon that I could come for an interview. The internship interview resulted in an offer to do my internship there. However, before this interview, I send another two emails to Lüning and Aronsohn. From these two, Lüning approached me to also have an internship interview with them. At first, I doubted if I should do this interview because I already had an offer, but I decided to do the interview anyway. That was the right decision as I ended up choosing this company for my internship. The choice was based on the fact that Lüning is a company that specialized in Timber structures, which I found very interesting.

My internship started in the first week of February. I chose to work three days a week, to be able to follow a course on the remaining two days. The internship consisted of the everyday work of engineers in the company and a research project. The first day, my internship supervisor instructed me to work on an 'Autarkische woning,' which was going to be located at the Veluwe. They asked me to calculate a part of the structure in a design software called Dlubal. It took a while before I had some results, but in the process, I learned a lot. That was because the questions that I had were answered by an elaborate explanation. It was nice that I did not feel like I was interrupting, and everyone was accommodating.

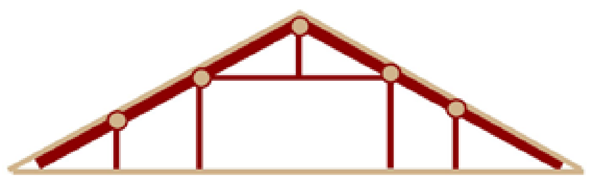
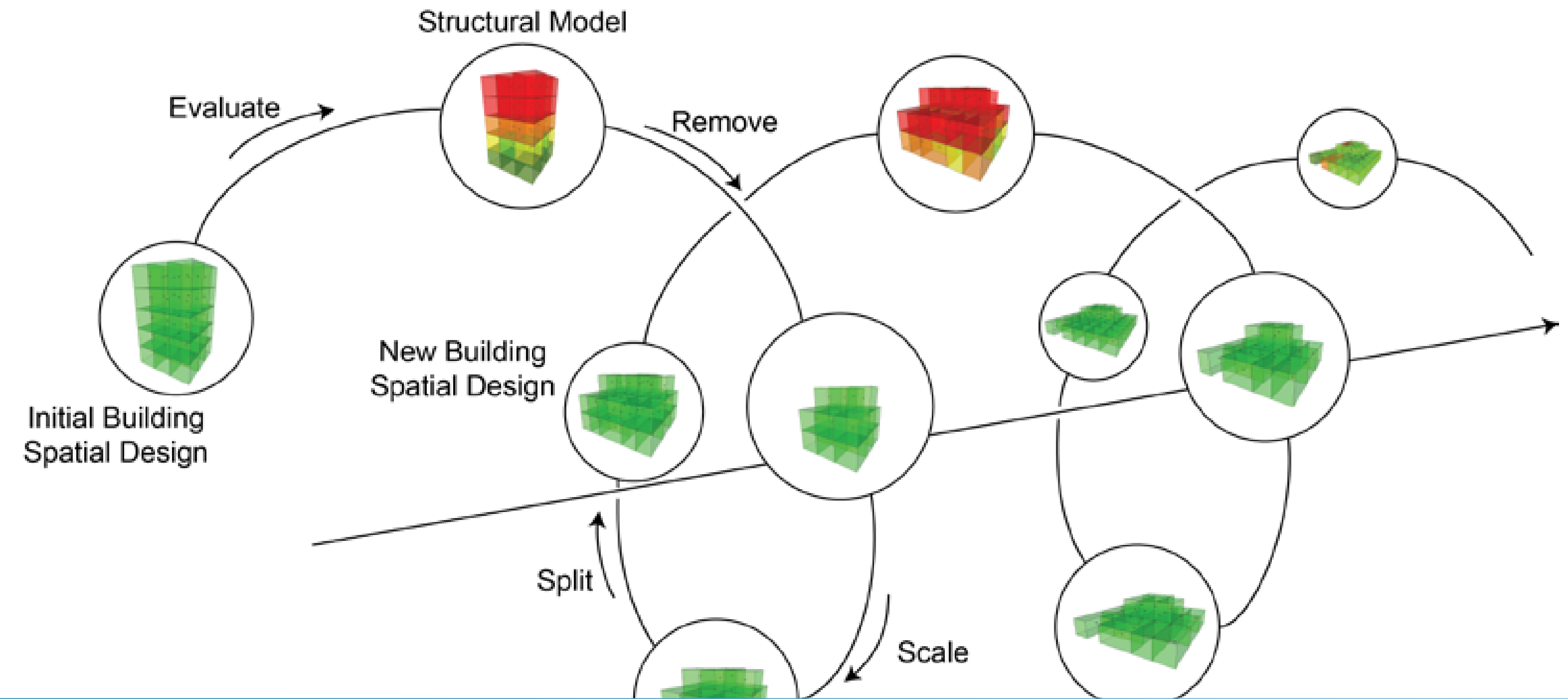


Figure 1: Front view of a rafter

I was involved in the project of the 'Autarkische woning' from the beginning, and I passed through multiple phase in the design project. For this project, I calculated a few rafters, taking into account deformation and load limits, see *Figure 1*. As the private party wanted to use whole logs for the structure of the dwelling, it was a challenge to limit the dimensions of the structural elements. I was involved in the discussions between the architect and the structural engineer as well. From this, I learned that structural engineers have a quite significant influence on the final design.

I also collaborated on a large project, which was the office building of HAVEP. For that project, I worked on the structure of a walking bridge in the building. In this project, I comprehended that for these kinds of structures, steel is needed in addition to the initially desired material timber.

To conclude, although the COVID-19 virus has made things a bit different and tough for me, I enjoyed my internship so far. Furthermore, as I believe that timber is a material that will be used more and more in the future, I think that the knowledge obtained through this internship will be precious in my future career. ◀



Master's Thesis

Heuristic Modification Procedures for Building Spatial Design Optimization

By: T.W. (Tomas) Snel MSc

Supervisors: dr.ir. H. (Hèrm) Hofmeyer, ir. S. (Sjonnie) Boonstra and prof.dr.ir. B. (Bauke) de Vries

The design process of a building can be described as "an iterative search process in which designers gather, generate, represent, transform, manipulate, and communicate information and knowledge related to various domains of design concepts" [1]. So, designers iterate over multiple design options and alternatives to find a design that meets all performance criteria to a satisfactory level. A correlation can be found between the amount of alternatives, or iterations, and the quality of the final chosen design [2], where a higher amount of alternatives correlates with a higher quality final design. Unfortunately, on average only three alternatives are considered in a normal design process. This is mainly due to the time constraints. Experts in the Architecture, Engineering, and Construction industry spend on average over a month to generate and evaluate a single design alternative [3]. This graduation project focuses on the rapid generation of early stage building spatial designs using a heuristic optimization approach.

In previous research [4] and [5], a foundation has been developed to start the graduation project. Hofmeyer & Davila Delgado [4] developed a toolbox which includes representations, shown in *Figure 1*, of an early stage building design, a FEM implementation capable of calculating the structural performances, and a procedures to optimize the structural performances. Boonstra et. al. [5] elaborated the toolbox and added a resistor-capacitor method to calculate thermal energy loss and developed evolutionary algorithms to optimize building spatial designs.

It can be stated that the toolbox as mentioned in itself is not capable of optimizing designs. It only provides performance values of the design and the spaces within the design. The optimization is included in the evolutionary algorithms, which optimizes designs using the results from the toolbox. While evolutionary algorithms can be powerful, they have an intensive computation time. Hofmeyer & Davila Delgado [4] proved that heuristic algorithms outperform evolutionary algorithms when only a couple iterations are requested.

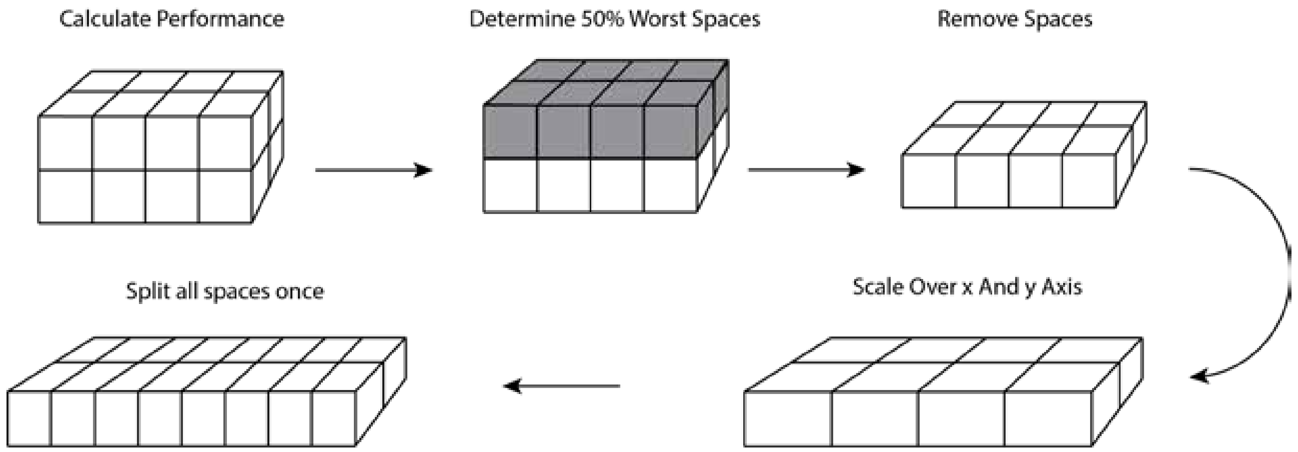


Figure 1: The initial heuristic procedure to optimize structural performances a building spatial design

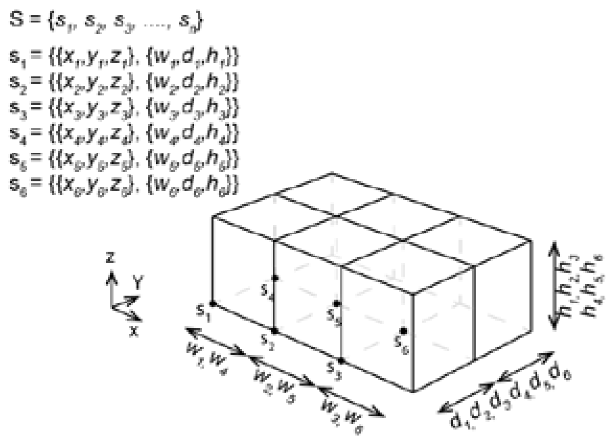


Figure 2: The building spatial design representation 'Movable-Sizable' as used for this study

Elaborating on the initial heuristic procedure and the aforementioned toolbox, an improved heuristic procedure is developed in C++, as shown in *Figure 3*. This research focuses on single disciplinary optimization, since the procedure should be capable of optimizing a single discipline before complex situation of multiple disciplines are introduced. Infrastructure and algorithms to apply multi-disciplinary optimizations are implemented for future research.

To generate new designs, the structural performance is defined as the total amount of strain energy and the building physics performance is defined as the thermal energy loss due to heating and cooling of spaces. The constraints for the procedure are set as follows: equal volume, equal space count, no overlap between spaces, and no floating spaces.

The heuristic procedure in *Figure 3* operates as follows: an initial design is required from which alternative designs are generated. The performances of the initial design are then calculated with the toolbox as developed by Boonstra et. al[5]. The following procedure is then divided into three sub-procedures: performance evaluation, space ranking, and building modification. For all stages, multiple parameters are developed and elaborated in order to interpret performances with different approaches, all resulting in different design solutions.

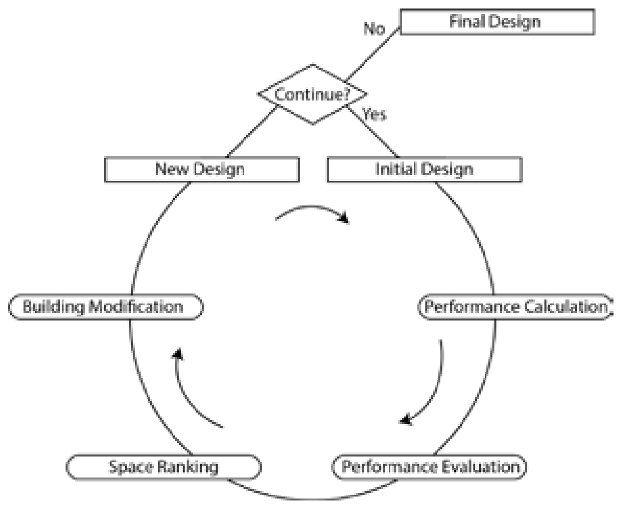


Figure 3: Heuristic Cycle as used in this study

The three sub-procedures are evaluated with a parameter study. This research shows that the procedure is capable of optimizing a building spatial design for either structural or building physics performance. For the performance evaluation procedure, it is shown that structural evaluation should rate spaces from best to worst as highest to lowest strain energy, as can be seen in *Figure 4*. Building physics evaluation should rate spaces from best to worst as lowest to highest thermal energy loss. Furthermore, it can be stated that combining a geometrical clustering approach with the evaluated performances is capable of improving a building spatial design for both disciplines. The space ranking in this study is straightforward since only one discipline is considered at a time. For the building modification sub procedure, the most effective parameters are those that move a building spatial design towards the most optimal shape for the given discipline. For structural optimization, this means a one storey high, square floor plan. Building physics optimization finds the best solutions when the modifications move the building spatial design towards a cuboid design.

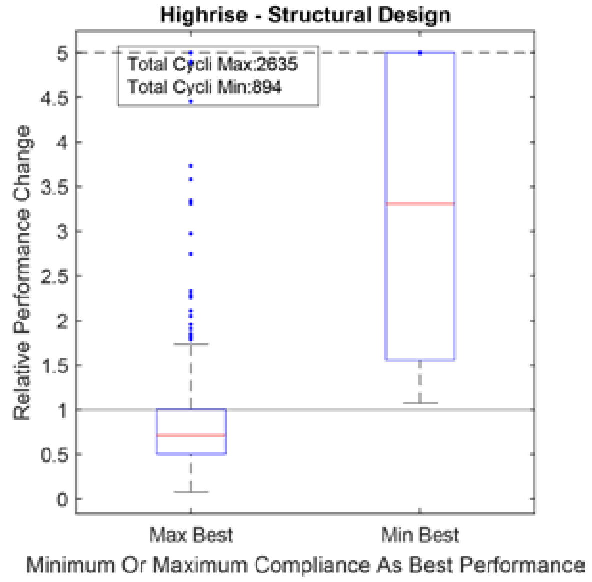


Figure 4: Structural optimization, highest or lowest space strain energy

While some conclusions and results of this study might seem straightforward, it was required to confirm that this procedure is capable of finding improved solutions to single disciplinary problems. This graduation project was developed as contribution to the PhD research from S. Boonstra (Eindhoven University of Technology). ◀

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Master's Thesis

Ductility analysis of aluminum alloy connections

By: ir. T.J.M (Tim) Schellekens MSc

Supervisors: Prof.dr.ir. J. (Johan) Maljaars, Prof.ir. H.H. (Bert) Snijder, Ing. J.M. (Johan) van Loon

Ductility is an essential aspect of designing safe and reliable structures and defines to what extent a structure can plastically deform until it collapses. The ductility depends on the geometry and material properties. The essential material properties include the ultimate strength to 0.2% proof stress ratio ($f_u/f_{0.2}$) and the strain at rupture. The ratio $f_u/f_{0.2}$ is relatively low for many heat-treated alloys. This thesis considers the influence of this ratio on the ductility at the structure level for aluminum alloys.

When welds are applied at heat-treated aluminum alloy members, the mechanical properties in a zone around the weld are affected by the heat input of welding. The material inside this Heat-Affected Zone (HAZ), tends to lose its strengthening effects obtained by previous heat treatments. This affection results in degrading strength properties and is usually associated with a higher $f_u/f_{0.2}$ ratio as compared to the base material, and hence, it may positively affect the ductility of a structure. On the other hand, the extent of the HAZ is relatively small as compared to the structural dimensions. Since the HAZ has lower strength than the base material, the extent of the plastic zone may be limited, resulting in a relatively brittle performance at the structural level. Currently, proper guidelines are present in the available standards related to the strength of aluminum alloy connections. However, clear guidelines regarding ductility performance are lacking. A literature review and an experimental study were performed to investigate the effect of welding on the ductility performance. Furthermore, a foundation has been created for a numerical model to easy and quickly examine the influence of welding on several aluminum alloy connections.

The outcome of the literature study show that welding of heat-treated aluminum alloys will result in poor ductility performance when a transverse weld is applied in the tensile zone of a member. Therefore, several studies recommend avoiding transverse welds in tensile zones where possible. In the field of ductility of longitudinally welded members, extensive studies are still limited.

By conducting the experiments, the performance of longitudinally welded cruciforms, transversely welded dogbones, and bolted joints are examined. 3D-visualizations of the three different specimens are illustrated in *Figure 1*. The longitudinally welded cruciforms contain a weld over

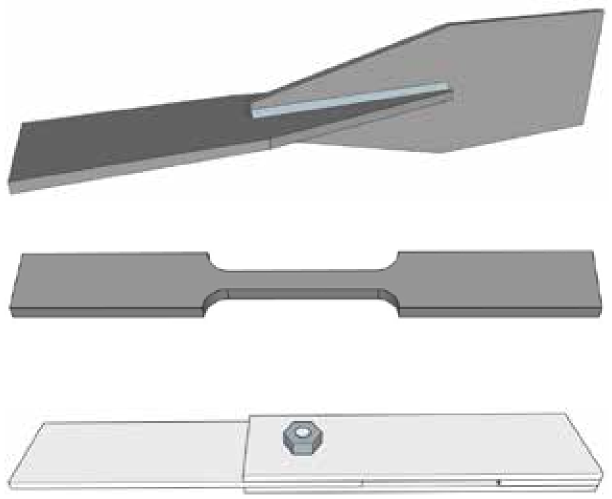


Figure 1: Schematizations of the different specimens

the longitudinal axis of the member. Depending on the size of the member, the HAZ extends partially or entirely over the width of the member. By applying a transverse weld on the dogbone specimen, a fully heat-affected cross-section is obtained.

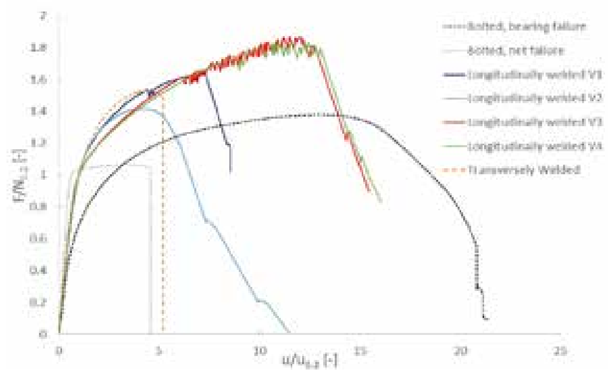


Figure 2: Normalized load-displacement plot of the experimental results

In *Figure 2*, a normalized load-displacement plot of the experimental results is shown, where the results are normalized by the elastic limit load and the corresponding elastic limit deformations. The results of the experiments show that transverse welds indeed failed by minimal normalized deformation for a heat-treated aluminum alloy 6082T6. Furthermore, the longitudinally welded cruciform variant 2, with a limited member width, showed relatively small deformations up to failure. In both cases, the critical cross-section was fully heat-affected. The longitudinally welded cruciform variant 1 contained a larger member width and hence a partly heat-affected zone. For this variant, a better ductility performance is experienced by larger deformations. The welded cruciforms variant 3 and 4 resulted in the best ductility performance. These variants were dimensioned based on failure in a plate consisted out of a cold worked aluminum alloy 5083H111, and were therefore not affected by welding. The bolted experiment results show that net section failure leads to an expected poor ductility performance. The deformation capacity values of the fully heat-affected members were in the range of this poorly engineered bolted variant. The bolted variant which failed by bearing showed the best ductility performance of all tested connections. That this variant showed the best performance was also noticed from the pictures of the failed specimens. A picture of the bolted specimen failed by bearing and the failed longitudinally welded specimen is shown in *Figure 3*.

Figure 3: Failed specimens (bearing failure and longitudinally welded variant 1)

A numerical model is developed in order to easily and quickly investigate a large amount of different aluminum alloy connections in the future. These numerical models are based on the experiments and are validated with the corresponding experimental results. The implemented material models were calibrated based on the dogbone experiment results. With the established numerical model, a good first approach is obtained of the experimental results of the welded cruciforms with failure in the HAZ as shown in *Figure 4*. In the numerical analysis, a quite similar failure pattern is observed as in the experiments, showed in *Figure 3*. However, more research into the fracture model and behavior is required to improve the numerical model. This holds especially for the numerical models of the welded cruciform with failure in the cold worked plate. By these models, yet not a proper approach of the experiments is obtained.

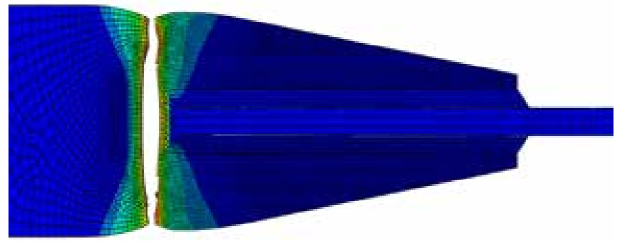


Figure 4: Plastic strain contour plot of the FEM model of the longitudinally welded cruciform V1

From this research, it is concluded that when a member is heat-affected over the full critical cross-section, it will result in relatively low ductility performance of the structure. This applies to both transversely welded and longitudinally welded connections. Furthermore, it is concluded that the changed ratio $f_u/f_{0.2}$ did not lead to a positive effect on the overall ductility performance. It is experienced that the extent of the zone of changed material properties had a more significant impact on ductility performance than the material properties themselves. Finally, it is shown that a low $f_u/f_{0.2}$ ratio close to 1.0 did not lead to early failure by a possible inability of stress concentrations redistribution in a bolted joint suffering from bearing failure.

Since transversely welded members contain a fully heat-affected critical cross-section, it is recommended to avoid transverse welds in heat-treated aluminum alloys where possible. For longitudinally welded members, it is recommended to apply a member width larger than the extent of the HAZ in order to ensure not the entire cross-section is heat-affected. In this case, a larger ductility performance will be achieved. Furthermore, it is recommended to ensure that failure will occur in a cold worked or fully annealed finger plate. Since this plate is not affected by welding and usually contains a high $f_u/f_{0.2}$ ratio, significant plastic deformation can occur before failure. For bolted connections using an aluminum alloy with a very low $f_u/f_{0.2}$ ratio close to 1.0, it must be guaranteed that bearing failure occurs before net section failure occurs. This is important since net section failure will result in minimal plastic deformation. ◄

Penetrated Circular Hollow Section X-joints in steel

By: Marc Nijenhuis

Supervisors: prof. dr. ir. H.H. (Bert) Snijder, dr. ir. P.A. (Paul) Teeuwen (Witteveen+Bos), dr. ir. H. (Hèrm) Hofmeyer

Steel circular hollow sections (CHS) are widely used for structures in the civil industry, such as mooring and offshore structures. A common joint in these structures is the X-joint, in which two coaxial braces are connected to either side of the chord, the main structural element (with the biggest diameter and/or wall thickness). In most cases, the braces are welded to the chord, without piercing it at the intersection. However, in civil structures, another type of X-joint for circular hollow sections is frequently used. These joints are referred to as penetrated CHS X-joints in which the brace passes through the chord, as shown in *Figure 1*. Although extensive guidelines and rules are available for X-joints in which the braces are welded to the chord, there are no specific design rules available for this type of penetrated CHS X-joints.

The aim of this graduation project is to gain insight into and be able to predict the behavior of penetrated CHS X-joints. Since it appears that the design rules for CHS X-joints, as provided in the EN 1993-1-8, do not apply to penetrated CHS X-joints, a suggestion for an adjustment or addition to the existing design rules will be provided.

Penetrated CHS X-joints are frequently applied by Dutch engineering firms in civil structures, little academic research has been done on these joints. Therefore, literature research into a similar connection, plate-to-structural hollow sections (SHS), has been done. Analogous to the penetrated CHS X-joints and their welded equivalents, the behavior of through plate joints is compared with their corresponding branched plate equivalents. It has been found that the former has a capacity of more than double the capacity of their equivalent branched plate joints. Furthermore, it is concluded that, when the effective chord length is at least ten times the chord diameter, the effects of the chord end boundary conditions can be neglected.

In a similar way, a numerical model will be created in this graduation project of both a penetrated CHS X-joint and its 'standard' equivalent in which the brace is welded to the chord. To gain insight into their structural behavior and the possible differences between both joints, a numerical parameter study will be conducted in which applied loads, geometrical dimensions, and material behavior will be varied. If possible, the effects of boundary conditions will be excluded by applying an effective chord length of at least ten times the chord diameter, as concluded from previous research.

By varying the load cases, the different failure mechanisms of the joints are identified, and a failure map based on material and geometrical properties may be constructed. For the geometrical parameter study, several dimensional ratios will be adopted and varied. By varying the brace width-to-chord width ratio 'β' and the chord diameter to thickness ratio '2γ', a relation between the behavior of the joint and the dimensions of the brace and chord may be shown.

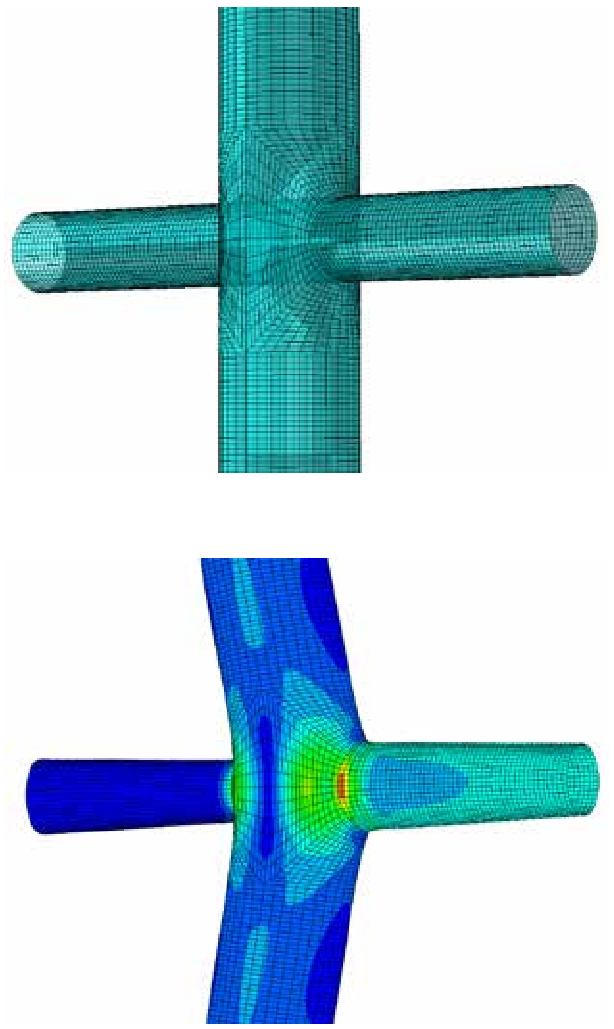


Figure1: Penetrated CHS X-joint

While varying the load cases and geometrical properties, a parametric three-dimensional FEA will be conducted. To prevent the FEA to become computationally too heavy and user-unfriendly, linear elastic material behavior will be imposed. To show the influence of the material behavior on the accuracy of the results, additionally, the material model is varied once. In this study, linear elastic, elastic-perfectly plastic (bilinear), and elastic-plastic with linear hardening material behavior will be evaluated.

By analyzing the results of the parametric study and the different failure mechanisms of both joints, a suggestion will be made for adjustments and/or additions to the existing design rules for CHS X-joints. Presumably, additional rules for the design of penetrated CHS X-joints will be required. The aim of this graduation project is a clear and uniform set of design rules for penetrated CHS X-joints in steel. ◀

Stress-constrained topology optimization for 3DCP

By: Irma Bouw

Supervisors: dr. ir. H. (Hèrm) Hofmeyer, ir. S. (Sjonnie) Boonstra, dr. ir. R. J. M. (Rob) Wolfs

Topology optimization is an engineering method that is aimed at finding the optimal distribution of a certain amount of material within a given design domain. As such, topology optimization might, for example, be used to obtain higher strength-to-weight ratios of structural elements by preventing the presence of redundant material in a design domain.

Initial publications on the topic of topology optimization mainly considered the maximization of a structure's stiffness for a given amount of material. However, these stiffness-based methods do not guarantee that the stresses in the final design meet their limits. The result is an optimized design that still requires significant post-processing to assure its structural integrity.

In order to include strength, rather than stiffness requirements in the topology optimization process, a slightly newer point of focus is the development of stress-constrained volume minimization algorithms that result in designs that directly fulfill strength requirements, while minimizing the amount of material in the design domain. These algorithms might be used to develop design-for-manufacturing tools, in which an optimized digital design can be directly manufactured from its digital model, without the need for further post-processing. A possible application might be found in the field of 3D concrete printing (3DCP), where a digital model could be send directly to the concrete printer. However, direct application of optimization results into the 3DCP process requires the presence of several material- and manufacturing constraints in the optimization algorithm. There are many different methods to perform the stress-constrained volume minimization. To find out which optimization method has the highest potential to be used in the 3DCP industry, the current research focuses on the comparison of several existing and adapted topology optimization methods. The main focus of the comparison is on the material behavior of concrete, which has asymmetrical strength limits in tension and compression, and whether these properties result in suitable geometries in the optimization procedures.

Three optimization methods are considered in this thesis, which are referred to as: (i) Traditional Topology Optimization (TTO), which refers to the currently most widely used density-based type of optimization methods with mathematical

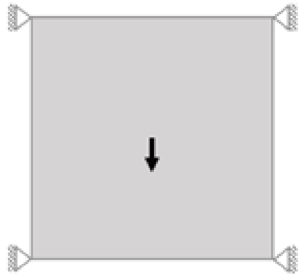


Figure 1: Design domain and boundary conditions

solvers; (ii) Bi-directional Evolutionary Structural Optimization (BESO), which provides pure black-and-white solutions based on ordering of the element sensitivities; and (iii) Proportional Topology Optimization (PTO), which is a relatively new method with a fully heuristic and non-gradient based material distribution algorithm that distributes the material proportional to the element stress values. For each of the three methods, a stress-constrained volume minimization algorithm was written in MATLAB, after which simple benchmark simulations were performed. For some typical benchmark problems in which either tensile- or compressive structures can be formed, the simulation results show that PTO and BESO tend to provide tensile structures, while TTO tends to provide compressive structures (an example in *Figure 2*). Due to the higher compressive- than tensile strength of the concrete material, the compressive structure requires less material (less structural volume) to fulfill the strength requirements compared to the tensile structures. Consequently, it is stated that the TTO method provides more optimal solutions than the BESO and PTO algorithms. Therefore, TTO might be considered as a more suitable tool for 3DCP design-for-manufacturing tools, compared to PTO and BESO.

In my thesis, the statement that TTO provides the most suitable optimization results for 3DCP applications will be worked out in more detail. Subsequently, the stress-constrained TTO algorithm will be extended from its current 2D environment into a 3D environment. Furthermore, possibilities to implement manufacturing constraints or a print-path into the developed algorithm will be briefly investigated. All in all, this research will give a basis for the further development of a design-for-manufacturing tool for 3DCP. ◀

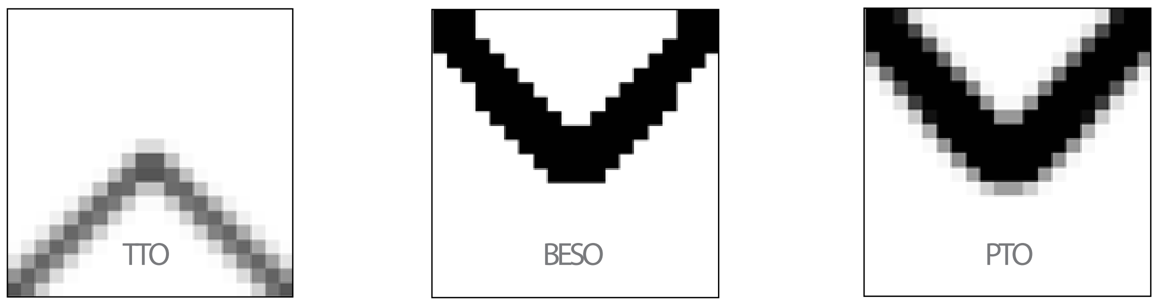


Figure 2: Results stress-constrained volume minimization for different optimization methods

PhD update

Quality control of 3D printed concrete

By: ir. D.H. (Derk) Bos
PhD candidate 3D concrete printing

3D printing or additive manufacturing of concrete structures allows for more efficient material use, freedom in design, and a safer and automated construction process. In the beginning of the innovation, the technique has relied mainly on trial and error, which has resulted in the validation of the applicability of the method. Over time, models have been created that model the fresh and hardened state of printed concrete and allow us to study the influence of various parameters on the printability and buildability of the object. The strength and stiffness development is tested over time by means of uniaxial and triaxial compressive tests as well as ultrasonic pulse velocity tests on extruded material. These material properties are mostly determined by the interdependency between the material and the system up to extrusion. Therefore, the current research aims to understand the parameters that determine the material behavior at extrusion.

To control this quality, a better understanding of the relationship between the process and the material has to be built. Concrete is a shear-thinning material, which means the strength and stiffness drop when a shear load is applied. When not in shear, the material properties develop as a function of time and temperature. Since the material is pumped through a hose and forced through a nozzle, it is expected that the shear-thinning behavior largely determines the properties of the extruded material. Furthermore, temperature is introduced to the material due to friction, and the material might take up to several minutes to be transported to extrusion. This means that the extruded material properties are highly influenced by the system, which makes it necessary to study them together. To do so, two major steps have to be taken.

Figure 1: Viskomat XL - Rheometer for mortar and fresh concrete (left)
Figure 2: SLIPER – Sliding Piper Rheometer (right)

Firstly, the behavior of the material has to be captured in a material model. This model is created by conducting physical experiments and comparing them to numerical models. Examples of physical experiments are the Viskomat XL and the Sliding Pipe Rheometer shown in *Figures 1 and 2*. For the numerical simulation, a Computational Fluid Dynamic (CFD) approach is applied. The material properties in the numerical simulations can then be changed until the same results are obtained for both the physical and numerical experiment. The risk here is that the numerical model does not accurately describe the physical experiment, which would result in a wrong material model. To reduce this risk, the material is exposed to various testing conditions as well as various testing equipment.

Secondly, the material model can be applied to various parts of the printer. This will result in the material properties of the concrete at extrusion, which is an important input parameter for further analyses on the quality. By varying the input parameters, the model can be used for more than just that. For example, to understand what material properties are desired for a certain printer, how printers should be developed for a better product, and how printers should be operated to maintain a certain quality.

Once a valid model is created, the quality of the material can be guaranteed, which creates both safer structures and reduces the environmental impact because more accurate prediction of material properties allows for further optimization of the structure and therefore reduces the material need. ◄

Davide Leonetti

New on floor 9

Interview with: Davide Leonetti
Assistant Professor in Steel and Aluminium Structures

By: Tom Diks and Evelien Dorresteijn
Editors KOersief

In every edition of the KOersief, a new member of the staff on floor nine is introduced. This time, Tom and Evelien have interviewed someone who has actually been around for a while, but recently moved to the new position of Assistant Professor in steel and aluminum structures: Davide Leonetti.

Where are you from?
I am from Naples, Italy. Well, actually from a small city just outside Naples, Caserta. For my study, I moved to Naples. After I finished my Master in Naples, I moved to the Netherlands.

What are your hobbies?
I brew beer with a colleague of mine. We brew three or four different types of IPA. I also love skiing, I have done this since I was 15, but unfortunately this winter was not a good one for skiing. I also love to cook pasta, pizza, bread, and desserts. Like a typical Italian.

What is your career path so far?
First, I did my Bachelor and Master in mechanical engineering in Naples. For the Master, I choose the track structural design and production, with the focus on the railway application. For my Master thesis, I did a research on the strength of railway switch maneuvering system. Due to the use of new high speed trains in Italy, the devices for locking and move railway switch rails had to be rechecked on higher dynamic loads due to the passage of faster trains. After I worked for a couple of months at the University of Naples on the same subject, I did a PhD at the chair of steel and aluminum structures, modeling the fatigue strength of welded and riveted joints for bridges. Even though I still have to defend my PhD in June, I already applied for Assistant Professor in steel structures at the University of Eindhoven and now I am working here. As an Assistant Professor, I will focus on the research part of steel structures and structural monitoring. This will be implemented in existing courses for students in the future, I hope to bring new ideas to be applied in the education.

Why did you choose to do a PhD at the TU/e?
After the Master, I definitely wanted to do more research and go deep into some subjects. This would be impossible at an engineering company, therefore, I decided to start a PhD. I was looking for a PhD on fatigue and fracture mechanics, that would also include the application of probabilistic methods. I could find this in the PhD position offered here, in Eindhoven, and I really liked it. Besides, I liked the research group of Structural Engineering and Design. The group grew very much in the last four years.

What is the most beautiful aspect of Structural Design?
Structural design as a discipline has a strong structural relevance. As an engineer, you have a big responsibility to make structures safe. At the same time, I see it as some sort of art. In a sense that you have to make use of the studies you did, and of your experience to come up with your own sensibility to see how a structure reacts on the external loads. The numbers are another story, but if you really got the essence of designing and understand how a structure behaves, that is an art.

What is your preference: steel or aluminum?
In general, aluminum is lighter but less stiff. It's hard to say, but let's say steel, it pays my salary. ◄

Multiple Day Excursion Committee
Every year an excursion to a destination in Europe is organized. Last year a group of KOers-members visited Bucharest.

Bram van Rijssen
Iris Cornelissen
Wendy Peters
Monica Suijs
Anne Derks

Hello, my name is Bram, a first-year master student. This year I helped to organize the KOers multiple-day excursion (MDE) to Madrid. It was my first time attending a committee, and I was named chairman of the committee.

Joining a committee was exciting and a lot of fun. Organizing such a big event is an ongoing process with a constant debate, ups and downs, and decision making about the best option in order to give the MDE attendees the best experience during the trip.

For my first time as chairman, I had to get used to the role in the committee and get a bit familiar with the process. As a chairman, it is important to guide the process correctly in order to retain an effective way of working together. It was very educational to work with a group of individuals who all have their own way to tackle challenges. In the end, I had a lot of fun and would definitely recommend joining a committee.

Study Trip Committee
The goal of this trip is to get in touch with other cultures, architecture history and special structures.

Tom Diks
Timo Frielink
Anke Leemans
Linda Versteegh
Sue Ellen de Nijs

Digital Concrete Committee
The digital concrete committee helps with the organization of the 2nd RILEM International Conference on Concrete and Digital Fabrication in July 2020 at the TU/e.

Amy Hendriks
Jelle Versteege
Leonie van der Molen
Tom Diks
Hidde van Wezel
Pamela Schippers

KOers Committees

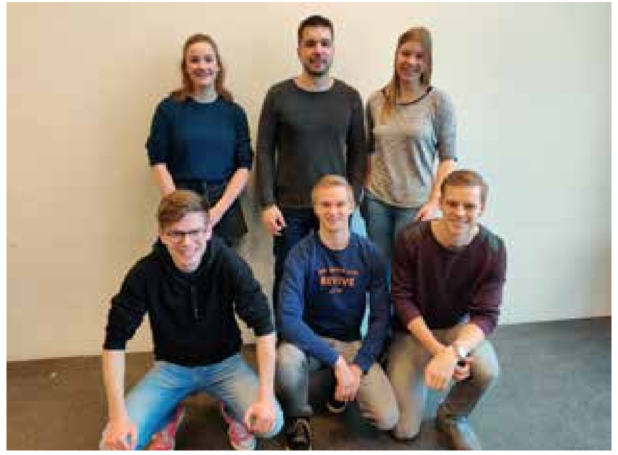
KOersief committee
The KOersief is a structural design magazine that is made by students. It contains articles about projects, graduation reports and other topics that have something to do with structural engineering.

Olaf Vens
Laura Dings
Tom Diks
Pamela Schippers
Femke Hermans
Bart van der Born
Leonie van der Molen
Pieter van Loon
Maikel Brinkhoff
Evelien Dorresteijn

My name is Tom Diks and I have been a member of the KOersief committee since September 2019. I felt right at home at the oldest KOers committee. If you come up with a good proposal for a specific article, there is always support for that. We also move with the times by publishing more online.

Because the members do all this in their spare time, you notice how passionate everyone is. It is great to have the opportunity to see all kinds of different companies. Recently, I had a nice interview in the field of building acoustics, which resulted in a very interesting article.

I am therefore very proud of the first edition that I was able to participate in. That many more may follow!



BetonKanoRace Committee
The BetonKanoRace is a yearly event where students of different universities and colleges race against each other in (homemade) concrete canoes. Special care is put into the innovative-canoe.

Bas van den Beuken
Jelle Versteege
Jeroen Spierings
Joes Sloots
Marijke Veenstra
Willem Bouwsema
Marc Nijenhuis
Femke Heuver

Activity Committee
The Activity Committee, a new committee for KOers. Organizing a Pubquiz, a Design Challenge, and an upcoming competition.

Mike Veenhuis
Bas van den Beuken
Marc Nijenhuis
Jef Verstegen
Olaf Vens
Hidde van Wezel

KOers Puzzle

By: Pieter van Loon, Derk Bos, and Denise Kerindongo
Creative KOers members

Growing a Timber Tower

Eindhoven has some timber towers coming up on its horizon with the concept design of the Dutch Mountain finished. The Dutch Mountain project is envisioned to be two timber-based towers of respectively 110 meters and 150 meters high, situated between our beloved Vertigo and the railway. High rise towers like these easily have a gross floor area of $1000m^2$ per floor, requiring roughly $400m^3$ of timber to produce all the necessary mass timber elements for such a story. Totaling about 70 floors, and a large auditorium of an additional $10,000m^2$ as well, that leads to a whole lot of timber required. But where does all that timber come from?

Pieter did some research and ended up with a paper about forestry from Wageningen University and Research [1], giving him insight in forestry and timber production. Pieter has learned that forests are divided into patches that undergo a cycle of three distinct phases. Phase one is growth, trees are planted in a cleared patch, and the trees get to grow unhindered. Phase two is the thinning phase. In this phase, trees are occasionally cut down or trimmed to maintain an optimal growth rate for the forest. Phase three is the harvest phase. In this phase, the patch is cleared completely, and all the trees will be cut down. After phase three, phase one can start again. A forest for timber production has the following properties:

- Growth phase duration = 20 years
- Time between thinning a patch of forest = 10 years
- Time after which a patch of forest is completely harvested = 40 – 80 years
- Yield from thinning per year = $60m^3$/ha forest thinned
- Yield from phase three harvesting per year = $180m^3$/ha forest harvested

With the listed forestry characteristics and the estimated gross floor area of the Dutch Mountain, the minimum required managed forest area can be calculated. Can you help Pieter with the following questions?

1. **What is the minimum area of forest that is required to produce enough timber for projects like the Dutch Mountain on a yearly basis?**
2. **Is this minimal area smaller or larger than Eindhoven?**

References:

[1] E.J.M.M. Arets et al., Global wood Production, Assessment of industrial round wood supply from forest management systems in different global regions, Alterra report 1808, page 17.

Bending VS Buckling

Consider the two structures given in *Figure 1*, all made of a material with Young's modulus E, yielding resistance f_y. Furthermore, all members are square with sides h. For members in compression the Euler buckling $2EI/L_{cr}^2$ load and the compressive stress should be considered, and for members in bending the bending stress should be considered. In which combinations of f_y, E, h and L does structure 1 have a larger capacity than structure 2?

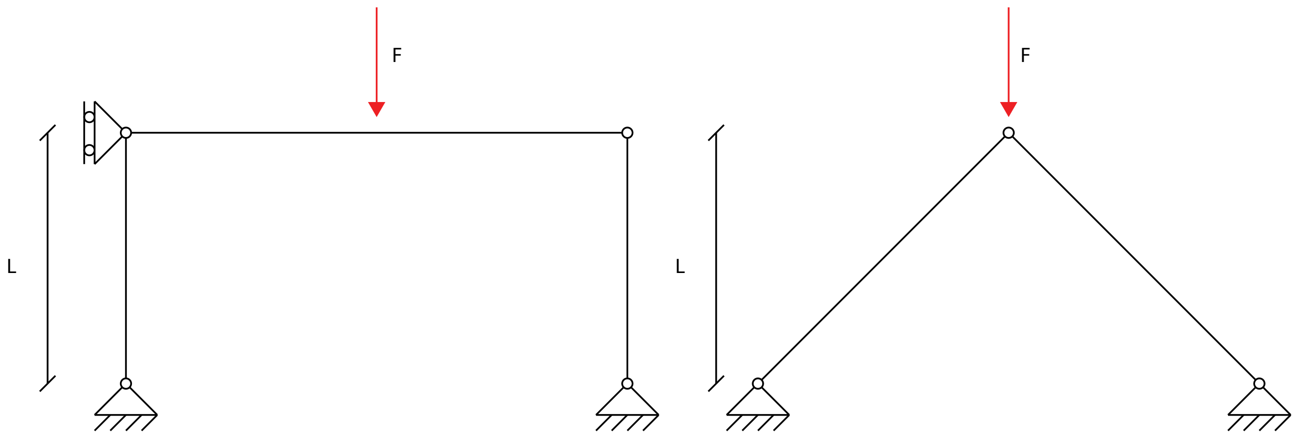


Figure 1: Two structures

Nonogram

The puzzle is solved by coloring the squares. Every number represents a **sequence** of colored squares. If there are more than 2 numbers, there must be at least one blank square between each sequence. The **order of the numbers** is important too. The order in which the squares need to be colored is the same as the order in which the number are noted. If you know for sure that a square is supposed to stay blank, a cross can be put in that square.

	5	1 3	1 2 3	5 3	3 4 3	4 4 3	5 2 3	5 4	7 5	14	6 6	7	11	11	9
4															
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1 5 2 3															
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2 4 2															
11															
9															
7															

Every edition a new puzzle, can you find the correct answers? Try, and send them to koersief@koerstue.nl, this is possible until the 21st of december 2020. Good luck!

Column

Default, one and a half meter!

Hans Lamers

We are raised to be brave, to defend ourselves, against all kinds of wild animals. We fought tigers, bears, mighty mammoths, crocodiles, buffaloes, and other large animals with spears, bows and arrows, and afterwards gunpowder. Smaller animals like insects are more annoying, buzzing mosquitos, itching fleas and lice, clouds of grasshoppers who eat our yearly food supply within less than an hour. These small creatures come in large numbers, so a sharp spear or a fast bullet is rather useless. We need poison to kill these bastards. Smaller creatures like bacteria are invisible to us but can be as lethal as hell. The Plague in the fourteenth century killed a third of all Europeans, millions of people! Even smaller enemies are viruses, like Influenza, Smallpox, Herpes, Rubella (rodehond), Measles, Rabies, Ebola, and the Zika virus. More recently, a new troublesome pandemic virus with the 'royal' name Corona has spread, undermining our worldwide society. No medicine, no vaccine (yet). Just one and a half meter social distance and washing the skin from our hands.

We have to fight a different war without superior weapons to defend ourselves. The government tells us to hide nervously at home to avoid contagion and, by doing so, trying to stay away from hospitals and mortuaries. Society has to reflect on simple things like meet and greet, shopping, having a haircut, and public transport. Our buildings are not ready for a sudden demand for social distance. Elevators, stairways, corridors, open office spaces, theatres, restaurants, or stadiums bring people to close to one another. All kinds of temporary features are needed. Many of them consist of transparent screens to avoid contact with minuscule airborne droplets carrying the Coronavirus. Will the design of future buildings change thanks to the Coronavirus? It is not clear how long this virus wants to cling to our delicate lungs, is it? Do we get wider corridors, new concepts of ventilation systems with a lesser chance of contagion, self-cleaning door handles, or maybe building concepts with complete voice control functionality? For now, the polymer business is doing very well selling transparent polycarbonate and acrylic glass, protective masks, Latex gloves, plastic goggles, and aprons (schorten). Funny, the past decade, plastics have got a worsened reputation, for example, as a result of the 'plastic soup' in the ocean. Now the same so often questioned plastics are our best friends, our life-savers. Plastic is the 'royal' material against the 'royal' Coronavirus. Priorities change instantly when short term threads emerge. Despite this time of hardship, many victims and economic misery one positive feeling thrills me; mankind is undeniably still a part of our blue planet's versatile nature.

Colophon

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