STUDIEVERENIGING KOers
CONSTRUCTIEF ONTWERPEN

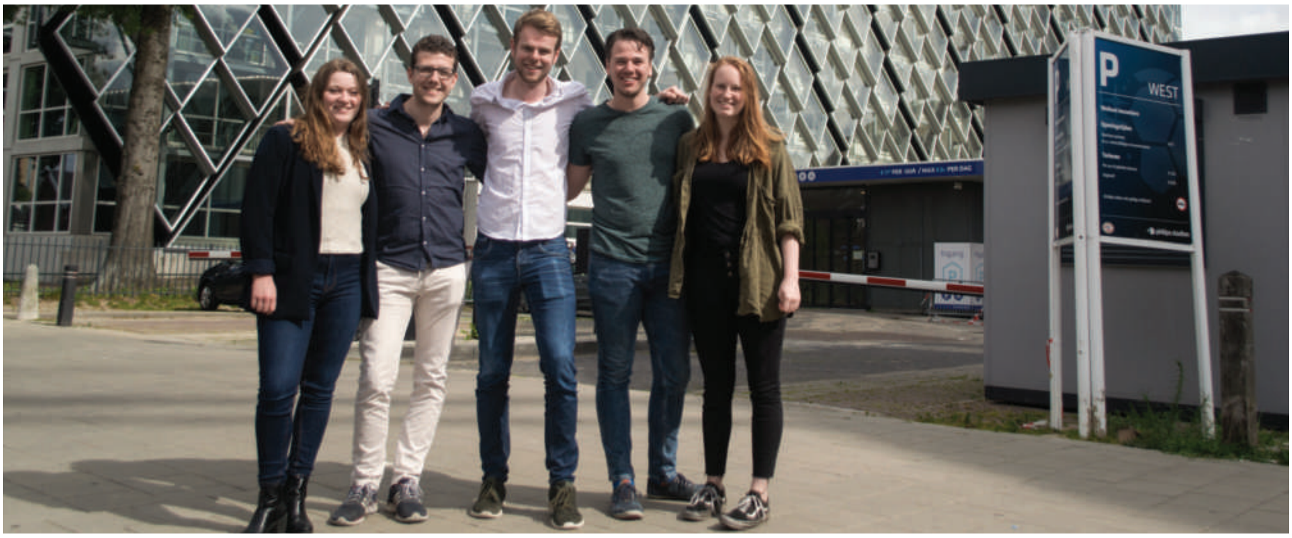
Kersief

EDITION 108
March 2019

Innovations

PATCH22, Amsterdam | Beeldmateriaal: Luuk Kramer

Editorial



Dear reader,

Innovation is a broad and interesting subject for basically any industry. It is not only what keeps our jobs and studies interesting, it is also a necessary requirement for further development. Fortunately, universities and companies from all over the world are working together regarding an innovative future. With a rapid growing world population, evidently, the building industry constantly needs to develop and innovate.

In order to keep up to those innovations, such as additive manufacturing, 3D-concrete printing, and the digitalization of the construction site, a new generation of Eurocodes is in development. In this edition of the KOersief, you can read about of these innovative initiatives.

Furthermore, futuristic structural innovation processes or materials are in development. For instance, reinforcing a building against earthquakes using carbon fiber strand rods or creating stunning pavilions by making use of Arachnid design.

But why should we limit ourselves to our little cozy planet? In this edition of the KOersief you may also read an article about 'Martian concrete'. This might be a new innovative building material for the neighbor planet!

In addition to these interesting articles on innovation, you can read several articles written by KOers members and employees of the unit Structural Design. Because in addition to the innovative developments already ongoing, the future of innovation lies in the hands of our own university. We should be pleased to be a part of it!

On behalf of the editorial board,

Thomas Haan
Editor-in-chief KOersief 108

Chairman's note

Dear KOers members and relations,

Already half a year has passed since we started the 49th board of KOers. Since then, we have had many activities and a great and memorable 8th lustrum, but we are not done yet. With another half year to go, there are still many opportunities to make it an even greater year and we will start this off with a new KOersief on "Innovation".

Innovation is, of course, an important aspect of every field, except for history maybe. It is part of our study, our university, the companies we work with and even our study association. Innovation can be executed in many ways, the most important aspect for us, as study association KOers, is to come up with new activities every year to attract new members. By doing so, we like to look forward to a long and prosperous future. Of course, this KOersief will focus on the structural part of the innovation in the built environment. You can read about this in all the upcoming articles of this edition.

Looking forward to the rest of the year, we still have lots of activities to go. We will start with some lunch lectures, building visits, courses and, in the end of May, we will once again join the BetonKanoRace. This year, the BetonKanoRace will be held in Den Bosch.

Finally, we will end our year with two great study trips. First, the multiple day excursion to Bucharest in June where we will abide for four days and our international study trip to Canada, where we will visit Toronto and Montreal in July.

Lastly, I would like to thank the editorial board for this new edition of the KOersief and I hope you will all enjoy reading this edition just as much as the last one.

Yours sincerely,
On behalf of the 49th board of KOers,

Willem Bouwsema
Chairman of the 49th board of KOers

Agenda

Lunch lecture BAM *October 11th*

Betondag 2018 *November 15th*

KOers Lustrum Talks *December 12th*

KOers Lustrum Gala *December 14th*

Masterclass Continu

March 14th Enversed, Eindhoven

On Thursday, March14th, Continu is organizing a masterclass at an unknown location. With previous editions as a masterclass on a cruise ship and one in the Efteling, its surely something you do not want to miss. At the moment of writing, this years theme is not revealed, but more information will be available soon. Please visit the KOers corner for more information and subscribing is possible on our website.

Drink with AnArchie

April SkyBar! Underground

This year, KOers will organize a drink with AnArchie. The exact date and theme will be announced later, since we are still brainstorming. Do you have a good idea, do you want to beat AnArchie in a specific game, or do you just want to have a good reason for a cup of coffee, visit us at the KOers corner.

Batavierenrace

May 10th - May 11th Nijmegen- Enschede

This year, KOers is participating in the Batavierenrace and is competing against many other student teams, like for example Cheops. Everyone is welcome to motivate our runners and cheer them to finish line. The race starts in Nijmegen and the runners will finish eventually in Enschede.

BetonKanoRace

May 24th - May 26th Den Bosch

KOers is going for victory this year! KOers has had a few years without winning a race on the BetonKanoRace, with the excuse that its surely the boats that are not fast enough. But to our surprise, a German team actually won a race in our canoe last year. This year, no excuses, we are going to win races and take home some gold. If you want to join the team, look at our website, send an e-mail or come by in our KOers corner.

KOers Lustrum Excursion *December 19th*

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The development of the self-made tool VeriCon One

Automatization of the engineering of houses

By: J. (Jos) Hoonhout
Director VeriCon

In the pursuit of specialization, VeriCon started the development of automatizing the engineering of houses and in this process developed the self-made tool VeriCon One. Already 400 houses have been constructed with the help of the engineering tool, for clients, contractors, and colleague engineers.

Simply put, parametric design is a 'machine' that uses the design problem as input and generates the design solution as output. This can be used during every step of the construction process. This process of designing, engineering, planning, and realizing is similar, or at least partly similar, to the production process of a product. While a construction can be considered more unique than a regular product made in the factory, both processes entail numerous steps, diverse amounts of raw materials, and multiple components and intermediate phases. Such a process can be optimized by using mechanization, automation, and robotization for all links and phases. For the construction process this optimization can take shape in parametric design.

Experience

In 2006, VeriCon started using BIM and making 3D-models with meaningful object information. Soon, the need to execute these repetitive actions arose. The choice was made to use C# code and the API on Tekla Structures to link multiple modelling tasks to simplify and speed up the work process. The first parametric tools were created. Quickly, the output became more than just a drawing. For example, the output of models could be linked to structural analysis software. Also, customers need more information than just structural reports and drawings.

When all information is retained in meaningful objects in 3D-models, this information can be retrieved in multiple ways and forms, not only as a drawing but also as a file-to-factory data for production or ERP-systems.

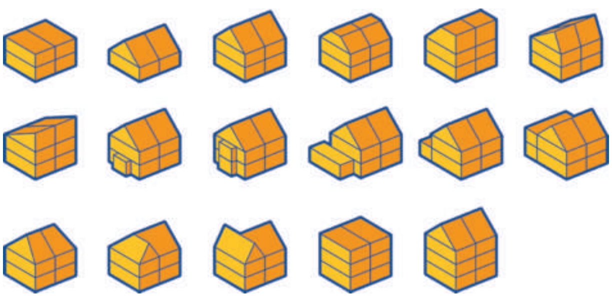

Figure 1: Typology

Self-developed software is needed for the exportation of the right information, because regular off-the-shelf software is often just not good enough. As many engineers know, just not good enough is actually just wrong. Hence, VeriCon is constantly developing software and parametric tools to improve their own productivity and to provide clients with more file-to-factory data.

VeriCon One

One of the most important tools developed by VeriCon is VeriCon One. This tool is able to do everything a structural design engineer has to do for a project-based house construction (*Figure 1*). Not just for uniform simple terraced houses, but for all kind of typologies of residences in all sort of orderings. For example, houses can be staggered next to each other, different types of roofs can be modelled while automatically connected, houses can easily expand or adjoin, and get bay windows (*Figure 2*).

Figure 2: IFC file of the architect in BIMsight

How does it work?

The information is inserted into VeriCon One (*Figure 3*) via its own interface or by reading the IFC-file from the architect. This can be checked and/or extended with additional information in that same interface, such as the construction system, materialization, geometry, and type or number. When all information is entered, the design engineering can start.

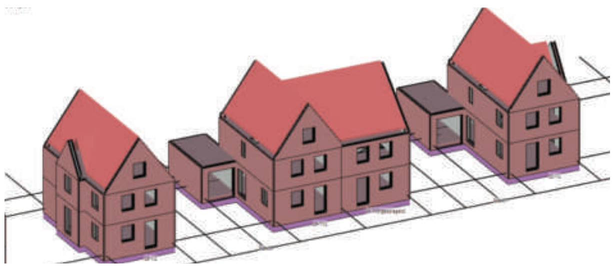

Figure 3: Preview in VeriCon One

Completely automatic, dependent on the chosen parameters, the following is generated (*Figure 4*):

1. the weight- and stability calculations;
2. the strength calculations of the structure (e.g. testing sand-lime bricks, lintels, steel beams);
3. the 3D BIM-model and following from that also the IFC-model that meets the "BIM-baseline ILS" (*Figure 5* and *Figure 6*);
4. the required drawings for construction permit, with designation of all structural elements, details, and load-information for suppliers;
5. the shop drawings for the pile plan and the foundations (*Figure 7*);
6. structural analyzes reports.

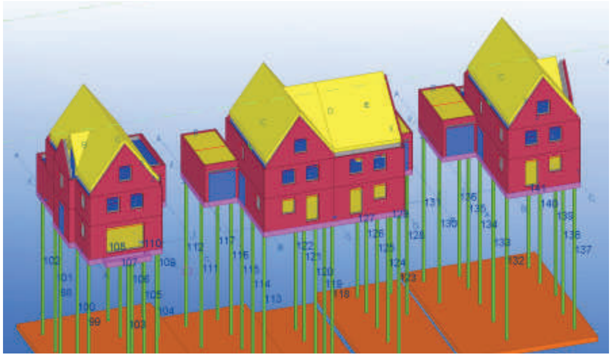

Figure 4: Fully generated blocks in Tekla

Since all this information is generated from parameters, recipes, and procedures, adding options in hindsight, for example by expanding and adding bay windows, is simple. Moreover, even changing the width or construction system retrospectively is no problem. Furthermore, the generated documents always have the same specific high quality because the information is automatically analyzed in the same way. BIM (and BIM based ILS) is the default. In addition, the system is also quick and input can be generated into output in just one day.

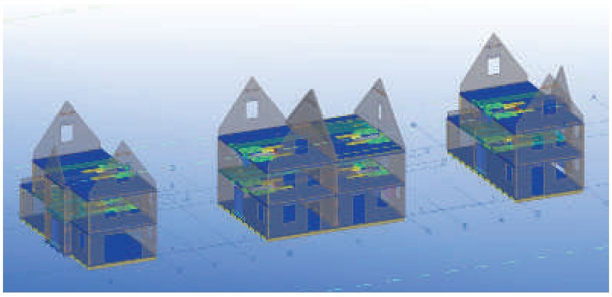

Figure 5: Generated blocks in Tekla - prefab casco

Software as a service

VeriCon One is a service. So, why not just deliver the software instead of providing a service? The tool exists largely out of an autonomous and specific software code, but is intertwined with existing software also used by other firms. Moreover, making the software completely 'foolproof' is too large of an investment for the time being.

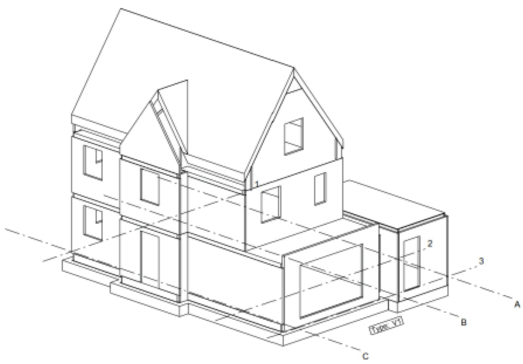

Figure 6: Fragment of generated drawing

Right now, the VeriCon One-toolset has provided construction advice for around 400 houses. Since the start of the tool, it has been constantly improved and it undergoes a continuous process of perfection. The number of home typologies and the number of possible ordinances of dwellings is going to be expanded. Furthermore, the reading and processing of less qualitatively IFC files will also be possible in the future. The IFC-model can already be made specific for suppliers with their parameters, for example for sand-lime brick. This will make the work preparation for the contractor easier and might even make checking the engineering of the supplier superfluous.

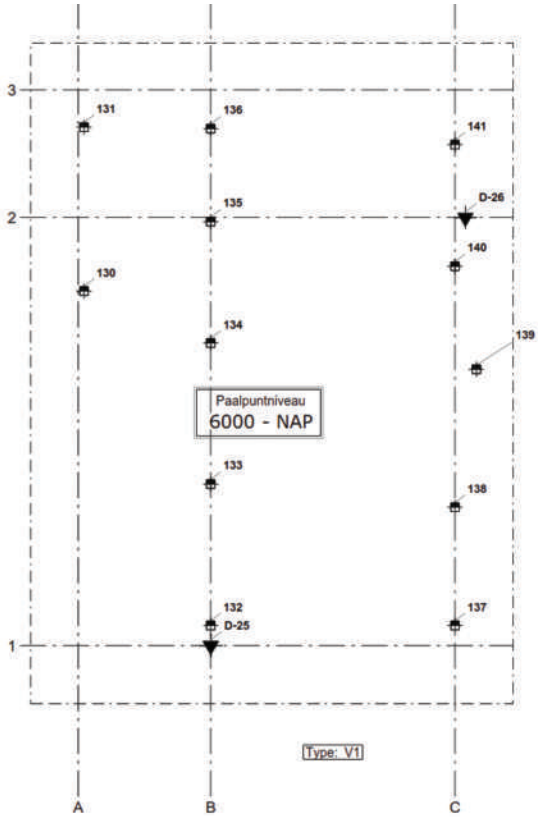

Figure 7: Fragment of generated pile plan

Specialization and parametric design

It is important to specialize as an engineer. If not as a company, then as a business unit or department. The pitfall of willing to do everything is that you can not be good at everything and hence cannot realize an optimal margin. Parametric design in design and engineering offers an enormous amount of opportunities for engineers. Engineers in nature, due to their background and education, have the skills to successfully learn all forms of parametric design, engineering, and (visual) programming. We would strongly advice that in our profession we should not compete again on these new skills and opportunities. That is why the VeriCon One-tool is made readily accessible for colleague-firms in the business of construction advice. This will also impact their margins and hence impact our profession. We would like to urge our colleagues not to develop the same parametric tools but share the information of your own developments and sell the service you can provide with your new toolset to your colleague-firms. Moreover, because your toolset will be used more, you also get the opportunity to perfect it and tune it to other components in the design process or production process. In this way, you do not only improve your margins and cut costs for your colleague-firms, but also immensely improve the quality and structural safety of the built environment. ◄

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Building on other planets

Martian concrete

By: Denise Kerindongo
Editor KOersief

Someday, many people hope, humans will travel to Mars. If we are going to colonize Mars, we will need buildings to live and work in. But shipping building materials across 225 million kilometers of space—the average distance between Earth and Mars—would be a nightmare. It costs a lot of money and effort to launch a kilogram of material to low Earth orbit and many times that amount to send it to Mars, so trying to ship tons of concrete would be financially ruinous and logistically very difficult. Researchers have made a cheap and strong concrete out of "Martian" soil in order to solve this problem. A new kind of concrete was developed that does not require water and is more than twice as strong compared to ordinary concrete.

Once humans arrive on the red planet, they will require high quality buildings in which they can live and work. They can take certain structures with them but this can only be a temporary solution. The first colonizers will quickly have to find a way to build structures using the planet's own resources. But how?

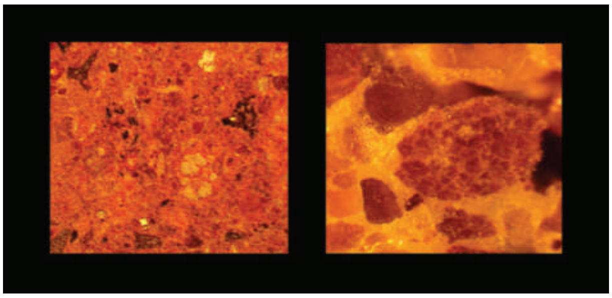

Figure 1: Microscopy images showing different particle sizes - Martian concrete (left) compared to the conventional sulfur concrete (right)

This could be answered thanks to the work of materials scientist Lin Wan and her colleagues at North-Western University's Center for Sustainable Engineering of Geological and Infrastructure Materials (SEGIM) in Evanston, US.

They have figured out how to make Martian concrete using materials that are widely available on Mars. More crucially, this concrete can be formed without using water, which will be a precious resource on the red planet [1].

When we start colonizing other planets like Mars, we are going to need concrete to make buildings and infrastructure. However, concrete needs water and Mars does not have any. How do we make it then? A team of researchers at Northwestern think they have the answer: sulfur liquefies when it is heated up to 240 degrees Celsius and then it can be used instead of water. Mix it with Martian soil, which acts as an aggregate, and then let it cool. The sulphur solidifies, binding the aggregate and creating concrete. This is the way Martian concrete is made [1].

Of course, the idea of using sulfur to bind aggregates is far from new. Engineers have been experimenting with this kind of material for at least a century and initially found that sulphur-based concrete had its fair share of problems [1].

For instance, as sulphur cools, it solidifies to form monoclinic sulphur and then transforms into orthorhombic sulfur, the stable allotrope at lower temperatures. However, it also shrinks during this process and this shrinking creates cavities and introduces stresses that severely weaken the material [1]. In addition, in the 1970s, materials scientists studied the possibility of using sulfur concrete to build lunar bases

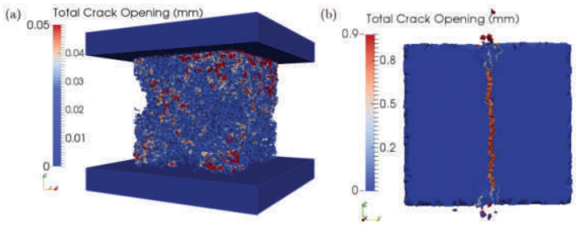

Figure 2: Tests results for Martian concrete

on the moon. They discovered that in a vacuum, sulfur sublimates - it turns from a solid directly into a gas. So, any sulfur concrete on the moon would quickly disappear into the ether [1].

An important question is whether sulfur concrete can be made strong enough and durable enough to be useful on Mars.

To find out, Wan and her colleagues tried to make some Martian concrete. They used simulated Martian soil consisting mainly of silicon dioxide and aluminium oxide with other components such as iron oxide, titanium dioxide, and so on [1]. They also tested various different sizes of particles in this aggregate (*Figure 1*).

The tests were straightforward (*Figure 2*). The aggregate was mixed with different percentages of molten sulfur after which the material was allowed to cool into blocks. Once cooled down, the physical properties of the resulting material, such as compressive strength and failure mechanisms, could be measured. In addition, they also chemically analyzed the mixture and simulated its behavior.

The results are interesting. It turns out that using an aggregate of smaller particles reduces the formation of voids, which significantly increases the strength of the material. Apparently, the best mixture for producing Martian concrete is 50 percent sulphur and 50 percent Martian soil with a maximum aggregate size of 1 millimeter [1].

Figure 3: Cube specimen (a) before and (b) after unconfined compression test

It is also a strong material, reaching a compressive strength in excess of 50 MPa. In particular, if it is compressed during curing to reduce the formation of voids (*Figure 3*). This strength is also partly a result of the chemical bonds that sulphur makes with the Martian soil. This compressive strength will be necessary on Mars, since the planet's atmospheric pressure and temperature range so widely compared to Earth's more hospitable conditions [2].

There are other advantages too. Martian concrete can be recycled by reheating it, which melts the sulfur. So, it can be re-used repeatedly (*Figure 4*). It is also fast-setting, relatively easy to handle, and extremely cheap compared to materials brought from Earth [1].

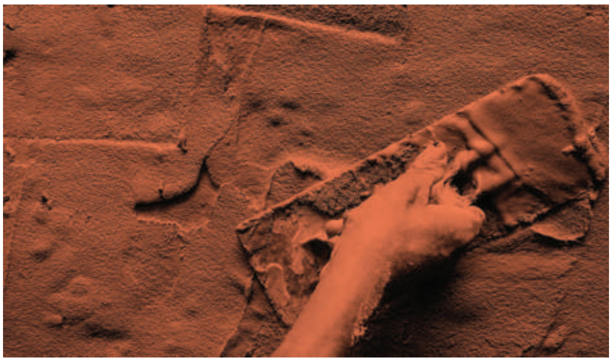

Figure 4: Re-use concrete

This means that the first permanent structures on Mars should be straightforward to make. All that is needed is a new generation of Martian architects to design buildings made of Martian concrete that will be suitable structures for humans to live and work in [1] (*Figure 5*).

Figure 5: Mars in the future

Of course, we are many years away from Martian colonies. However, the idea that generations of humans in the not-too-distant future will live, work, and play on Martian soil does not seem so far-fetched. If the Northwest team is right, we may be working with a superior version of the same material we use on Earth [3]. ◀

Reference

[1] *Materials Scientists Make Martian Concrete. MIT Technology Review. [Online] January 5, 2016. https://www.technologyreview.com/s/545216/materials-scientists-make-martian-concrete/.*

[2] *Brownlee, John. Why Martian Concrete Might Be The Best Building Material In The Solar System. Fast Company. [Online] January 7, 2016. https://www.fastcompany.com/3055172/why-martian-concrete-might-be-the-best-building-material-in-the-solar-system.*

[3] *Liverani, Stephanie. 'Martian concrete' could be key to future human colonization on Mars'. The American Ceramic Society. [Online] January 8, 2016. https://eramics.org/ceramic-tech-today/martian-concrete-could-be-key-to-future-human-colonization-on-mars.*

Figures

Header, 1 — *Fast Company*
2,4 — *Northwestern University*
3 — *The American Society*
5 — *Architectural Digest*

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

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

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

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

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

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

Michiel Visscher, Constructief Ontwerper

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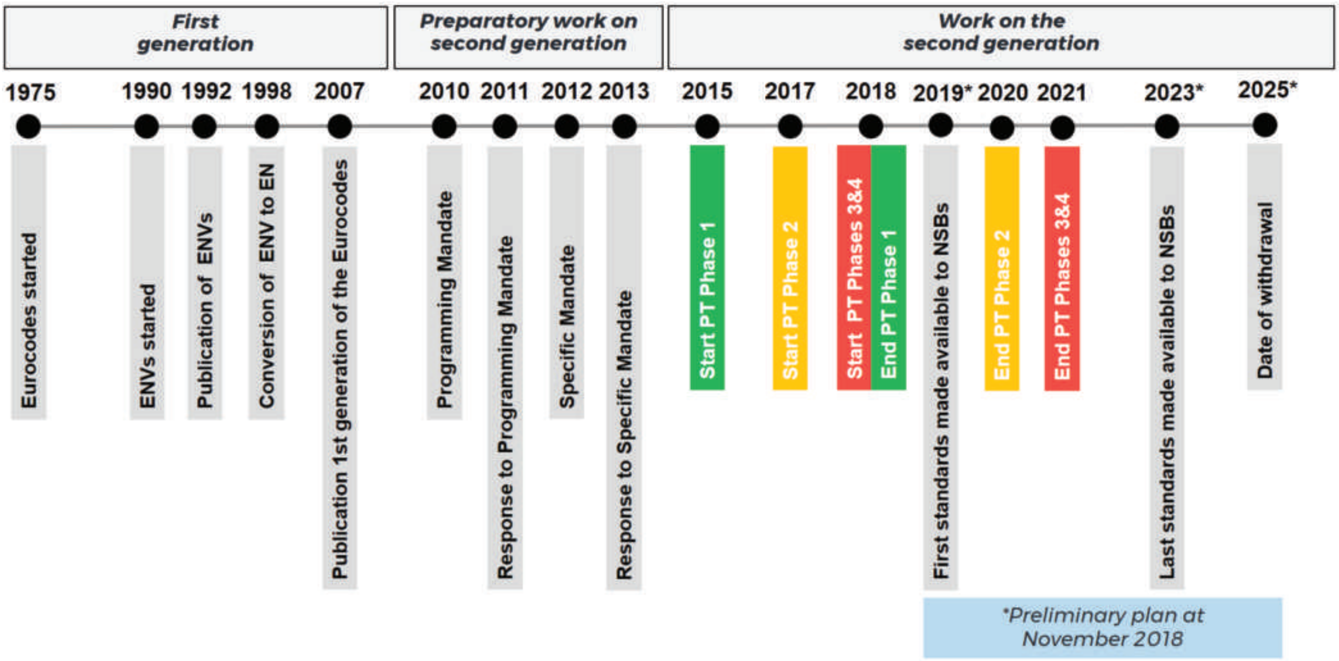

Development of the second generation Eurocodes

Interview with: prof. ir. S.N.M. Wijte
Chairman TGB concrete structures and member of SC2/WG1

By: Monique Morren
Editor KOersief

The Eurocodes are the most extensive and technical coherent system of standards for structural and geotechnical design in the world. The development was a great achievement and represented the completion of over 30 years of collaborative effort. Since the publication in 2007, the impact has been considerable, affecting the day-to-day work of around 500.000 professional engineers across Europe. The Eurocodes comprise 10 Standards in 58 parts and are guiding in 33 European countries. At the moment, many experts in the field are working on the second generation of Eurocodes.

In 1975, the Commission of the European Community started an action program to improve the trading process and to harmonize technical specifications in the field of construction. This initiative was the start of the development of the Eurocodes. The Eurocodes initially had to act as an alternative to national regulations, with the aim to eventually replace them. In 1989, it was decided to transfer the preparation and publication of the Eurocodes to the European Committee for Standardization (CEN) to provide an European status for the future. The Eurocodes were issued as pre-norm, but they were very limited used in the Netherlands. Harmonizing the determination of structural safety in the construction industry was not an easy task due to variety in national character, traditions, and safety levels of the European countries. This, and the need to provide specific national information on the geographical and climatic conditions, gave rise to the use of National Determined Parameters (NDPs). For each part of the Eurocode values for the NDPs are described in a National Annex, which are available for each European country. The first generation of Eurocodes and their national annexes were published in 2007 and are the standards for the structural and geotechnical design which we are currently working with. The main objective and advantage of these European standards is to enable free trading. This holds not only the availability of European product standards, but also free trade of structural engineers' services. This makes it easier to work as an engineer abroad. Downside is the more complex process of development of the Eurocodes.

In the past, only a few years were needed to adapt national standards. The revision of the Eurocodes, however, requires a much longer period and calls for work of many experts and feedback from the building practice of all member states.

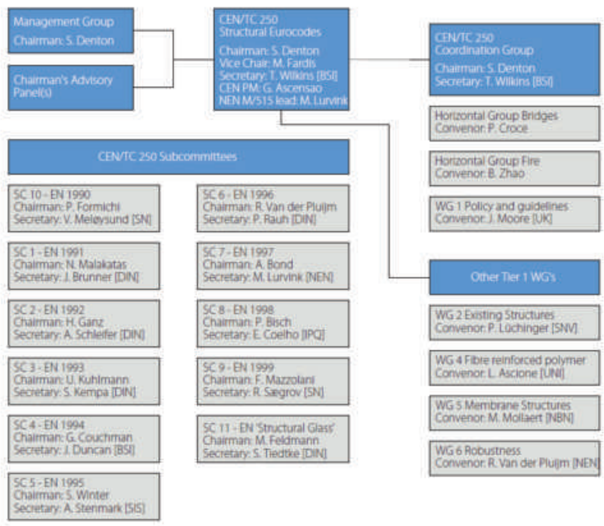

Figure 1: Organogram CEN/TC 250

In 2010, a start was made on the evolution of the Eurocode system, leading to the aim to publish the second generation of EN Eurocodes in 2020. Due to some delay, the new generation of Eurocodes is now expected not earlier than in 2023. The Eurocodes are drawn up under responsibility of the European standardization Platform CEN, by Technical Committee CEN/TC 250 (*Figure 1*). This committee consists of various subcommittees (SC) and working groups (WG), in which each member state can have a seat. There is a subcommittee for each Eurocode. For example, SC2 is put together for Eurocode 2 and includes working group 1. Dutch normative interests are represented in the Netherlands by NEN. For the revision of the Eurocodes, a number of main objectives are formulated. An important one is to enhance the ease of use. Furthermore, updating the standards to the latest state of the art is of importance. It is also aimed to reduce the number of NDPs.

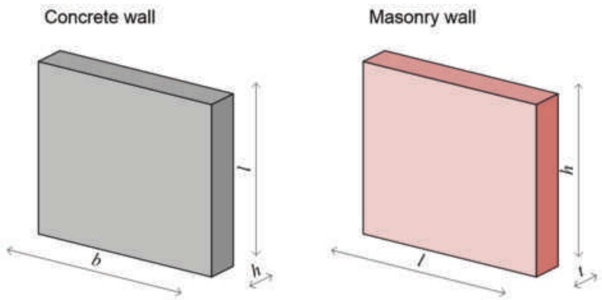

Figure 2: Different terminology of a concrete (EC2) and masonry (EC6) wall

Development of Eurocode 2

In 2012, work on developing the current Eurocode 2 started. At that time, SC2 put together working group 1 (WG1) with the task to coordinate and implement the revision work. All countries that are a member of CEN may be represented in this working group. To achieve a well-founded revision of Eurocode 2, task groups (TG) are formed in the sub-areas such as: fiber-reinforced polymers, steel fiber concrete, assessment of existing structures, punching shear, fire, analysis, time-dependent behavior of concrete structures, fatigue, bridges design, and durability.

Prof. Simon Wijte is a member of SC2/WG1 and contributes to the revision of Eurocode 2. The work of SC2 started with requesting comments from all member states on the current version of the Eurocode. Engineers in the field were asked for their opinion about what they believe that should be adapted. After the UK, the Netherlands was responsible for the second most comments. All these comments were collected, edited, and submitted by WG1. According to Simon Wijte, the development can be looked at in two ways. On the one hand, the Eurocodes can be compared to the previous national standards that were used in the Netherlands and comments can be submitted on this basis. Another way is to look at how international standards can be further developed, so they can be applied anywhere in Europe and also meet international needs. Regarding the latter, comments are much more constructive. In WG1 they consider all tenders and try to make decisions about how this can be implemented in the revision. It sometimes appears to be complicated to make decisions due to different interests of member states and work that is done on voluntary basis. Money has been made available by the European Union to take steps towards the main objectives. This essentially concerns adding new aspects to the Eurocodes and improving the ease of use.

According to Simon Wijte, the latter is of high importance. The Eurocodes are a tool for structural engineers, it should not become a scientific document. Often, structural failure cannot be blamed to incorrect design factors, load effects, or material properties. Generally, it is due to the fact that humans make mistakes. For this reason, it is important that the Eurocodes should not be too difficult for their task.

An improvement can be made in consistency of terms. An example is shown in *Figure 2*. The difference in terminology between the dimensions of a concrete and masonry wall is presented. Other examples where the different Eurocodes do not consistently deal with symbols and expressions are slenderness and rotational stiffness (*Figure 3*). In the second generation of Eurocodes, it is aimed to create unity in the use of symbols and terminology. In addition, attempts are made to limit the number of pages of the Eurocodes. Working groups of all Eurocodes casts a critical eye at the content and are looking for possibilities to combine parts of the standards. For example, SC2/WG1 is working on the improvement of Eurocode 2 part 1-1 to make it applicable to the design of bridges, in addition to building structures. Due to this, there is no need for the concrete Eurocode for the design of bridges anymore (EN 1992-2). This results in bringing down the amount of additions and reduces the number of documents which a structural designer needs for making a design.

Slenderness:

EC2	Concrete columns and walls:	$\lambda = l_{buc}/i$
EC6	Masonry for walls:	$\lambda = h_{ef}/t_{ef}$

Rotational stiffness or restrained:

EC2	the relative flexibility of rotational restraint	$k = \theta/M \times EI/l$
EC3	the rotational stiffness	C
EC6	the rotational stiffness	$k_r = \theta/M$

Figure 3: Unconsistent use of symbols and expressions

A proposal of Simon Wijte is to develop a code of practice for each Eurocode. With this summary, it should be possible to perform the structural design of 90 percent of the buildings. This might result in slightly larger dimensions. However, the question is if highly exact calculations are the most optimal. Some reserve capacity increases the possibilities for re-use of structures, which is required for sustainability. Another important objective is updating the Eurocodes. Adjustments are made based on new scientific insights. For example, punching shear of flat slabs is a phenomenon that is widely studied already for many years. Furthermore, innovations such as fiber reinforced polymer, re-use of granulates, and new types of cements are included. In all probability, the revised Eurocodes will be used until 2040. The development of the second generation of Eurocodes includes preparing the standards for innovations in the future regarding aspects as new materials, sustainability, use of non-linear analysis, and BIM. ◀

Figures:

Header,1 *CEN/TC 250*
2,3 *prof.ir.S.N.M. Wijte*

An innovative way to make buildings quake-resistant

Carbon fiber strand rods

By: Denise Kerindongo
Editor KOersief

Earthquakes are one of the most destructive forces on the planet. As tectonic plates collide and rub, enormous amounts of potential energy is unleashed as they quickly snap past each other - like snapping fingers-, but with insanely huge rocks that float on a sea of magma. Most buildings do not collapse from the actual earthquake, but rather from the displacement of the foundation that causes the top part to sway and resonate until the tensional forces are too great which causes the building to collapse. A Japanese company, called Komatsu Seiren, has developed a method involving carbon fiber tethers to make buildings more resistant to earthquakes.

Komatse Matere fabric laboratory
The CABKOMA Strand Rod for seismic reinforcement is a thermoplastic carbon fiber composite. It uses carbon fibers as the interlining, which is an advanced material, while its outer layer is covered with synthetic fibers and inorganic fibers. It is finished by impregnation with thermoplastic resin.

Features of the carbon fiber strands:

- High tensile strength, while it is the lightest seismic reinforcement in the world;
- The strands are delicate but have a strong structural body;
- The strands have a great aesthetic quality that achieve lightness.

For the seismic reinforcement and renovation of the former head office building of Komatsu Matere, a carbon fiber strand rod that was still under development (hereafter, 'CF rod') was used. In addition, a proposal was made that considers the possibility of a seismic reinforcing material with aesthetic quality. Reinforcement with the CF rod is seen as something that is over and above the requirement, and as a seismic reinforcement that satisfies the seismic performance required for conventional seismic reinforcement. The *Header* shows a building with the rods in place and shows how the exterior facade was designed using the motif of fabric. The three-story building serves as workspace, exhibition, and research facility for Japanese fabric manufacturer Komatsu Seiren. The architect Kengo Kuma and Ejiri Structural Engineers were recruited to collaborate on a visionary application for the headquarters, where they have used the Strand Rods as an architectural element [2].

Figure 1: Carrying the strand rods

The used material on the exterior gives the appearance of a soft and organic lightweight curtain wrapped around an office building, resulting in a carbon fiber curtain that looks light, but has considerable strength and can provide seismic reinforcement. The carbon fiber strands have been created to help protect buildings from earthquakes. The material has the property that it is very strong, yet it could be said that it is the lightest seismic reinforcement in the world. In the early design stages, Kuma approached the scheme by developing a hybrid, carbon fiber material called 'Kotmatsu Seiren's CF rod' [2].

The design concept drew upon the local technique of rope braiding. The fiber rod is a combination of old and new technologies to create a knitted light rope-like rod that embodies strong and flexible properties. However, there were some structural challenges involved in mixing the old with the new, like how to deal with buildings that were built with older technology [2].

These buildings are retrofitted with the features needed, but it involves bracing and bolting the building to its foundation which can be troublesome, expensive, and the look is not particularly aesthetically pleasing. In contrast, the Komatsu Seiren Fabric Laboratory has come up with a rather novel idea, namely the carbon fiber strands that could hold buildings down [2].

Comparison of mechanical strength

Figure 1 shows a roll of the CABKOMA Strand Rod. Since a roll with 160 meters of strand only weighs 12 kilograms, the material can be carried by hand. Metal wire with the same degree of strength is about five times heavier. *Figure 2* shows the CABKOMA Strand Rod compared with an traditional reinforcement. The strand rod and the steel shown in the figure are almost equal in terms of strength [1].

Figure 2: Carbon fiber compared to conventional reinforcement

Komatsu Matere began developing CABKOMA in 2010. It was selected for the Ishikawa Prefectural Government funds for creating next-generation industries. Since 2012, the development project has received a subsidy for advanced technology demonstration and evaluation facility development, from the Ministry of Economy, Trade, and Industry [1].

Reinforcement approach

The reinforcement was positioned such that the target reinforcement values would be reached with the story drift in the seismic reinforcement proposal for the building;

- Seismic reinforcement was achieved with exterior CF rod drape and interior partition brace bearing walls;
- The structural investigation was aimed at investigating how to prevent the reinforcing materials from affecting the existing building as well as evaluating the seismic strength;
- The target values of the reinforcement criteria are as follows: for the exterior rods it is approximately 3 percent and for the partition brace bearing walls approximately 10 percent.

Figure 3: Reinforcement wall

In addition, there was the initiative of the CF rod drape. This is a proposal for seismic reinforcement based on the tension bracing effect of the CF rod. The reinforcing effect for the overall building can be obtained by linking the roof level and ground level (foundation level) [1].

Another idea to make use of the CF strand rods in the form of a partition brace bearing wall (*Figure 3*). This is a proposal of a reinforcement method using tension brace comprising CF rods laid out in a diagonal mesh form [1]. The reinforcing effect of the CF rods' tensile resistance can be obtained by binding the surrounding steel frames to the existing building frame (*Figure 4*).

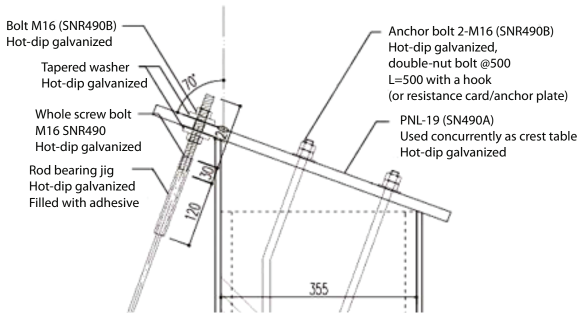

Figure 4: Connection detail

CF in the future

How might this company continue with this new material? It seems unlikely that the whole of Japan will begin covering its buildings with this 'string' as it would be impractical, not to mention impossible in more urban settings. Instead, it might be more useful in more remote locations where space is available or used to protect historical landmarks which might not have been reinforced. All in all, it is a promising development of which we will see more in the future. ◀

Reference

[1] *Komatse Matere. Features of the carbon fiber strand rod. CABKOMA. [Online] 2016. https://www.komatsumatere.co.jp/cabkoma/en/.*

[2] *Thermoplastic carbon fiber composite aids seismic reinforcement. Owano, N. 2016, Tech Explore.*

Figures:

Header, 1-3 *Komatse Seiren*

Which innovations are the future and why are they needed?

Digital innovation at the construction site

By: Hidde van Wezel
Editor KOersief

The building engineering is one of the slowest innovating industry in the Netherlands, even though more and more students choose to do an engineering study. The problem does not seem to be within the field of research in laboratories and offices, but with the lack of innovations on site. Workers on site are doing the same job as their grandfathers may have done too, but then 60 years ago. Masonry walls are still constructed by hand and also pavement is laid by people working on their knees with their back bowed. New innovations are screamed for and it begins to look like the industry final has heard these screams.

In this article, it will be showed why innovations are so important and the newest innovations are introduced, which can help the workers on the construction site.

In 2018, the economic research office of the ING Bank published an article which gives insight in how much the building engineering is trying to innovate [1]. The article compares the building industry with the numbers of all other industries. There are two main reasons why the

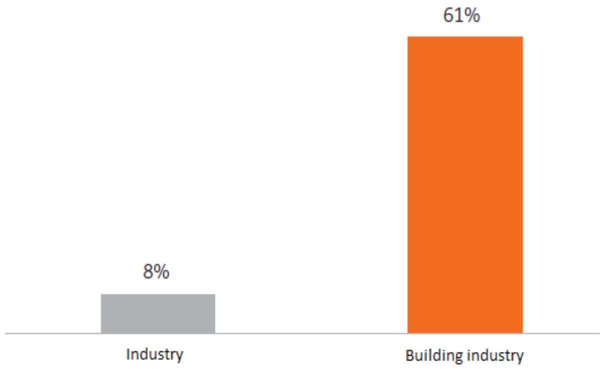

Figure 1: Cost raise since 1995

building industry has to change so badly. The first reason is that the building industry becomes too expensive and therefore is a less big competitor to other industries (*Figure 1*). Simply said, consumers will choose for other things like buying a car before thinking about a new expansion to their home.

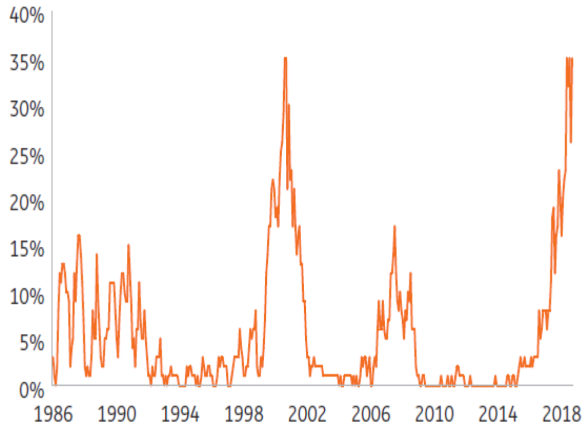

Figure 2: Shortage of employees in the building industry

The second reason is that the industry suffers from a lack of workers (*Figure 2*). There are simply said not enough workers to work on all the projects that could be executed. A more efficient way of constructing buildings would mean a need for less workers. Nowadays, the man or woman on the construction site has, compared to other industries, far less valuable equipment to their disposal (*Figure 3*).

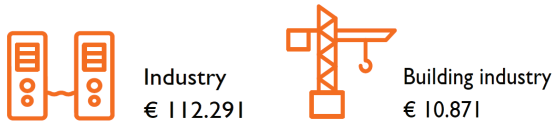

Figure 3: Value of equipment available per worker

So, how to solve these problems? The ING research team introduced the big seven [1]. Seven technologies of which they think will have impact on the building industry. Two important ones that could really help on the construction site are robotic and artificial intelligence.

A couple of years ago, Google introduced the Google glasses. Glasses which not only improve your sight but also could show you movies and social media updates. This never came to be a big thing, but Daqri saw an opportunity for the building industry and invented the Daqri Smart Glasses [2] (*Figure 4*).

Figure 4: Worker using the Daqri Smart Glasses

These glasses work with augmented reality. This is a sub reality added to the users sight. It shows the user information that normally is printed on a paper or viewed on a tablet, which make these not needed anymore. Also misinterpretations will be less. The projected sub reality can be projected at, for example, reinforcement bars showing which diameter the user holds and which classification it has.

In addition to general information, the glasses can also be used to help workers get through situations where they are unknown with. The glasses do not only project a sub reality but can also film the situation where the worker is in. Giving another, more experienced, worker on distance the opportunity to see what the situation asks for and give advice or explain what to do.

Althogether this all sounds very helpful and has a big apple feeling about it, it can be said that these are all possibilities for which the glasses can be used, however does depend on how much this will develop in the coming years. All information given by the glasses to the user has to be put in the system and still then the system can make errors in judging all the different situations it encounters.

Artificial intelligence (AI) is the big connector in this story. Where plenty of data is found, which is everywhere, AI can help. Not by organizing the data, but by learning from it and using old data to judge new data. For example, in the road maintenance where cameras are used to film the tarmac roads and an AI algorithm judges if maintenance is needed. People are not needed to watch the tarmac anymore, only film it with a three-dimensional camera.

In the future, it could be that a building can be analyzed by cameras and the algorithm will tell us which kind of damage there is and what caused that damage. This is just the beginning to get a shape, and therefor companies start small with little projects. The ICT group has started a trail with recognizing road signs and green strokes next to roads. Arup uses AI to see if their workers are wearing their safety equipment. If a worker is filmed not wearing the right equipment, the algorithm will recognize this and send a message to the construction site, which makes the work on a construction site more safe.

The best thing of AI is that it runs on data. Due to BIM, more and more data seems to become available. However with most of the data nothing is done yet. While in the future this data can be used for many applications.

The available data is gathered by drones among other things. This technology is already known by many, but primarily due to news adds of drones flying around airports. Since a couple of years, the role of the drone gets bigger on the construction site. By putting a camera on a drone, it can capture parts of the construction site that are hard to reach. Also, by putting equipments on drones they can make adjustments if needed. Because of the help from the drone, workers do not have to spend much time and high risk to reach such difficult places [3].

Drones can also be used to transport small goods or equipment in a fast tempo. Preventing workers from walking around or having to place toolkits at clumsy places. Droned can also measure volume quantities. By capturing the construction site, the site manager can get insight in where progress is made and where not. This can be used to adjust the planning. Images that drones make can also be used to keep qualities high by checking if everything is done correctly.

Generally, a lot of new innovations are coming and the possibilities in usage are endless. Think of a drone which is self-directing and all data collected by his camera is handled by an AI algorithm. In this case, no workers would be needed. ◄

Reference

[1] *ING_EBZ_ConTech_Bouw digitaliseert volop maar industrialiseert nauwelijk*
[2] *Daqri.com*
[3] *www.richardvanhooijdonk.com/blog/drones-disruptieve-innovatie-die-de-bouw-voor-altijd-zal-veranderen/*

Figures

Header *www.drones.nl/nieuws/2014/06/drones-vliegen-de-bouwplaats-op*
1-3 *ING_EBZ_ConTech_Bouw digitaliseert volop maar industrialiseert nauwelijk*
4 *Daqri.com*


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A design based on nature's strength

Arachnid Design

By: Lars Hogenboom
Editor KOersief

The Institute for Computational Design (ICD) and the Institute of Building Structures and Structural Design (ITKE), both from the University of Stuttgart in Germany, came together to create a pavilion in 2014-2015. It was developed at the intersection of the two institute's research fields and was realized, including the design and research phase, in one and a half year. Their aim for this innovative pavilion was rethinking our construction method by looking at nature and using this as a starting point for the construction of this structure. What can we learn from nature? Is a computer able to construct in an efficient way without interfering during the actual construction time?

For the 2014-2015 research pavilion, the interdisciplinary team got inspired by the so-called Agyroneda Aquatic, the water spider. This spider lives almost its entire life under the water surface and will only briefly surface to replenish oxygen. To breathe, the spider creates an interesting diving bell. First, the spider builds a horizontal sheet web under which an air bubble is placed.

In the next steps, the bubble is reinforced by the spider in a hierarchical arrangement of fibers from within. It can, of course, withstand water pressure and it can even withstand mechanical stresses, such as changing water currents, to provide a safe and stable habitat for the spider (*Figure 1*).

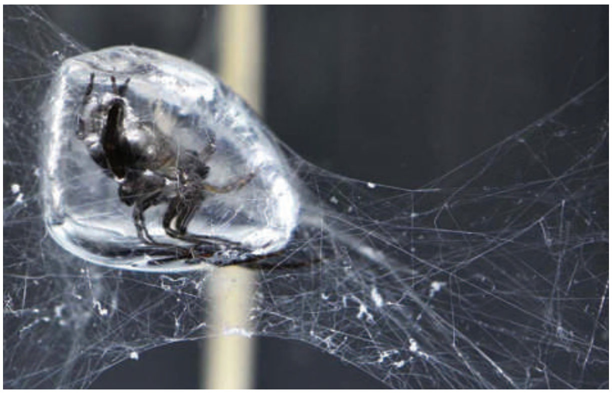

Figure 1: Semi-detached house, before the renovation

Figure 2: The robot's printing process

The materials in which the pavilion was constructed where carbon fiber for the structure and EFTE polymer. The carbon fiber was chosen for its large stiffness. This would reduce the amount of fibers needed resulting in more transparent pavilion. The EFTE polymer was chosen due to its suitability as a pneumatic formwork and a minimal plastic deformation during the printing process. In addition to being the formwork during construction time, the polymer would also function as the skin of the pavilion, making it air and water tight. By allowing the formwork to serve as crucial part of the building itself, the waste during construction time as reduced to a minimum. To create a bond between the carbon fibers and the EFTE pneumatic formwork, an adhesive composite was also applied by the robot. Working from the inside, the robot was able to print the carbon fibers onto the membrane on the places where it was needed according to a finite element analysis executed by the University of Stuttgart. The shell, initially supported by air pressure, gradually stiffened by the application of

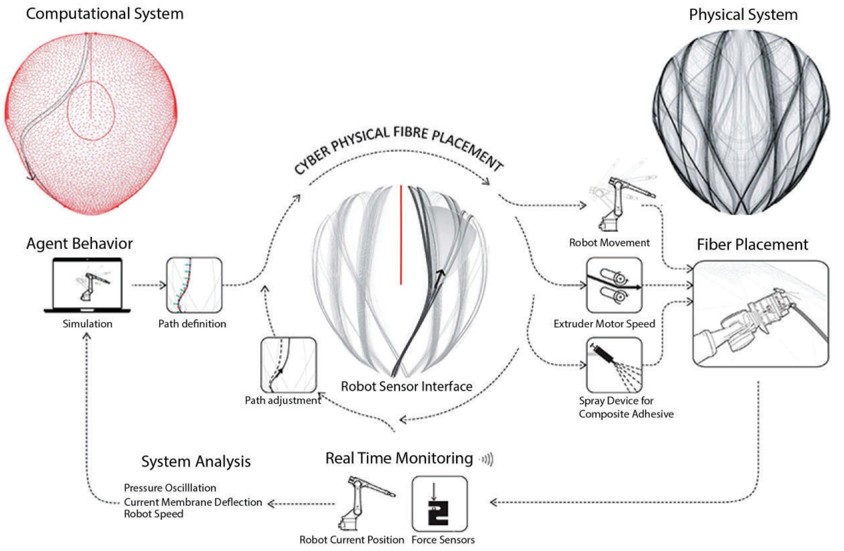

Figure 3: The processing of the robot, which makes it possible for the robot to interact on altering situations

the carbon fibers. Before the construction started, the computational design generated a shell geometry and main fiber bundle location, regarding the structural and construction limitations. The best options for the placement of the main reinforcement was analyzed in the finite element analysis, creating a clear distinction between main reinforcement and reinforcement needed between the main carbon fiber bundles (*Figure 2*).

By applying this main reinforcement according to the plan as was computed, which was needed to provide stiffness for the pneumatic structure, a changed stiffness of the bubble was created. These changes resulted in deformations during fiber placement. To control these changes and let the robot adapt to the altered printing surface, an embedded sensor system was integrated into the robot which recorded the current position of the robot and the contact force between the robot and the EFTE polymer.

This development allows constant feedback between the production conditions, the EFTE polymer in this case, and the robot which was coded to create something in a 3D and static, environment (*Figure 3*).

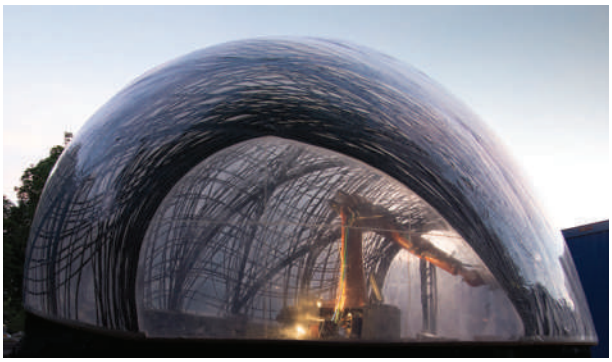

Figure 4: Construction of 2014-2015 pavilion

Especially this technique, very similar to the spider sensing the bubble and constructing wires, creates new possibilities for adaptive robotic construction processes. It is needless to say that the technical development of the robot, with its construction limits, and the structural limits of the carbon fibers in combination with the EFTE polymer form an integral part of the architectural design process. The additive process has not only allowed stress-oriented placement of the fiber composite material, it also minimized the construction waste since the material is placed on the exact location where it is needed. Where 3D concrete printers are already an innovative construction method, replacing manual labor by machines, this process goes a step further. The machine can communicate with the engineers, by providing valuable information of, in this case, the formwork. In addition, it can also print carbon fibers by itself on places where it is needed. However, the actual threshold of where the material is needed, is still programmed by the engineers.

The 0.2 millimeters-thick EFTE film spans maximum 25 centimeters between the bundles of carbon fibers, which on their turn range in diameter from 1 millimeter to 2 centimeters. The total structure weights 260 kilograms, which corresponds to a weight of 6.5 kg/m^2. It is designed to resist all the loads from the region's wind gusts, which can reach up to 26 meters per second (*Figure 4*).

In later years, the University of Stuttgart developed the technique of robots printing fibers and creating structures that show great similarities to nature due to the biomimetic investigation. The larger span of the 2016-2017 pavilion shows further development of the revolutionary idea of a robot getting real time feedback from the formwork to create an optimal structure which does not lose the feasibility of constructing it. ◀

References:

[1] *Arachnid Architecture as Human Shelter. Architectmagazine. (2015).*
[2] *Subaquatic waterspider nests inform ICD/ITKE research pavilion 2014-2015. Designboom. (2015).*
[3] *ICD/ITKE Research pavilion 2014-15. University of Stuttgart. (2015).*

Figures:

Header *Architect magazine.*
1-4 *University of Stuttgart*

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What is the perspective of 3D concrete printing in the future?

State of the art of 3D printing

By: Lars Hogenboom
Editor KOersief

An innovation that immediately comes to mind, considering innovation in the Built Environment for every student Structural Design, is 3D concrete printing. Our 3D printer even reached the Guardian, as one of their articles stated: "Netherlands to build world's first habitable 3D printed houses". But what about its future? Can we eventually rely on a 3D printing robot for our construction on site? Zeeshan Ahmed is trying to sketch the perspective for the future of the built environment with us.

It is fair to say that the 3D concrete printer divides the structural engineers in at least two camps. The ones who think positively on the development of the printer and its capabilities and the ones who just simply do not see it happen on a short notice. The 3D concrete printed bridge (*Figure 2*), which was fabricated in the laboratory and was placed in Gemert, is the first 3D printed bridge in the world. The bridge mainly consists out of 3D printed concrete, but is also prestressed by large steel cables to avoid tensile stresses and excessive cracking of the bridge. The opening of this of course was enough reason for critics to reply. Johan Riezebos states at Booosting, a platform for innovation in the construction industry: "The future of the technology does not include the printing of entire houses, the exclusion of the necessity of construction workers or the absence of waste materials." His message: a very bright picture, without meeting these promises in recent developments.

"For me it is all about this industry 4.0 and creating an intelligent loop, to help develop the building industry."

In our conversation with Zeeshan, he made clear that the future of 3D concrete printing was not making one single robot that simply does everything: "It is the same as the car industry. You have a lot of robots, even with similar properties, doing their own specific job. For the future, this is the same for the construction industry in the built environment." Without contradicting critics, the future is bright, according to the ones pro 3D concrete printing. An industry can, and should, change to keep up with developments. Prof. Salet states in the latest Chepos: "It seems we are stuck in industry 1.0. We do have a control room and a shovel, but that is pretty much it. There is some mass production in prefabricated facades,

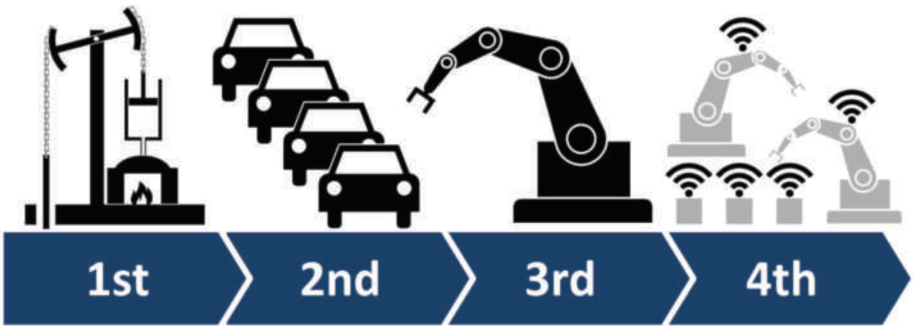


Figure 1: Industry 1.0: mechanization, industry 2.0: mass production, industry 3.0: automation, industry 4.0: cyber physical systems

Figure 2: First 3D printed bridge in Gemert, the Netherlands

industry 2.0, but there are hardly any robots let alone industry 4.0, since the processes of our design are not at all adjusted to one another. In short, for me it is all about this industry 4.0 and creating an intelligent loop, to help develop the building industry (*Figure 1*). The printing is mainly because of the freedom it gives and the way it can help save on material usage, to help meet sustainability goals." So one can read between the lines that prof. Salet is not arguing the fact that construction workers are necessary, but he thinks that their profession can change a lot parallel to the innovation of the 3D concrete printer.

"Even a self-adapting robot is actually reacting in a way you programmed it to do. This all starts with discovering what could happen during the construction process and during the printing of concrete."

In answer to our question whether we can ever reach industry 4.0, as prof. Salet states, Zeeshan says: "We can definitely reach this phase with a 3D concrete printer, as is possible with any robot. At the TU/e, we are actually busy developing possibilities, but we are carefully making the first steps to this industry 4.0 where the robot can adapt to different situation by itself. The robot does what you tell it to do, so even a seemingly self-adapting robot is actually reacting in a way you programmed it to do. This all starts with discovering what could happen during construction and during printing of concrete."

Figure 3: Project Milestone

The exact future for the 3D printing of concrete is still uncertain. It very much depends on the progress of knowledge on certain concepts and discovering possibilities. When the range of possibilities, for example architectural freedom, becomes larger, companies will get more involved in 3D concrete printing. This immediately changes the future of 3D concrete printing and is therefore of crucial importance. This proof of concept is one of the main topics at the TU/e, and certainly of Zeeshan.

On the question whether the 3D concrete printer of the TU/e differs from those of certain companies: "Some printers differ from each other, but the actual way of printing remains the same. Several companies are involved in research on this technique and other companies could be merely focused on discovering limits of their 3D concrete printer. On our university it is important that we can backup a certain new development with fact based research. It is, of course, of vital importance for most companies to decide whether they are jumping in this technique or not."

"A design team should ask themselves what is most important. Guaranteed circumstances are more expensive to create on site."

To finalize our conversation, we asked him if the elements for Project Milestone (*Figure 3*), the first 3D printed concrete houses, are made on site or are made in the lab and transported to the specific location: "Anything we do in our laboratory, can basically also be done on site.

However, you should ask yourself the question, especially as an engineer, what a different situation would do to the material. We are currently researching what different conditions do to the state of the concrete and thus the printing process.

Before the start of every process including a 3D printed object, the design team should ask themselves what is most important. Guaranteed circumstances are of course more expensive to create on site, and therefore again to proof the concept, it might seem more rational to choose fabrication in the already created controlled environment." A final answer is not given, but we do sense the ambition to actually create one of Project Milestone's buildings on site. ◀

References:

[1] *Verslag cobouw activiteit 3D betonprinten. [Online] January 8, 2019. https://booosting.nl/news/show/id/1245*

[2] *Innotie in Brabant: 3D-geprinte betonnen fietsbrug en complete rotonde "ingeschoven". [Online]. October 17, 2017. https://www.baminfra.nl/nieuws/innovatie-in-brabant-3d-geprinte-betonnen-fietsbrug-en-complete-rotonde-ingeschoven*

[3] *'s Wereld eerste 3D geprinte gewapend betonnen brug geopend in Gemert. [Online] October 17, 2017. https://www.linkmagazine.nl/s-werelds-eerste-3d-geprinte-gewapend-betonnen-brug-geopend-gemert/*

Figures:

Header	*www.3dprintedhouse.nl*
1	*nl.wikipedia.org*
2	*www.sustainableurbandelta.com*
3	*www.3dprintedhouse.nl*

An innovative construction method for the metal industry

Additive manufacturing

By: Stefan Slangen, MSc.
Structural Engineer at Arup

Additive manufacturing (AM) can be defined as the process of joining materials to make objects from 3D model data, usually layer upon layer. The idea of producing 3D objects layer by layer existed long before the development of ideas around additive manufacturing. The first concept patented can be traced back to Peacock for laminated horseshoes in 1902. However, not until the advent of computer-aided design and the integration with robotics the use of AM could take flight.

AM processes are fundamentally different from traditional, subtractive, manufacturing processes such as cutting and milling. The main difference resides in the fact that in traditional processes shaping of objects takes place by removing material whereas in AM the shaping of objects primarily takes place by the addition of material in the form of filaments or layers. This difference gives rise to a number of advantages of AM over traditional processes.

AM offers high degrees of design freedom and customization with little impact on manufacturing complexity and costs as the tooling and associated cost component do not exist for AM processes. Moreover, a significant reduction in material use, waste, and production time can be achieved with AM processes. This is beneficial in an environmental point of view and meets the sustainability demands of the built environment. In addition, geometrically complex and individualized components can be fabricated. While doing so, traditional manufacturing processes can be cost prohibitive.

Currently, polymer AM is accessible and affordable. Therefore polymers are the most used materials for AM. The demand for high-quality components with strength requirements in the aviation, aerospace, and automotive industries shifted from the use of polymers to metals. Where conventional manufacturing reaches its limitations in both, terms of design freedom and manufacturing capabilities, metal AM techniques are transforming the manufacturing industry. For example, there are already about 30 components, produced with metal AM processes, installed in a Boeing 787.

Techniques
According to the standard terminology for AM by ASTM (American Society for Testing and Materials), AM technologies for metal components can be mainly classified into powder-bed fusion, directed energy deposition, binder jetting, and sheet lamination. Typical metal additive manufacturing materials are stainless steels and aluminium or titanium alloys. Current metal AM technologies use these materials generally in the form of a powder or a wire, and therefore can be classified as either, a powder-feed/-bed process, or a wire-feed process with regard to how the material is supplied.

Powder-bed
The majorities of the research in AM have been focused on the powder-feed/-bed AM, where the laser or electron beam equipment is used as power source. In this process, the object is built up layer by layer from thin layers of metallic powder. When a layer of powder is deposited, the metal particles are fused together using lasers or an electron beam, producing a small slice of the final object.

A new layer of powder is then laid on top and fused together. The entire process takes place inside an oven in which the environment is controlled.

Wire-feed
The wire-feed additive manufacturing (WAAM) process is based on a widely known technology called arc welding. A robotic WAAM system consists of a robot arm with a nozzle, connected to a controller, a power source and a gas and wire supply. The wire is fed through the robot arm, and the electric arc is formed at the nozzle (the end of the robot arm). By slicing up a 3D computer model of a component, toolpaths are created. The robot arm can move according to these toolpaths, building up the 3D object.

Structural applications
Small-scale
The powder-bed approach is better developed due to its capability of fabricating parts with high geometrical accuracy. The size of the printer and the low deposition rate limits its application to small-sized components. An example where this technique is applied is the structural node, designed and engineered by Arup, which is optimized with a topology optimization process (*Figure 1*). The result of the project is a printed node in a tensegrity structure that is 75 percent lighter than the original, welded, node.

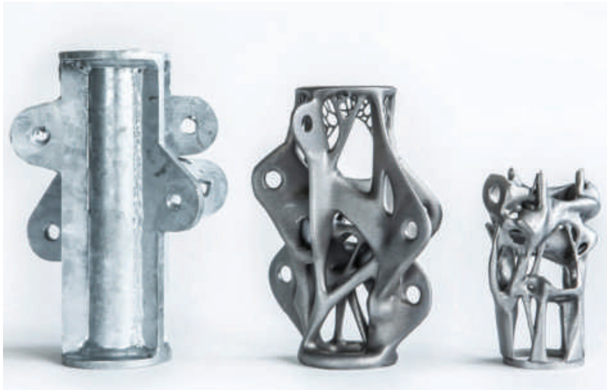


Figure 1: Original node (left) and optimized nodes by Arup

Large-scale
Wire-feed AM has a much higher deposition speed and the use of the robot arm allows for a large reach, making it more suitable for printing medium to large-sized applications. One recent application is the steel bridge that is printed by MX3D in Amsterdam (*Figure 2*). MX3D is an Amsterdam based company, founded by Joris Laarman, which is specialized in digital fabrication.

Arup worked in close collaboration with MX3D to come up with the design which is based on a structural (stress-line) optimization, defining the beam layout of the deck and the removal of unused material in the handrailing. To prove the structural capacity of the bridge, without existing regulations for metal additive manufacturing, Arup set up an experimental text program. In addition, Arup is currently providing technical advice on site and supporting MX3D in the ongoing communications with the municipality.

What's next?
Additive manufacturing is beginning to find its way in our industry. Although still early days, this production approach (and related design freedom) has triggered the interest of many different parties throughout the design and construction process. It is shown that additive manufacturing can provide mass customization, material reduction, and integration of different functionalities.

Figure 2: The printed stainless steel bridge by MX3D at the Dutch Design Week 2018 in Eindhoven

Nevertheless, the available technologies are not yet attuned to our applications and certification will take time to be developed, requiring a lot of engineering judgement. Better understanding of material properties and behavior is required and the influence of printing imperfections (such as welding flaws, variating thickness and deviation from the neutral axis of the printed geometry) and residual stresses needs to be explored (*Figure 3*). These effects and imperfections differ greatly per material and AM technology that is used.

Currently, the design for AM is, in most cases, based on traditional thinking. Even though AM provides a lot of design freedom, the production process can still become really complex if the requirements are not taken into account. An integrated project approach is required, not only by engineer and producer, but also the involvement of the designer and builder is essential.

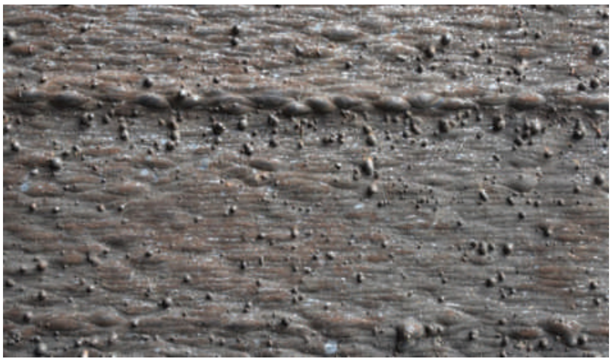
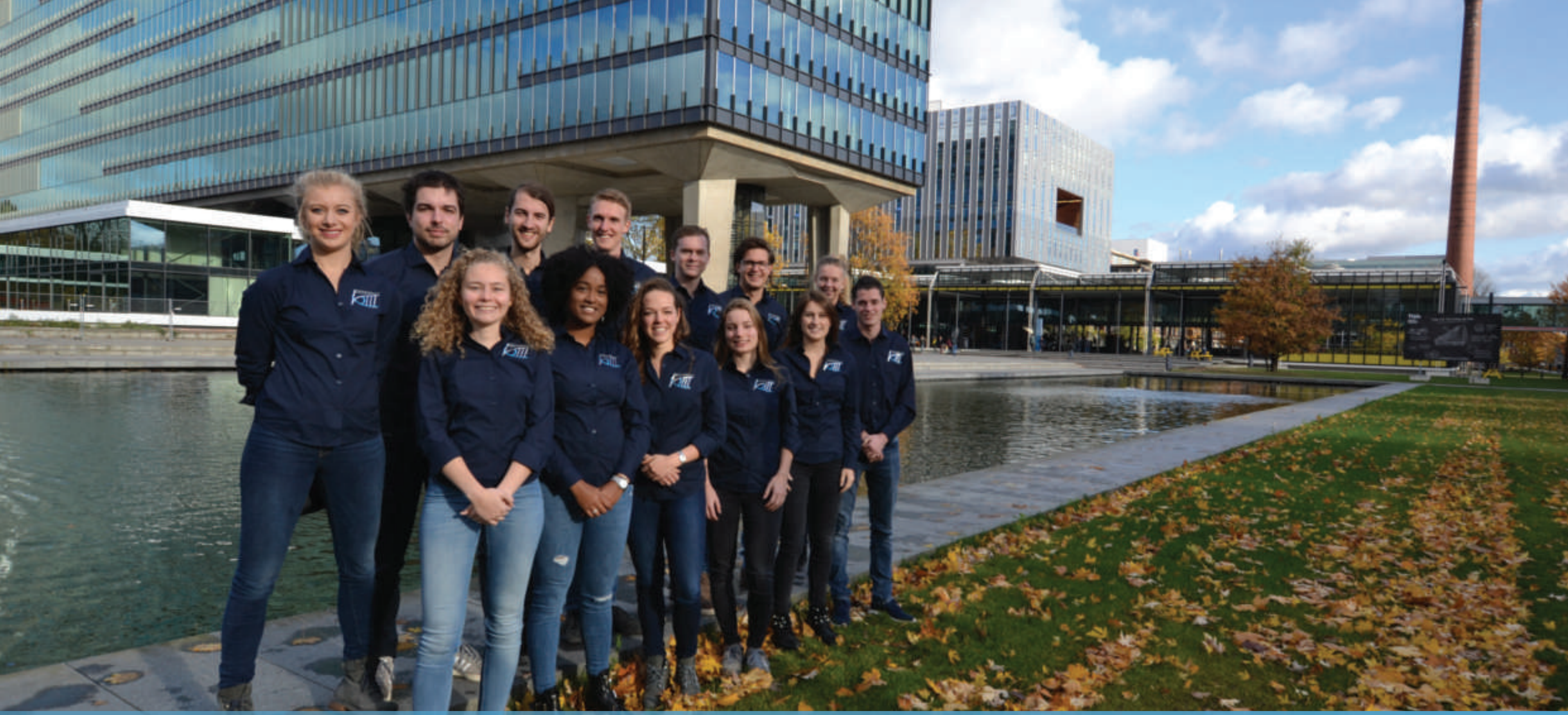


Figure 3: Rough surface of an element printed with wire-feed additive manufacturing

Arup invests continuously in ideas to support innovation and to add value to our projects and clients. The structural node and the MX3D bridge project showcase the design freedom and innovation of additive manufacturing (AM) in the context of a real Arup project. In this phase we investigate further properties, qualities, and search for the possibilities of this technology in the built environment, based on lessons learned from the previous phase. ◀



The real story on how the KOers gang survived the 8th lustrum

The KOers maffia

By: Derk Bos
Member of the 8th KOers lustrum committee

December 3rd 2018 – 7:15pm
Our police department receives an alarming call of a cold blooded murder in Eindhoven. Me and my colleague hurry to the grand café where the murder occurred. When we arrive, we find a relaxed group of approximately 80 alumni and students that are enjoying a dinner together. During the opening of the lustrum, inspiring talks were given by alumni. Also, the exhibition, which would be visible throughout the whole month, was opened spectacularly.

After the opening and viewing of the exhibition (*Figure 1*), the group has moved to the restaurant where the students and alumni got to know each other while enjoying a dinner. It seems as if nobody has noticed anything of the murder. A celebration does not feel like the time to start killing people, but between the first call and our arrival, two other murders have been committed as well! This must be a professional at work. We take our notes and leave the crime scene to start thinking. What could be the motive of the murderer? Also, how is it possible to kill three people in one afternoon and evening without anyone noticing?

Figure 1: Overview of the exhibition

December 7th 2018 – 11:00am
After a few quiet days, we receive another disturbing call that seems to be related to the 8th lustrum of KOers. This time, only a group of students is present when we arrive. They are working with heavy machinery to construct bridges out of recycled material. Three smaller groups are formed, each building their own bridge (*Figure 2*) that is put to the test later that day under the supervision of the qualified jury. Strangely, none of the participants seem to have noticed any murdering. Maybe one of the hammers is used to conduct a murder? We stay in closer contact with the association and make sure that we are present during the next activity to see what is happening with our own eyes.

Figure 2: Building bridges during the ABT design challenge

December 12th 2018 – 3:00pm
We have infiltrated. During the so-called 'Lustrum Talks' (*Figure 3*), not only a big group of students is present but also some staff and passersby, so our presence will hopefully not be too obvious. We receive interesting presentations about self-healing concrete, metamaterials, 3D printed steel, and

chemically threatened glass. After the interesting lectures and discussion about the future of structural design, one of the students comes to us. "Are you officers?", she whispers, "I think someone tried to kill me". We walk to a different room to be able to have a normal conversation. "Did someone threaten you or what do you mean by 'think'?". "No, nobody threatened me, but they tried to make me say something". She explains "I really cannot tell you what, it is too dangerous" and she walks away.

Figure 3: Lustrum talks

December 14th 2018 – 7:00pm
Again, we do not hear from any occurred murders for a while. One of our colleagues does find an e-mail stimulating people to murder others to earn 'points'. It seems like this is not the work of a single serial killer, but a structured organization. The lustrum celebrations continue with a dinner and gala at a different location than the campus. When we arrive at the Paviljoen Genneper Parken, we see a beautiful scene full of well-dressed people (*Figure 4*), who are enjoying a luxe three course dinner.

After the dinner, the group moves to the dancefloor and more people join the festivities. Everybody seems to enjoy themselves, but approximately every 20 minutes we hear that someone is murdered. Unfortunately, collecting evidence is not as easy than one would expect. The only track of blood we thought to have found turned out to be a splash of wine.

Figure 4: Lustrum gala

December 19th 2018
The last week of the lustrum has started. It is about time the KOers Mafioso reveal themselves or we may never find the mastermind behind these cruel murders. Luckily, we still have two activities on the horizon. The first being an excursion to a distribution center in Eindhoven (*Figure 5*). Under the presence of the project manager and leading engineer we are informed about all the details and get a tour around the site. Again, a very interesting activity that taught us a lot, but no murders were committed this time. We expect that the Mafioso knew that we would be present and took cover for a while. Tomorrow is our last change, so we better make it count.

Figure 5: Excursion to Nieuw Acht, Eindhoven

December 20th 2018
We are in disguise again. This time we can completely overview the room as bar personnel in de Oude Rechtbank during the Pubquiz. Ten teams are competing against each other to prove they have the most knowledge about varying topics. The building knowledge of the contestants gets tested, but they also must prove themselves on more general topics such as music, topography, and random facts. Again a few people get murdered in between the quiz rounds, but we are not able to find any dead bodies whatsoever. Just after the quiz is finished, we are ready to take our defeat and go home. But then something unexpected happens…

The moment we have been waiting for. Willem takes the stage to announce the winner of the 'Murder game'. Murdering people is not a game really, I think to myself, and is the chairman also the leader of the KOers Mafia?! We wait patiently to find out more. He continues to explain that the results were very close, and that Tim came out as the ultimate winner! We keep still to see what happens next. At 12:00am exactly, the 21st of December, bottles of champagne are opened to celebrate the birthday officially.

After the event, we arrest Willem and Tim to find out more about the criminal activities they are involved. At 2:30am we start asking questions. "It was just a game" Tim screams. "Nobody got hurt!" Willem continues. We interrogate them for 5 hours during the night but are not able to get anymore information about the cruel deeds that have been done in December 2018 and due to missing evidence, we had to let them free after a long night.

We hope everybody was able to enjoy all the festivities and was not disturbed by all the murdering that was going on. And for us, the failing detective team… We got kind of inspired to study something else like Structural Design after all the interesting activities we got to visit.
Case closed. ◄

Albert Cuyp Garage

By: ir. J.W.J. (Jan-Willem) Hoekstra.
Senior Advisor at Van Rossum Raadgevende Ingenieurs b.v.

An impressive design with an even more impressive feat of engineering. An innovative principle has been used to create a floor that integrates the underwater concrete floor with the final floor of the garage. The floor is reinforced with steel fibers to optimize the thickness of the floor as much as possible. This reduces the amount of concrete needed and also reduces the depth of excavation.

The pressure on the parking spaces in the center of Amsterdam is very high. That is why the Municipality of Amsterdam decided for drastic measures in area 'de Pijp', by creating a car park underneath a canal, the Boerenwetering in this case (*Figure 1*). This almost is the most ideal place for a car park, regarding the straightness of the canal and its location in between the streets. Van Rossum is involved in the project as structural engineer since the tender stage.

Figure 1: Overview rendering of the project

This is the first car park in Amsterdam which is built underneath the canals. It solves the lack of space in the center of Amsterdam rather smart with technical ingenuity. Because its potential, the car park under the canals will get a sequel in and outside Amsterdam. In Amsterdam, the next car park will be tendered in a few months. Should in the (near) future parking spaces in city center become obsolete, they can be used for commercial or public functions with a little adaption, because the building under the canals are future proof. In the design, we investigated the possibility to remove a floor to create an extra high space for a shopping mall.

To realize the idea of a car park underneath a canal, the municipality created a tender for a Design & Build contractor.

Figure 2: Slab floor with EPS weight reduction

The contractor had to realize 600 parking spaces for cars and 60 parking spaces for bicycles. Van Rossum joined with Max Bögl as structural engineer to win the tender. The architect involved in this project was Zwart & Jansma Architect.

To create the 600 + 60 parking spaces needed, it was necessary to design a garage with two parking levels. It is located 3 meters beneath canal water level and the underside of the lowest floor is 10 meters below ground level. The garage has a width of 30 meters, a length of 260 meters and is located a little off center to the canal so there is room for an entrance next to the canal, to be entered directly from the street. The structure from bottom to top is as follows. The lowest floor consists of an integrated underwater concrete floor – basement floor. Parallel to the length of the garage, loadbearing prefabricated walls are placed with one row of columns in the middle, which gives a floor span of 15 meters. Both the second floor and the roof of the garage consists of a wideslabfloor with blocks of EPS to reduce the weight of the floor. The parking floor has a thickness of 50 centimeters and the roof of the garage, which also is the bottom of the canal, has a thickness of 70 centimeters. Both floors have an integrated floor beam across the columns (*Figure 2*). The prefabricated loadbearing walls do not seal the garage from the water, therefore the sheet pile wall has been welded to create a watertight structure.

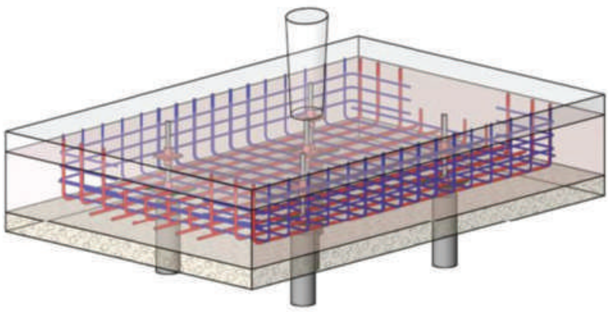


Figure 3: Integrated pile cap rebar in underwater concrete

The depth of the structure makes it necessary to use an underwater concrete floor. Usually, this floor is regarded as a temporary structure and the thickness is added to the total height of the structure. To optimize the total thickness of this floor, we integrated this temporary floor with the final structural floor. The underwater floor is strengthened with steel fibers and the rebar required in the pilecaps is integrated in the thickness of the underwaterfloor (*Figure 3*) this saves excavation and a lot of concrete. ◀

News

By: Cement
Knowledge platform about concrete structures

Comfort pedestrian bridges
The sensitivity to vibrations is an important, but often underexposed, theme in the design of bridges. Especially with slender pedestrian bridges (*Figure 1*), the comfort requirement with regard to the vibrations of the bridge deck can become decisive above the strength requirement. This is because slender bridges have a relatively low natural frequency and the frequency of pedestrians can come close to the natural frequency of the bridge.

In that case, a bridge, due to the rhythmic excitation by pedestrians, can come into resonance. This can be unpleasant for other people present on the bridge. In the extreme case when people feel unsafe, the bridge will be (temporarily) closed for research and possible measures follow. Therefore, it is important to take comfort into account when designing relatively light pedestrian bridges.

Figure 1: Pedestrian bridge Voldijk

The comfort of a pedestrian bridge is described by the accelerations that occur. Maximum requirements are attached to this acceleration. A simple and insightful way to calculate the accelerations is to schematize the structure in one or more one-mass spring systems. Such a system has a number of natural frequencies. Only the bridges whose natural frequency falls in the area of the frequency of the impact must be assessed.

Underwater concrete floor loaded after 72 hours.
The Hoofdstraat at Driebergen-Zeist station (*Figure 2*) has been a major bottleneck for decades. That is why the station area gets a thorough facelift. One of the challenges in the project is the underwater concrete floor.

Figure 2: Driebergen-Zeist

This underwater concrete floor is part of the new underpass. For this part, a train free period (TVP) of only 16 days was available. To use this period as efficient as possible, a solution was sought in which the underwater concrete floor could be loaded as quickly as possible. In other words, that the construction pit could be emptied as quickly as possible.

Critical for the floor was controlling the crack formation. For this reason, the floor is reinforced with glass fibers. This solution has been extensively investigated beforehand, which included consideration of the processability of the mixture and the fiber dosage required to prevent leaking cracks. Various test pieces have been produced and tested in the laboratory of the supplier of the fibers in Chambéry (France). A test dump was carried out in the preparation for the actual dumping.

A FEM calculation has been carried out based on all data. All phases of the floor are considered, from just after pouring of the concrete, to pumping out of the water. The different models showed that the occurring crack width in the floor would remain within the desired margins. This made it possible to conclude on the basis of the calculations that the floor would be waterproof after pumping out of the water. Eventually, the floor was poured on 17 August 2018. After 72 hours, the stress on the floor was released by pumping the water out of the construction pit. ◀

More about testing comfort and a calculation example can be found on:
https://www.cementonline.nl/dynamica

More about the project Driebergen-Zeist station area, both on the underpass and the insertion of the decks, can be found on:
https://www.cementonline.nl/station-driebergen-zeist-1

Without innovation and data, there will be no future

Importance of innovation

By: Willem van Dijk
Heijmans

Heijmans was established in 1923 and quickly knew how to stand out from the crowd using innovative ideas. This culture has blazed quite a trail over the last 90 years. And anyone who thinks it is going to stop will have made a fool's bargain. Because the essence of innovation and data is that it must always continue, modernization is a necessity to become better, faster, and more intelligent. The construction industry is not really considered a distinctly innovative sector, certainly not in comparison to for instance IT, the food products industry or the energy sector. However, appearances can be deceiving. The building industry makes a lot of use of innovations from other sectors and adapts them for use in the buildings it creates.

Our unique quality is the integrated approach to construction and installation technology. Furthermore, our contracts that include long-term management, maintenance and service are increasing. A good example is the DBFMO project National Military Museum, which includes the realization as well as the maintenance and management for a period of 25 years (*Figure 1*). The integration of these activities and results in knowledge of conceptual as well as constructional skills. This in turn produces generic living and residential concepts, such as Heijmans ONE, Heijmans Huismerk, and Heijmans Wenswonen, and underlying standardized work processes and cooperation with partners. This makes it possible to realize complex city center transformation projects, as well as new serial development projects.

Figure 1: National Military Museum

Digital construction

Constructing and maintaining a building can be done in advance with computer simulation. We can calculate a multitude of scenarios (rainfall, heat, power failures, many more / fewer people who use a building) and vary them in variants in time and money to find out exactly where the weak points are, but also strengths in the design. This enables us to create buildings that are better prepared for the future and make the execution process safer and more predictable. This predictability also continues by applying artificial intelligence and parametric design. In the complex issues of geometry and constructions on the present day, parametric design offers the possibility to make changes to a responsive model in the various stadia of the design process. With the use of algorithms, designs can be generated instead of a created, generative design. This allows us to spend our time efficiently on more other aspects like the built environment.

This process of 'Design by Performance' enables us to generate models quickly and performance-oriented and thus create added value. It is essential to optimally use the digital possibilities of big data to optimize business processes and building management. BeSense goes beyond just collecting data (*Figure 2*). The power lies in the total picture, linking smart systems to people and users. Developing together with partners in a creative and open way ensures that BeSense is unique, so that we can respond optimally to the wishes of our customers. We will apply these techniques and initiatives more to other professions like structural engineering, building physics etc. With this knowledge we are ready for the future.

Figure 2: BeSence

Modular and circular

Circular economy thinking increasingly finds its way into our projects. Our team of multidisciplinary experts aim to integrate circular principles in our designs, as it becomes more and more naturally to assess future-use scenarios during project inception. We also research the re-use of complete existing buildings, 3D modular building elements, and new building materials or incorporate those options into a completely new design for future change of use. By looking at a building's various layers, an appropriate circular design strategy can be found for each part. Excellent cooperation between client, contractor, and the construction supply chain is essential. This makes our buildings better, smarter, and more sustainable. Ultimately, ideas and solutions can create added value for clients, if they are also good for the living environment. As Heijmans that is exactly where we can make a difference for the built environment. Therefore, we strive to combine creating value and social relevance.

Do you want to be part of this further innovation and part of the root of development in new concepts? Contact the organization Design & Engineering for jobs or possible graduation research. ◀

Thomas van Vooren

The experience of...

By: ir. Thomas van Vooren
Structural designer at Aveco de Bondt

In March 2018, I graduated from the master Structural Design at the Technical University in Eindhoven. Before this, I already signed to work as a structural designer for Aveco de Bondt in Eindhoven. In November 2017, I spoke with some employees, now my colleagues, of Aveco de Bondt at the Bouwkunde Bedrijven Dagen. I was interested in this company because of the diversity of projects in terms of scale but also in terms of design, referring to the wide range of different projects they are working on. In addition, I saw it as a company that had a lot of different specializations under one roof. This results in a broad view on the total building process, from asset management and pre-design phase all the way to the final design phase and construction phase.

So, in April last year, I started working as a structural designer at the structural design unit of Aveco de Bondt in Eindhoven. My first projects mainly consisted of foundation calculations for residential projects in Noord-Brabant and Limburg and some calculations for steel structures in larger projects such as Brainport Industries Campus near the A2 in Eindhoven. Furthermore, together with colleagues, I went to construction sites for inspection and, by order of insurance companies, to buildings with water damage due to heavy rainfall or structures with fire damage. On these structures, a safety investigation had to be performed.

After those weeks, I started with a larger project, namely two residential buildings on top of a parking garage and 49 houses in Zeist (*Header*). The fun of this project is the interaction between the architectural design and structural design, which I experienced in this project for the first time at a larger scale. As a structural engineer, you are not only just the person who performs the calculation, but you are an important factor in the predesign phase where the challenge is to understand what the architect wants and transferring that into a realistic and safe design. In addition, I worked on several parts of the steel structure design of several distribution centers around Eindhoven and I went on some more inspections for insurance companies. I still work on the housing projects with foundation calculations sometimes. However, these projects are now expanded with a control part of the construction which includes more interaction with the construction partner.

Since last year, Aveco de Bondt has a special association for young employees called 'the Young Bondts'. This association organizes several formal and informal activities during the year for all the young employees of the different offices and departments. Last year, we had lectures, workshops, and drinks and for coming year new activities are already planned. These opportunities are very suited for talking with colleagues in an informal way, but also to get to know more about the many different career possibilities within the building sector.

A tip I would give to you as a student is to orientate as much as you can. Talk with professionals at meetings like the Staalbouwdag, the Betondag, or the Bouwkunde Bedrijven dagen. But more important, do an internship and talk with other students to compare each other's experiences. There is a huge demand for structural engineers, so there are a lot of opportunities. Make use of that! ◄

Studying abroad, a once in a lifetime occurrence!

Exchange experience of a KOers member

By: Merel van de Ven
Master student Structural Design

It is almost over. I am leaving for Eindhoven again soon, after having lived and studied in Lund for almost half a year. It was a once in a lifetime occurrence, which I will never forget for sure! Lund is a city in the province of Skåne in the South of Sweden. Malmö, a bigger city, takes 15 minutes by train and from there, when you pass the famous Oresund bridge (also known from the Netflix series 'The Bridge'), Copenhagen takes you only an additional 35 minutes.

Lund University, also known for its very romantic with leaves covered university library (*Figure 1*), is one of the top five universities in Sweden. This becomes really clear when you walk or bike through Lund. It is all about the students! Student accommodations are everywhere, crappy bikes are parked on every corner of the street, the whole city consists of faculty buildings, and student nations - which are called after the big cities of Sweden - are always open for fika (coffee with a snack), lunch, dinner, pub nights, or parties.

Figure 1: University Library

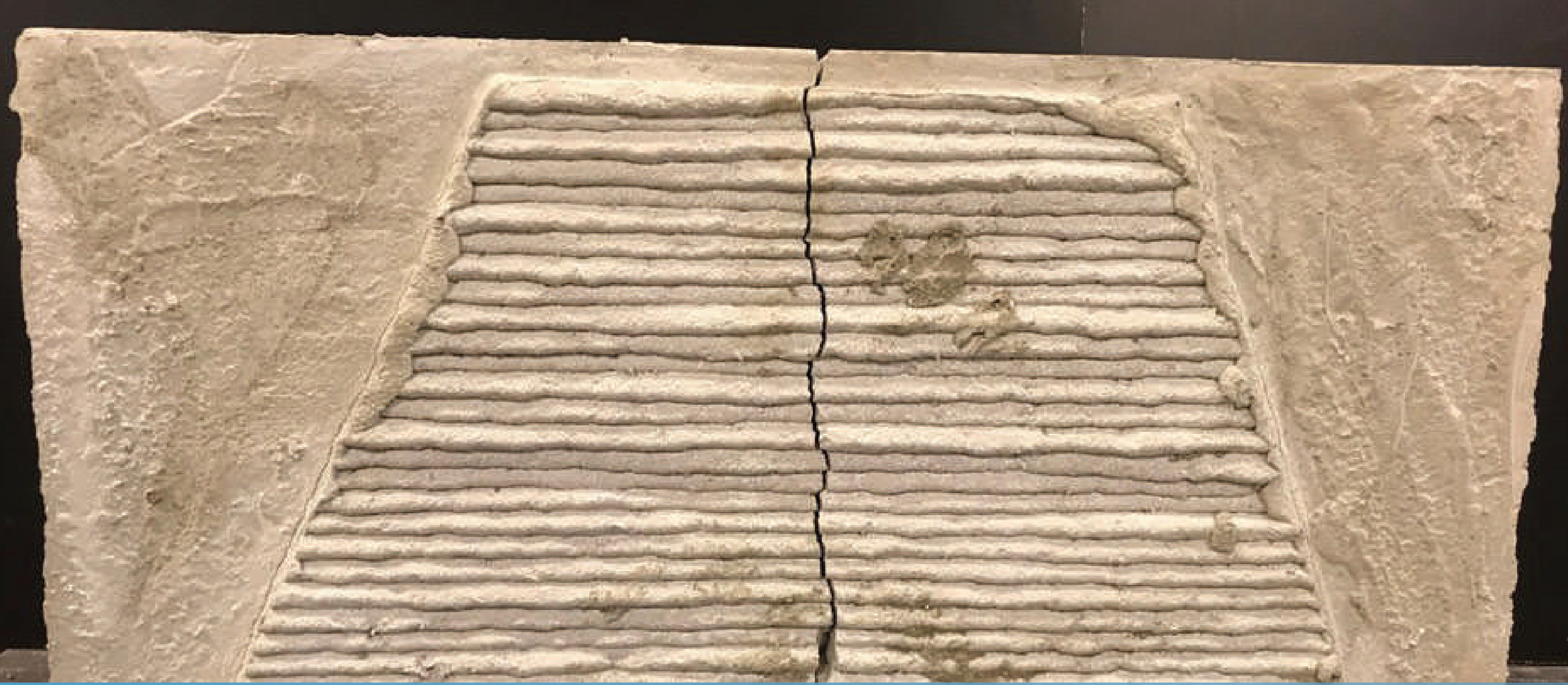
It all started in August with an introduction from the university where we, as international students, could attend events such as 'speed friending' in which we learned to 'mingle' with other international students, awkward but useful! After that, I did a two week Swedish introductory course. Knowing a little bit of Swedish helps a lot when you live in Sweden. Then, the four week lasting Nollning started, which is the introduction week for the student unions.

I thought that the Dutch introduction week was rough, but the Swedish students are worse! They behave like Vikings by jumping in lakes, sing like crazy at sittings (fancy dinners with authentic Swedish food), and party all day and night.

At the Faculty of Engineering (LTH), I did my free electives in Civil Engineering. I had a course in bridge engineering, where I worked together with an Austrian student on a composite road bridge that we had to calculate entirely, and on conceptual designs of a pedestrian bridge. The projects were very realistic because we were supervised by a bridge construction company. In addition, we got the unique opportunity to go on an excursion to the Oresund bridge (*Figure 2*). During this excursion we walked over the trusses which is normally not allowed.

Figure 2: Oresund bridge

Another course I took was Field Investigation Methodology. Here, we learned about non-destructive methods to investigate geology and, for example, different types of bedrock. This was an interesting addition to my studies in Eindhoven. We went on a two-day field trip where I got to experience the Swedish weather to the fullest. Believe me, the myths are true: it could be grey, without seeing any light for days long. The other courses I took were Acoustics and Risk Management in Construction Technology Applications. Generally, the master level, study load, and type of education are very similar to that what I am used to in Eindhoven. However, the fact that hierarchy in the system barely exists distinguishes Swedish education from Dutch. Even if you have a 75-year old professor in front of you, he will insist on being called by his first name. In addition, all the professors and supervisors know you by name and know where you are from, which is really pleasant. Everyone speaks English perfectly and that was beneficial for me. Colleague students are modest, quite individually focused, but very polite. And of course, as an international student, you meet new international friends, which makes you not only experience Sweden, but also a lot of other cultures. ◀



Master's thesis

Element optimization by functional grading of fiber reinforced 3D printed concrete beams

By: T.P. (Thomas) Dam

Supervisors: prof.dr.ir. T.A.M. (Theo) Salet, dr.ir. F.P. (Freek) Bos, MArch. Z.Y. (Zeeshan) Ahmed

Concrete printing is an upcoming construction method. In the meantime, the bridge in Gemert and Project Milestone in Eindhoven show its great potential. Reduction of labor hours, less waste material, and no formwork lead to substantial cost savings. There are two major types of element optimization involved with this construction principle: typology optimization and functional grading. This master thesis comprises the functional grading of beam elements by means of printing mechanical properties on demand. I would like to give a brief introduction to this innovation.

A lattice girder is an example of a topology optimization, in which the material is used as efficiently as possible regarding the force transmission in an element. Functional grading considers the material and mechanical properties at the required position within an element. Fiber reinforcement is applied in order to improve the tensile capacity of concrete. In traditional fiber reinforced concrete (FRC), there is a constant percentage evenly distributed over its volume. However, in most load cases this is not necessary. Take for example, a simply supported beam subjected to a concentrated load. This case has a larger flexural moment at the middle of its span, so more reinforcement at mid-span is required compared to other zones. Moreover, compressive forces are transmitted above the neutral axis where reinforcement can be omitted. The stress distribution depends on the slenderness. In deeper beams, direct bearing of a point load to the supports results in compression struts. As a result, splitting tensile forces occur perpendicular to these diagonals.

Prior to the study into the fiber positioning, the effects of the specimen size and slenderness are analyzed since the dimensions are restricted to the print path and deviate from Eurocode standards. The reference beams for the size and shape effects have dimensions of 150x150x600 millimeter and 40x40x160 millimeter, respectively, set on dimension factor 1.0. In addition, plain concrete (F0) and FRC (F1) concrete are tested after 7 and 28 curing days. *Figure 1* and *Figure 2* indicate the test results.

Generally, smaller specimens show higher flexural tensile strengths. The effect of fibers is larger in a small cross-section since the fiber dimensions are not scaled down. Plain concrete is more sensitive for a shape effect since FRC is

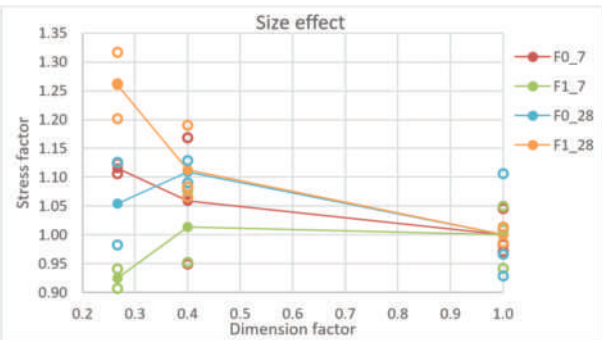


Figure 1: Experimental results of size effect

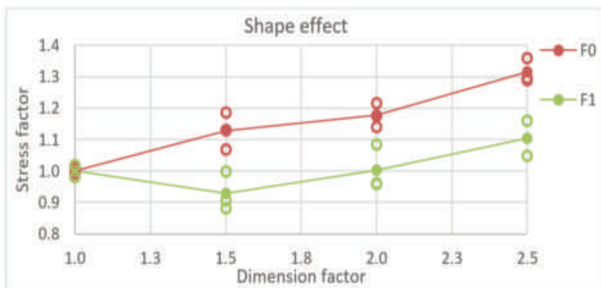


Figure 2: Experimental results of shape effect

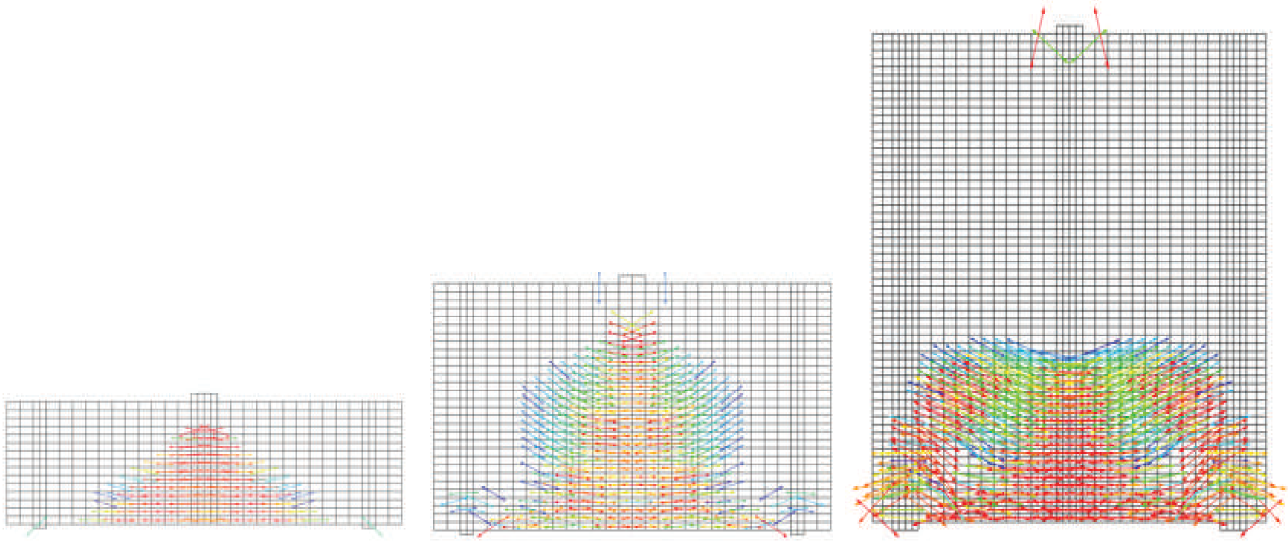


Figure 3: Critical tensile stresses exceeding the plain concrete capacity for a slender (h = 150 millimeters), deep (h = 300 millimeters) and very deep beam (h = 600 millimeters)

better capable to redistribute the stresses. However, there is no unequivocal proof for firm conclusions due to deviating values.

In addition, this study contains material studies to different fiber contents in order to determine an appropriate fiber type and content. Also, an innovation for the production of FRC printed elements is developed since this has never been done before anywhere. More information on these devices will be published soon.

Figure 4: Slender beam optimized by functional grading (h150_OPT2)

The layered manufacturing principle of 3D printing gives the opportunity of the application of different materials adjusted to their functions. A numerical model is established to investigate the optimized fiber positioning that shows the same capacity as fully FRC beams. *Figure 3* shows the critical areas where FRC must be applied since the tensile stresses exceed the maximum strength of plain concrete. The triangle-shaped zone changes into a trapezium shape by increasing the beam depth.

The strut-and-tie action causes splitting forces in the compressive struts. In this way, a 69, 55 and, 69 percent fiber reduction in slender beams up to very deep beams is achieved, respectively. However, the peaks loads are deteriorated with a 0, 6 and, 16 percent. The numerical study is verified by experiments. *Figure 4* shows the optimization of a slender beam. The FRC is printed and the plain concrete

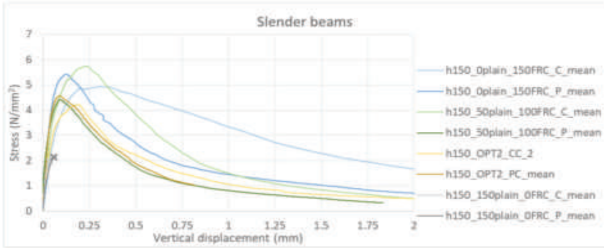


Figure 5: Flexural stress–vertical displacement graphs for slender beams (h=150 millimeters)

is casted since, at this stage, the printing equipment is not able to alternate the fiber supply at any exact location.

Figure 5 and *Figure 6* show the experimental results for slender and deep beams. Additional optimizations are tested consisting of casted (C) and printed (P) partially reinforced concrete. For example, h150_50plain_100FRC corresponds to 50 millimeters plain concrete on top of 100 millimeters FRC. The optimizations show similar peak strength and behavior as fully FRC beams. However, some printed specimens have a lower peak load or a worse post-peak behavior due to less homogeneousness of the material or less fiber supply during the production.

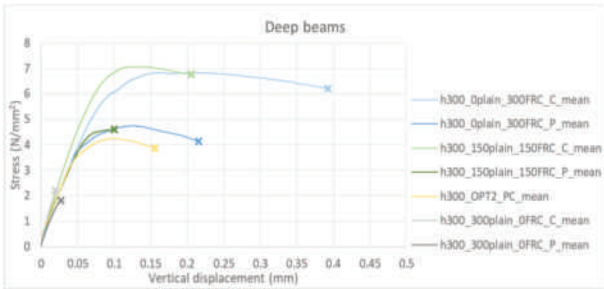


Figure 6: Flexural stress–vertical displacement graphs for deep beams

The combination of topology optimization and functional grading makes 3D printing unique. Hopefully, this master thesis contributes to make concrete printing a serious future alternative in contrast to the limitations of the traditional construction method. ◀

Master's thesis

Dynamic behavior of Timber-Concrete floors

By: Jemima Klaassen

The concept of timber-concrete composites (TCC) consists of a composite element with a timber element and a concrete slab that is connected by a special connecting device. The composite uses the compressive strength of the concrete and the tensile strength of the timber. Even though timber-concrete composites have been applied for several decades, the calculation methods are not yet definitive.

The Eurocodes for timber-concrete are still in development. There will be a section for TCC in the new Eurocode for Timber structures (Eurocode 5). For the vibration criteria of a TCC floor, there is a reference to the criterion in Eurocode 5. However, there is not much known yet about the dynamic behavior of TCC floors.

My project goal is to give some clarification on the dynamic behavior of TCC floors caused by walking loads. The topic of my research is the effect of the increased transverse stiffness of the concrete layer on the timber beam, what the effects are on the dynamic behavior and the comfort of the floor.

In addition, I will try to get a better general understanding of the composite material. For the experimental tests, I

Figure 1: Timber concrete floor used for the experimental tests

constructed a timber joist floor and used Tecnaria dowels as a connected before pouring the concrete. After testing the floor, it was sawed into five T-beams to compare the behavior. I performed two types of dynamic tests to simulate a walking load. These results were compared with the hand-calculations and a FEM model. ◀

Forcing columns into higher order buckling modes

By: Derk Bos

Buckling is an instability phenomenon that occurs when slender elements are loaded mainly under compression. In the built environment, buckling is critical in for example columns that are spanning over multiple floors, columns that are unbraced in lateral direction or slender plates that are used as sheeting. When an element fails due to buckling, the material is not fully used, since the ultimate strength is not reached when buckling occurs. The geometry of the element becomes unstable. From the Euler buckling equation it can be concluded that the resistance to buckling can be increased by increasing the Young's-modulus, second moment of inertia, order of the buckling mode or by decreasing the critical length. A different Young's-modulus can be achieved by changing the material, a different second moment of inertia can be achieved by changing the cross-sectional geometry and a different critical length and buckling mode can be achieved by changing the boundary conditions. In this research, it is proposed that higher order buckling modes can also be achieved by changing the geometry over the height of the element.

By applying an imperfection according to a higher order buckling mode, it is expected that the column will deform in this same mode. Just before the first buckling mode occurs, deformations have increased, and therefore more energy would be needed to force the column in the first mode. This would cause the column to skip the first mode and reach a stable equilibrium path according to a higher order mode.

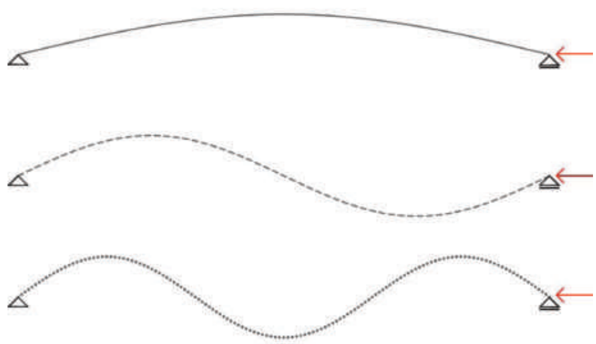


Figure 1: Regression analysis of experimental results

To research the problem, the weak form of the equilibrium equations, including von Kármán non-linear strains, are solved using a Galerkin approximation. The results are compared to a finite element model. After the model is validated, a parametric study on the influence of imperfections is conducted resulting in design graphs. As a third validation of the principle, an experimental study is conducted by performing compressional test on imperfect columns. ◀

A sound probabilistic approach

Fatigue resistance of structural details for bridge infrastructures

By: Davide Leonetti, MSc.
Ph.D. Candidate October 2015 – October 2019

Structural components should guarantee a certain predetermined safety level with respect to limit loads. In common practice, partial safety factors are used to guarantee a safety margin large enough to satisfy the required safety level. In the past, these values were obtained by engineers and practitioners based on their experience. Basically, the partial safety factor is a number that is multiplied to loads (resistance) in order to add conservativism considering what was not explicitly accounted in the load (resistance) model, e.g. scatter in material resistance and in loading conditions, trends, et cetera. In the recent years, the advances of research, the development of statistical methods with respect to structural reliability analyses, and the increased performance of computing machines allow the safety factors to be estimated based on sound physical and probabilistic approaches.

Most of the real structures are not only loaded monotonically but also cyclically when subjected to real in-service loading. The effect of cyclic loading determines an irreversible material deterioration process called fatigue that, under certain conditions, starts at the microscale, leads to the nucleation of crack(s) at the free surface, and eventually to sudden brittle collapse after the fatigue crack propagated. With reference to Bridge infrastructures, the most common structural details to be assessed are either welded or bolted, for relatively new structures, or riveted, for old bridges.

Due to the complex fatigue behavior of these components, a sound probabilistic resistance model for fatigue resistance has not been fully developed yet, whilst for design purposes, the Eurocode 3 - part 9 is adopted in Europe as the standard for fatigue design of steel structural details. In it, partial safety factors are recommended depending on the adopted design philosophy and the consequences of failure.

These values can be modified by each European country in the National Annex. Previous research supported to increase the partial factor up to 50 percent. Such an increase of the partial factors would determine relevant consequences for new bridges and more drastic for existing bridges since most of them are approaching or have exceeded the design fatigue life. The first task of the Ph.D. project includes the modelling of the fatigue resistance of welded and riveted structural components using fatigue resistance curves, which relate the load level to the number of cycles to failure.

Two types of load are considered: (1) constant amplitude (CA), which is used in the greatest part of laboratory works to characterize the fatigue strength of the material and structural components and (2) variable amplitude (VA), the type of loading that structural components experience in service.

For CA loading, the relevant features to be modelled are the trend of the scatter in fatigue life, which increases at lower stress ranges. It is also relevant to quantify the uncertainty for relatively low stress ranges, where few test data are available. The modelling of fatigue resistance under variable amplitude loading requires the evaluation of complex non-linear phenomena specific to this load type, i.e. load sequence and load interaction effects, and the effect of stress ranges lower than the threshold for fatigue damage accumulation, which do not contribute the fatigue failure since the beginning of the life of the structural detail.

With respect to these goals, phenomenological models based on sound statistical modelling of the fatigue life have been formulated since the beginning of the Ph.D. project for both CA (*Figure 1*), and VA loading.

Moreover, a statistical framework has been developed to estimate and reduce statistical uncertainty. This has been done using both frequentist and Bayesian methods. In the latter, informative and non-informative prior distributions have been generated quantifying prior knowledge on the parameters of the formulated model.

With respect to riveted connections, relevant laboratory work has been executed to measure the residual axial force present in the rivets (*Figure 2*), as it was recognized to strongly contribute to the variability in the fatigue resistance.

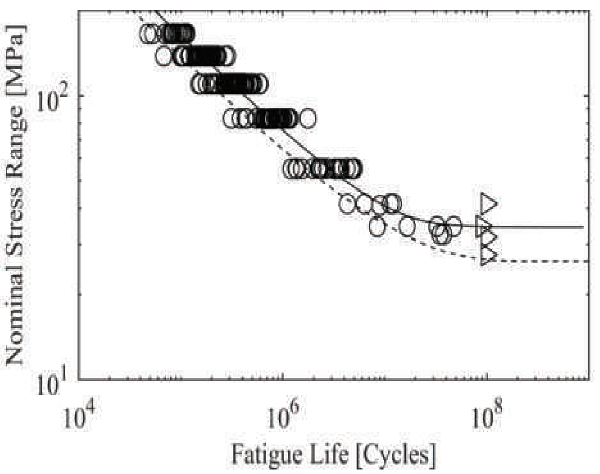


Figure 1: The probabilistic fatigue resistance curves resulting from the proposed statistical model, and fatigue test data for a welded detail obtained under constant amplitude loading. It can be appreciated the increasing variability of the fatigue life predicted by the model at relatively low stress ranges, the transition between the finite and infinite life determined by the so-called fatigue limit, the stress range below which no failure occurs, modelled as a random variable.

Approximately 70 data-points have been produced, substantially increasing the number of observation present in the scientific literature. The new dataset will be published together with a coupled non-linear thermo-mechanical finite element model that simulates the clamping process resulting from the cooling of the rivet considering the variation of the thermo-mechanical properties of the considered structural steel with temperature (*Figure 3*).

Also, a probabilistic model based on system reliability has been formulated to predict the fatigue life distribution of such structural components, which shows agreement with more than 25 datasets obtained by different scientists in the past 50 years.

Figure 2: The instrumented specimen used to measure the residual clamping (axial) residual force in the rivet. A special strain gauge is inserted in a hole produced in the shaft of the rivet, while it is clamping the plates. Subsequently, the rivet is ejected and the value of the initial clamping force is determined by measuring the relaxation of the rivet. The picture refers to a test terminated.

The remaining part of the project involves the evaluation method based on fracture mechanics in order to simulate the fatigue crack growth and obtain relevant information useful to estimate the safety of the structure when inspections are carried out. The Fracture Mechanics-based fatigue assessment intends to model the process of crack propagation due to the application of the load cycles. Therefore, it allows predicting the crack growth and plan inspection in order to monitor the status of the structure. Therefore, crack growth following inspection can be simulated and forms the basis of assessing the inspection intervals.

It follows that an important aspect of the safety philosophy of structures subjected to fatigue is the inspection strategy, the capabilities of the selected inspection method and the accuracy of the crack prediction model. Of particular interest is the so-called visual inspection, which is often applied to bridges for economic reasons, but characterized by lower reliability when compared to other methods. ◀

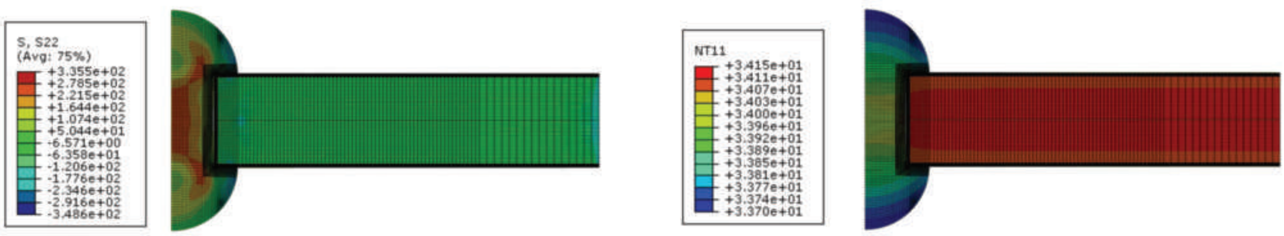


Figure 3: Temperature distribution (left) and residual axial (Y-axis) stress distribution (right) in the assembly at the end of the simulated clamping process. The finite element model is formulated considering axial symmetry with respect to the axis of the cylindrical shaft of the rivet.

New on floor 9

Dr. Ir. S.M. (Sandra) S. Lucas
Assistant Professor 3D printing Concrete

As in every KOersief, a new member of the staff on the 9th floor is introduced. In this edition, the new member is specialized in sustainable materials, has lived in multiple countries, and comes to work in the concrete chair as Assistant Professor 3D printing concrete: Sandra Lucas.

I was born in Aveiro, a small coastal town in the center of Portugal where I did my studies at the University of Aveiro. I graduated in ceramic and glass engineering and my research interest in sustainable materials led me to complete a master in the topic. This was followed by a PhD in functional sustainable materials and that was when I decided I wanted to continue doing research in this field.

Figure 1: Sandra Lucas

In 2012, after finishing my PhD, I was awarded a Marie Curie fellowship and spent two years in Germany working on a very exciting project on self-healing materials. During this time, I spent three months in Delft and became quite fond of the country. However, it would still take some time before my path crosses the Netherlands again.

"My career so far has given me the privilege of experiencing teaching in higher education in different countries and this has definitely contributed to shaping who I am as a lecturer now."

In 2014, I took a position as senior lecturer at the University of Greenwich, in the U.K. I spent 4 years teaching and conducting research in materials science and engineering. So far my career has given me the privilege of experiencing teaching in higher education in different countries and this has definitely contributed to shaping who I am as a lecturer nowadays. The level of multiculturality in the U.K. is reflected in the country's universities, having students from every continent in the world sited in the same class was both a rewarding and challenging experience.

"I am truly enjoying my new life here and settling in was not difficult at all."

While working in the U.K. I came across a position in 3D-printing of concrete at TU/e, I was very interested in the topic so decided to apply. Now here I am, living and working in Eindhoven. Since June 2018, I am an assistant professor at TU/e, working in the structural design unit at the Department of Built Environment. My research work includes investigating how the fresh properties and the composition of concrete can be optimized for the 3D-printing process. This is a new, revolutionary method of making concrete, we need to relearn how to prepare and produce it, but if we succeed, this will be a giant leap for the industry.

Figure 2: Aveiro Portugal

I am truly enjoying my new life here and settling in was not difficult at all. Living in the Netherlands – with its central location and easy access to neighboring countries – allows me to do one of the things I enjoy the most, travelling and visiting new places.

I am looking forward to continuing my academic career here, I believe TU/e is the right place, with the right conditions to continue my research. ◀

KOers Puzzle

By: Jelme Pennings, Tim Schellekens, and Derk Bos
Creative KOers members

In the previous edition of the KOers-puzzles, the submission of Bastiaan Overdorp was the closest one to the answers. Therefore, he won the previous edition of the KOers puzzle and a box of apple pastries! In this edition, there are some new puzzles and new chances to show your structural engineering skills. Submissions can be sent to: KOers@bwk.tue.nl

Question 1: Lars and his self-made huge super swing

During the last KOers Design Challenge, Lars learned a lot. Right now, he is able to build structures out of old construction materials. He is currently building a huge swing in his backyard and has just finished building a big stable and solid frame from old steel. The bucket of the swing is also finished. The only thing that is missing right now, is a bar to connect the bucket and the hinge of the frame. However, Lars has only a limited number of materials left. These materials and their properties are listed in *table 1*.

The height of the frame is 50 meters and the that of the bucket is one meter. The bar must be connected between the frame and the bucket. If the bucket is loaded (4kN in total), it should not touch the ground. The selfweight can be neglected. A schematization of the swing structure is shown in *Figure 1*.

a) Which pieces of materials are suitable for this huge swing?

b) What happens if the swing reaches a maximum speed of 15 m/s?

Table 1: Available materials

	Material	E-modulus [N/mm²]	Length [mm]
1	C20/25 Concrete column, 30x30	30,000	48,900
2	C24 Timber column, 20x20	11,000	48,960
3	S235 Steel bar, Ø6	210,000	48,900
4	6082T6 Aluminum bar, Ø6	70,000	48,900
5	PVC tube, A=390 mm²	2,500	48,650

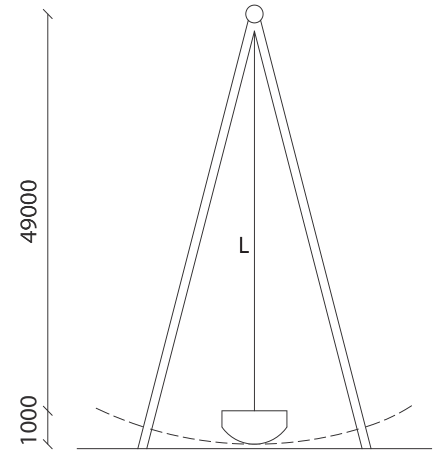


Figure 1: Lars' gigantic swing

Question 2: Willem Jo

Willem is designing a cantilevering truss for his house. However, he is unsure of the deformations that occur due to the force F on the tip of the beam. Can you determine these deformations for him using a Williot diagram? The cross-section of the thinner elements is equal to A and the thicker elements have a cross section of 2A. The Young's modulus is equal to E and the length of the elements are given in *Figure 2*. The selfweight can be neglected. Hint: use squared paper and a scale of FL/EA per centimeter.

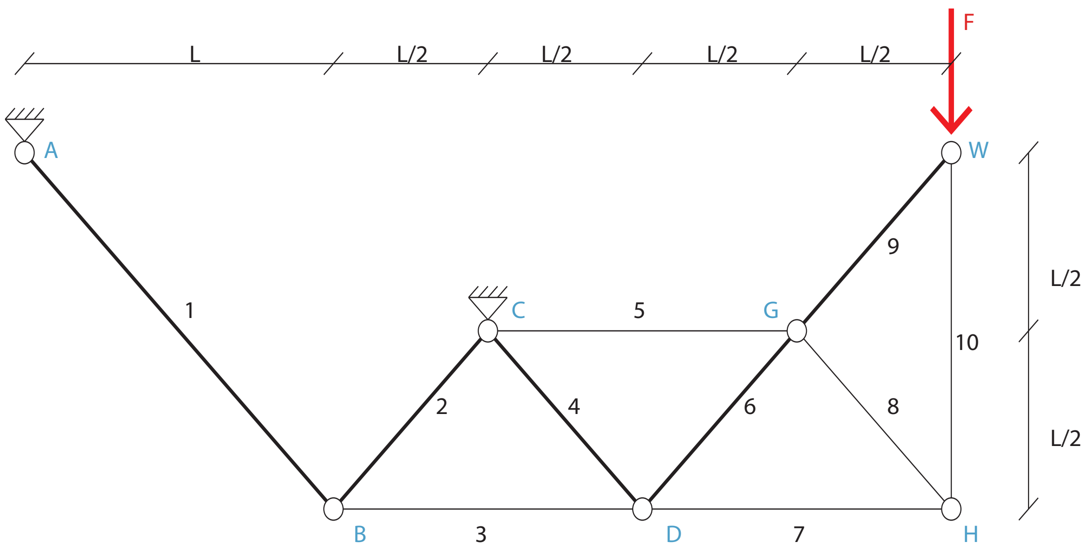


Figure 2: Willem Jo's diagram

Column

Innovative windmills

Hans Lamers

In fact, innovation is not a simple concept. In many cases innovative ideas have degraded into everyday issues, such as cost reduction or time saving. The building process in the Netherlands is fragmented, resulting in small scale innovations like material modification, material reduction, product optimization, or a more efficient principle of construction.

Actual themes such as 'the carbon footprint' are often dishonestly used as an occasion to promote a product and place it in an innovative spotlight. Companies suddenly claim that their product is 'green'. President Trump would call it 'fake news'. Maybe I am a little bit too skeptical. A lot of good developments are taking place. Real innovation comes from a helicopter view, fresh thinking.

The research at TU/e concerning 3D-printing with concrete is an example of exploring a new building concept. The printing of small bridges and houses is in progress. In this stage of the development process, every answer to a question generates two, or more new questions. Also remember, technical solutions itself give no guarantee to success and acceptance in the building market.

Of course, a more ambitious level of innovation leads to an increase in risks. My fresh thinking is rather moderate. I dream that we fearless Dutch, worldwide famous for our windmills, reintroduce these windmills and spread them all over the Netherlands. We must reintroduce these windmills and spread them all over the Netherlands. Use these innovative windmills as our new homes to live in and give them large modern turbine blades covered with flexible solar panels to produce our own electricity by both, wind and sunlight. This will give us optimal comfort.

However, I might better wake up and stop drinking.

Colophon

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