Academic year 2017 - 2018 #1 | December

MOLLIER
Study Association Building Physics and Services

INSIDE INFORMATION

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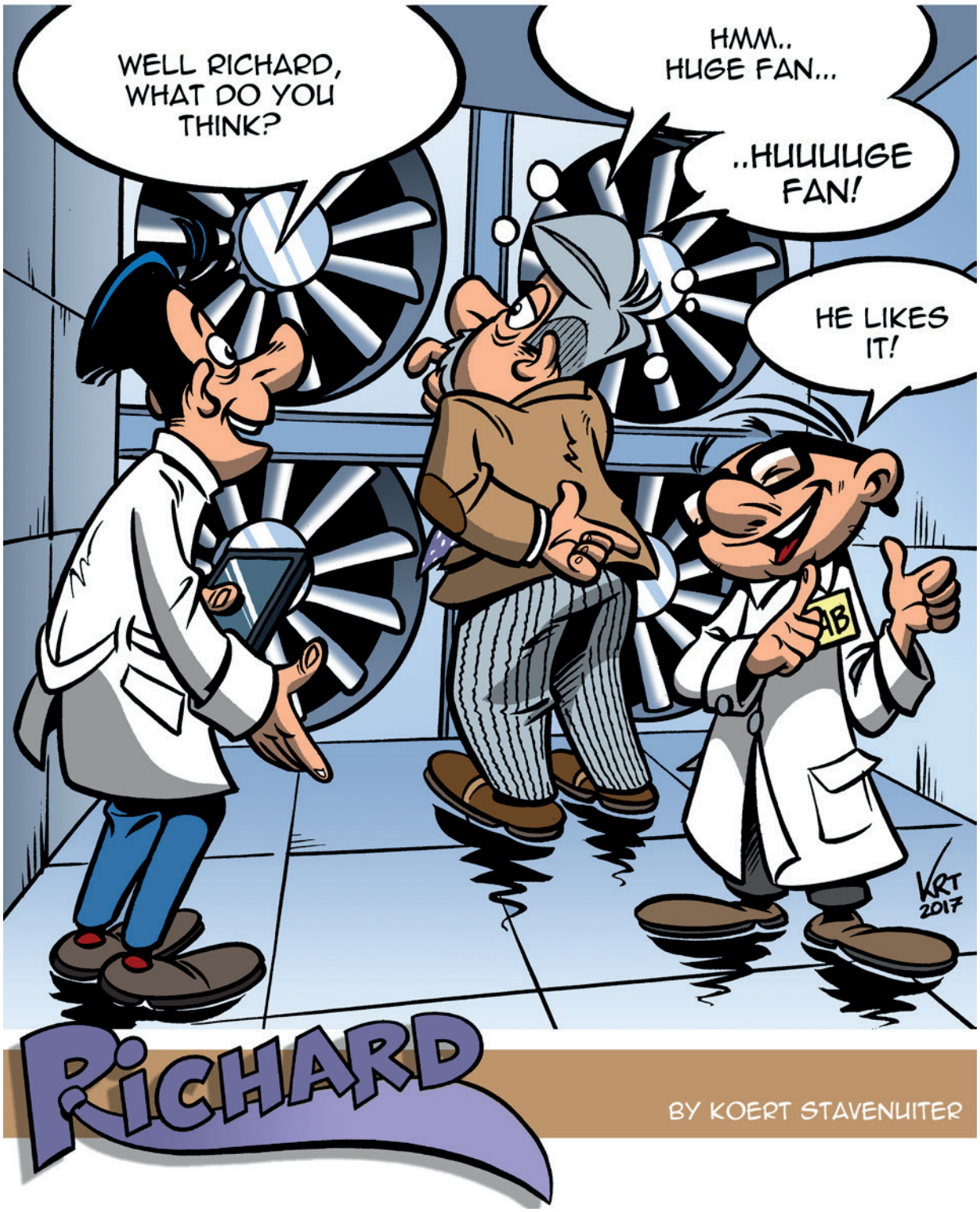
A new wind tunnel. In our department. What? Why? How?

prof. dr. ir. B. (Bert) Blocken

Healthy environments; research and students' involvement

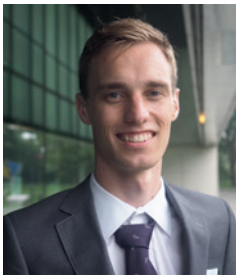
prof. dr. H.S.M. (Helianthe) Kort

THE THIRD ATMOSPHERIC BOUNDARY LAYER WINDTUNNEL IN THE NETHERLANDS!



Foreword

Ruben Hetebrij



Dear BPS-fan,

With great pleasure I bestow upon you the newest edition of the INSide information. For our new readers, this is the magazine of study association Mollier in collaboration with the unit of Building Physics and Services. Some of you may not know me yet. I am Ruben, the chairman of the 22nd board of Mollier.

As always, INSide information will feature updates about Mollier: articles from students, the Ice Breaker, Study abroad, Alumni at work and messages of the unit BPS. This time, special attention is given to our departments new atmospheric boundary layer wind tunnel, of which a preview is shown on the front. There are also interesting articles about the Health aspects within our environment by Helianthe Kort and PhD students. The older Mollier and Schoone Leij members will probably still know Peter van Mierloo, who is now working at Valistar Simonis. He has provided us with an interesting article of the renewed Atlas building.

In the upcoming year Mollier will again organize several day-excursions, lectures, workshops, a Meet and Greet with companies, the study trip and many more. Recaps of the past events are given in the Mollier Calendar. It is fun arranging these activities for you and I would like to invite everyone to join us.

I want to thank all the people that have made the new magazine possible. It takes some time, but the results are great. I wish you, as the reader, pleasure reading it and that it may be inspirational for your future decisions.

Yours sincerely,

Ruben Hetebrij
Chairman 22nd board s.v.b.p.s. Mollier.

Hester Thoen
(Editor in chief)

Gert-Jan Braun

Don Bremmers

Bram Dorsman

Jelle Reinders

Diyako
Shadmanfar

Sonia Soares

COLOPHON

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This INSide


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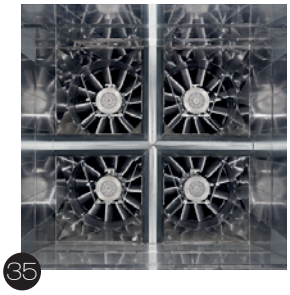
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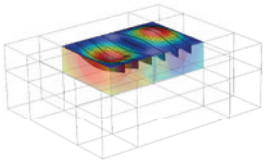
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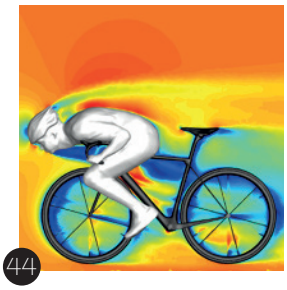
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Introduction of the 22nd board of Mollier

RUBEN HETEBRIJ
CHAIRMAN

Hello, I am Ruben Hetebrij, 25 years old, born and raised in Steenwijk which is a small city in the north of the Netherlands.

Buildings have always fascinated me, that is why after the HAVO (secondary high school) I did a Bachelor in Architecture and Construction Engineering at Windesheim in Zwolle. After that I still did not know what kind of company I wanted to work for. Because of that I started working at a detachment firm where I worked for short periods of time at different companies on multiple aspects of the building. These could be normal building drawings, but also lighting plans, mechanical or plumbing drawings. It was very interesting, but I had the feeling I did not have enough knowledge and still wanted to learn more.

During my bachelor, I did a minor in Building technology and building physics, which I thought was fascinating and I found that the TU/e had a master in this direction. So, last year I started with the premaster and now I am more than half a year into the master. This is going quite well for me.

After years of not doing any sports I was happy with the opportunity to swim at the sport center. I usually do this twice a week. However, during busy periods I tend to skip practice. Also, during the summer I like to run and I am in for some tennis. But that is something I still have to become better at. I love travelling and meeting new people.

Travelling and meeting people are two things I love. When I came to Eindhoven, I wanted to meet new people so I became a member of the activity committee of the swimming club and I also helped organize the study trip of Mollier to Seoul. Because there was a possibility that I would become a board member of the swimming association, Diyako, from the previous board, asked me quite early in the year if I wanted to become a board member of Mollier.

This opportunity I gracefully accepted. Now I am proud to be the chairman of the 22nd board of Mollier. My board and I will do our utmost best to offer you the opportunities to join us in the activities, meet new people and broaden your perspectives. I hope this upcoming year will be educational and fun for everyone.

REMCO VAN WOENSEL,
TREASURER AND VICE CHAIRMAN

Hi everybody! My name is Remco van Woensel and I am 23 years old. I currently live in Eindhoven, but for the largest part of my life I have been living in Elst. Elst is a town with Roman origins that is located in Gelderland, between Arnhem and Nijmegen. After I graduated from my secondary school in a town near Elst, I went to the Eindhoven University of Technology to get my Bachelor's degree in 'Bouwkunde'. During my bachelor's I discovered that I was attracted most to the technological aspects of buildings and not so much to the designing aspect, which is why I decided to do some specialisation courses related to building physics and services. Especially during the third year of my Bachelor's degree, I was quite certain that I wanted to do my Master's at the Building Physics and Services unit, and that is what I did. This was already more than two years ago and recently I started with my graduation project, which focusses on how to deal with the performance uncertainty of an adaptive shading system due to occupant behaviour.

In my spare time I enjoy playing squash once every week. I play just for fun and for me it's a good way to stay active. For the past year and a half I have found a new hobby: playing guitar. I wouldn't call myself a very good guitar player, but I try to play at least a few times every week to improve my skills. I'm also a scout leader at a scout group in Elst, where I guide a group of teenagers (15-18 years old) in organising their own activities and even trips to other countries. Finally, I spend some of my time on my part-time job, which includes updating the product database of a company that sells workwear and tools.

This year I will be filling the roles of treasurer and vice chairman of the board of Mollier. During weekdays, you can probably find me at the Mollier desk at floor 2 or otherwise at floor 5 of Vertigo.

GERT-JAN BRAUN,
COMMISSIONER EXTERNAL RELATIONS

Hello everybody, my name is Gert-Jan Braun and I am 24 years old. I have lived in Zevenaar next to Arnhem all of my life. After I finished my HAVO, I was sure I wanted to follow a technical study, however I was not sure in which discipline. I started with mechanical engineering at the HAN, but switched to building engineering, also at the HAN. After a while I was sure that this was the direction for me. I was focusing on becoming a project leader at a contractor, but after my final internship at 'BAM Bouw en Techniek' in Apeldoorn, I knew I wanted to understand the physical aspects of building better and eventually become a consultant, therefore BPS was the best fit. I finished my bachelors in January and had half a year before I could start with the Pre-Master at TU/e. During this time, I was able to work as a 'work organizer' at BAM and learn a lot more about the building industry. Eindhoven is too far to travel from Zevenaar, so I moved to Eindhoven to live in a student home for the first time.

Besides my studies and Mollier I really enjoy working out, I played rugby, tennis and judo when I was younger. Judo has had a lot of influence on the person I am right now, I still Judo sometimes and like to fitness to get my head straight with all the 'study stress'.

For me so far, BPS stands not only for a new study, but also for a new place to live, new friends and doing things you normally wouldn't have done. For example, becoming a member of the board of Mollier, this already is a great experience! I am looking forward to meeting everyone this year and to bring Mollier to an even better position.

JANTJE EDELBROEK
SECRETARY AND COMMISSIONER EDUCATION

Hey, my name is Jantje Edelbroek and I am 22 years old. I grew up in Zeist, but moved to Utrecht during my bachelors. I have wanted to become an architect for as long as I can remember, I used to draw houses as a child and my parents still have boxes full of my masterpieces. I changed my mind in high school when I realized how interesting science and physics are and decided to study architectural engineering.

I studied architectural engineering at the Hogeschool Utrecht and specialized in construction and building physics. Thanks to my internship at Nieman and the start of my own company, dB Brothers, I eventually decided I wanted to continue in building physics. To further my knowledge in this field and also to postpone getting a fulltime job, I decided to continue studying after my bachelor.

It became clear that I wanted to go to the TU/e quickly, so I signed up for the premaster directly after graduating in June 2016. I thought about moving to Eindhoven, but decided I wanted to stay in Utrecht.

Besides school I enjoy cooking, reading and occasionally go for a run. I also spend quite a lot of time at music festivals, but mainly backstage with dB Brothers. dB Brothers is a company I own with my brother and sister, we do sound monitoring for festivals.

During my premaster I was not very active in Mollier. I ended up going on the study trip. The trip was so much fun and the people were so nice that I decided I wanted to become more active. This escalated into doing the board this year. So far I have enjoyed this a lot and I have met many great people through Mollier. If you want to meet me in person I can usually be found at floor 5 in Vertigo.

BRAM DORSMAN
COMMISSIONER ACTIVITIES

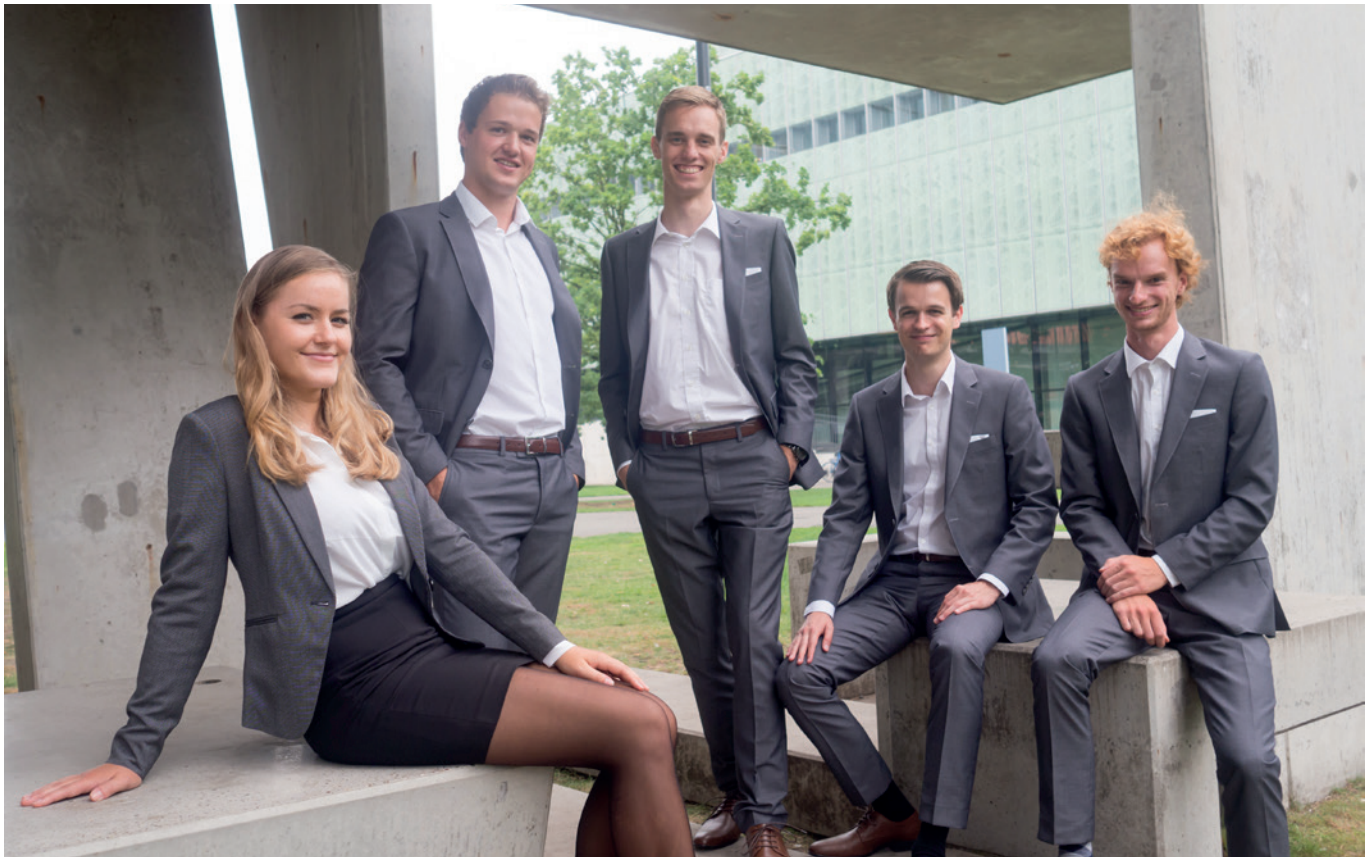
Hello, reader of this magazine. My name is Bram Dorsman, 23 years old, and I am proud to say that I am filling the function of commissioner of activities for this year for Mollier. I've come a long way; a short story of my life is printed below.

I was born in Kralingse Veer, a small part of Rotterdam where my ancestors lived for many generations. My parents broke that tradition: when I was 4 we moved to the sunny south, towards a pretty little town called Etten-Leur, everyone has heard of it of course. There I went to the elementary school and the secondary school. After fulfilling the HAVO, it was finally time to broaden my horizon. I went to Tilburg to Avans to study construction engineering, or 'bouwkunde' in Dutch. Before I began that program, I was planning to become an architect. However, after the first few architecture courses, I changed my mind and my interest in building physics became greater and greater.

When I finally graduated, there were two options: work or study further. I chose the latter, resulting in the pursuit of my premaster at TU/e. In the first year I was the commissioner of fun activities in the study trip commission to South Korea. This year, my function has expanded to become the activities commissioner of the whole study association. I will try to create as many activities as possible for our dear members like the start activity and a movie night.

It seems weird, but next to Mollier I have a second life. I'd like to play music on the piano and guitar, and occasionally I find time to practice my swimming.

When there are questions or recommendations regarding the activities of the study association, I'll be happy to help. When I'm at school you can probably find me on the 5th floor of Vertigo drinking coffee, contemplating life and some studying. ■



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Mollier Calendar
Past events

MEET THE BOARD DRINK
The 4th of October, everyone from Mollier was invited to drink with the new board, to wish them luck, to talk to other members of the association and of course to have some free drinks. We are proud to say a big delegation of new Building Physics and Services students came to this first drink of the academic year in addition to our familiar faces.

PIZZA AND MOVIE NIGHT
For the first fun activity, Mollier organised a Halloween themed movie night.
This was a good opportunity to get to know everyone and of course to have a good time together. Although it was a super scary, all attendees have succeeded to see the end of the movie.

LUNCH LECTURE #1
On the 15th of November we kicked off the with first lunch lecture of this academic year, inviting guest speakers from Van Hout and Arcadis. Van Hout is an installation and consulting company situated in Veldhoven and Arcadis is one of the leading global design and consultancy firms for natural and built assets.

Jan van Hout, director of Van Hout, held an interesting lecture about several installation and energy efficient applications by Van Hout in a way that it is clear for the customer. It is important to know who the customer is and what that person needs to know. What is the best choice and what costs can they expect? As an example, he discussed a project at Strijp in Eindhoven where they renovated a 40.000 m2 area with an industrial function.

OCTOBER

BACHELOR VERTIGO TOUR
The 18th of October, Mollier helped organizing a tour through the Vertigo building for Bachelor's students that are following a course related to building physics and services. The tour started in the basement of Vertigo and ended on the rooftop, showing the air handling units and other building systems along the way. We were glad to see that the students were interested in the way the systems were structured and how the climate inside the Vertigo building is regulated. Hopefully this encourages them to pursue their Master's degree at the unit Building Physics and Services.

NOVEMBER

POOL NIGHT
The second fun activity was held in a pool centre downtown Eindhoven. There were five tables reserved with four players each. Many Molllier members were present at this fun activity. As a result, the night can be called very 'gezellig'.

The second speaker was Victor Pastoor, senior consultant buildings for Arcadis, and he talked about how to use consultancy skills. Being a consultant is not only about having knowledge, as one should also know how to implement soft skills such as personality competences, communication skills and consultancy strategies. A lot of students and young engineers underestimate these skills, while they are essential for a successful career.

EXCURSION KUIJPERS

In collaboration with Kuijpers, Mollier is organizing an excursion to Amsterdam on the 7th of December. We will visit the Hermitage and the Hortus, two buildings that are connected by a thermal storage system. The Hermitage was renovated by Kuijpers in 2009. The building needed more cooling than heating, so the excess heat is deployed in the Hortus, a botanical garden that needs a lot of heat to maintain the subtropical climate. Because of the 400 meter distance between these two buildings, this is a very interesting project. The control system is extraordinary as well, because the two climates are so different from each other but they are both controlled by the same system.

SINTERKERST DRINK

Once again, traditional Sinterkerst of Mollier drink was held between Sinterklaas and Christmas on the 13th of December. The drink was organized in the Skybar! Vertigo.

LUNCH LECTURE #2

On the 6th of December, the second lunch lecture was held by Voort and Strukton. For Voort (a secondment company), a former board member spoke about how he found his dream job through this company and about the TVVL-education for the young professional. Strukton (a company for asset and building management and maintenance), spoke about circularity: a term that will be heard more frequently in the built environment.

DECEMBER

START ACTIVITY

The weekend of the 24th until the 26th of November was the weekend 23 people were waiting for. Friday afternoon we drove to the south with six cars, to a village called Bérisménil. This small village is located in the Ardennes. Here we had a nice dinner of macaroni with a bit too little Bolognese sauce. Afterwards, everybody was free to play games, chat and drink some beers.

The next day started with hike in which almost everybody participated. Although the hills in the Ardennes are not that high, the 10 km walk definitely had some rough parts. We had lunch (knakworst and tosti's!) and went on our way to the next activity: building a bridge. We were divided in two groups and each group had a different part of the river to bridge. After 75 minutes, the time was up and one group did indeed succeed to build a functional bridge out of the provided materials. The evening was spent at the house, with a Mexican style dinner consisting of nachos, wraps and taco's. There was even hot chocolate. That night, games were played, movies were watched and beer was drunk.

The next day, after breakfast, the house was cleaned and the bags packed. We left Belgium to go back to Eindhoven. However, there was still one activity planned before we went home: a visit to the La Chouffe brewery. Here we had a nice presentation about the history of the brewery, the brewing process and of course we had the opportunity to taste some beers. When the beers were finished, the group went on its way back to the north, with a quick stop at McDonald's for a late lunch. We would like to thank everyone for making this weekend Mollier-worthy and we hope to see you all at the next activity!

Ice Breaker
Meghana Kulhalli

Hello there! I am Meghana and I hail from the south of India, from the city of Bangalore; which is also where I graduated as a Bachelor in Architecture. Throughout my childhood, there was a constant atmosphere of design around me. My father is a strong propagator of the DIY culture. If he is not busy watching old movies and humming tunes, you will find us all watching him work on just another one of his many DIY projects around the house. Thanks to that, I was always surrounded by custom-designed furniture, interiors and spaces. Growing up with the renovation of my childhood home, spending days innocently watching workers getting things done through the process and other such subtle influences through my formative years lead me towards architecture.

During my five years studying architecture, I tried my hand at all the different activities that the university had to offer. Participating in competitions on a regional and national level gave me a chance for a well-rounded development. Through various internships in architectural practices, small and big, I tried to find where my interests within architecture lay. With every passing day spent in offices, designing based off of questionable decisions, having iterations rejected because they did not look good enough, with no clear right or wrong; the ambiguity of it all left me stumped. The lack of technical know-how needed in taking a design off the design board onto the site left me abundantly curious to pursue a technical path of study, which has a clear right from wrong and is backed by numbers and sound logic. I have always felt a strong attraction to Europe, owing to its architecture, history and diversity. The Netherlands has been very accommodating so far, and I feel right at home here. Although I have been cycling for a good part of my school life, I will always be amazed at the nearly utopian system for cyclists that have been implemented in this country. I am also positive I will never get used to the idea of motor vehicles stopping for cyclists to pass by! The commitment the Dutch people show towards healthy living is also very admirable.

If I'm not at the library catching up on assignments, you will either find me with my nose buried in novels, petting every dog in sight, or reading about the most random things on the interwebs. Nothing gets me wide-eyed and excited like a gripping thriller or suspense novel, or the best of both worlds: conspiracy theories. There's nothing like an endless conversation about the what-ifs and maybes of the world around. I also enjoy cooking, occasional writing, doodling and trying out and learning new things. I thrive on sarcasm and wit and like to think I am easy-going and an overall enthusiastic person with a questionable sense of humour. Did I already mention I love dogs? The feeling is also mutual. Do come say hello if you see me around! I love meeting new people.

I find that there's a healthy balance between work and play here at the TU/e. There are a lot of opportunities for one's holistic development; all you have to do is show up. Being a part of study associations and committees are a big part of student life for me and I look forward to engaging and contributing positively in any way that I can!

As I sit draped in multiple blankets (in what I have been reliably assured is not yet winter), I am counting on having a fun filled, challenging and exciting two years ahead! ■

Figure 1. Being in two countries at once; just EU things


Figure 2. Casual adventures on a high rope course

Energy savings for an open-office with occupancy-based dimming

Author
S.A. (Sonia) Soares

Supervisors
ir. C. (Christel) de Bakker
dr. T.M. (Timilehin) Labeodan

Lighting is a significant contributor to the electrical energy consumption of an office building. There are many strategies which help reduce this energy consumption: the use of energy efficient LEDs, daylight dependent strategies, and occupant dependent strategies. This research focuses on estimating the energy consumption for an open-plan office as a result of using an automatic occupancy-based dimming strategy.

MODEL CREATION

The open-plan office used in this assessment is located in a two-storey office building in Breda, NL. Data collected for this building indicates that lighting corresponds to 38% of the total building electricity use [1].
A model of this office was created using the energy simulation software IES-VE (Integrated Environmental Solution – Virtual Environment).

The lighting system works to ensure a minimum of 500 lx on the workspace, 300 lx and 100 lx in the surroundings of an occupant as indicated in Figure 1. There are 31 luminaires in the open-office. Depending on the absence or presence of an occupant, the luminaires surrounding that occupant are dimmed to three different levels of illuminance.

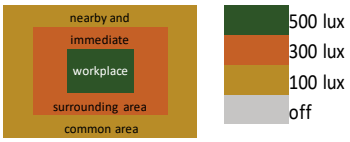

Figure 1. Lighting around the workspace

OCCUPANCY ANALYSIS

There are 12 occupants in this office, grouped into three zones with four occupants in each zone. A control scheme (Figure 2) indicates which luminaires are important for each occupant. Using this control scheme, similar zonal control schemes were developed for each zone. This made it possible to calculate the average illuminance in each zone for a particular arrangement of occupants. All possible combinations of occupants were accounted for in each zonal control scheme. Actual occupancy was recorded over a period of one month, from 15-February-2017 to 15-March-2017, using mechanical sensors embedded in the chairs (aka chair sensors) of individual occupants.

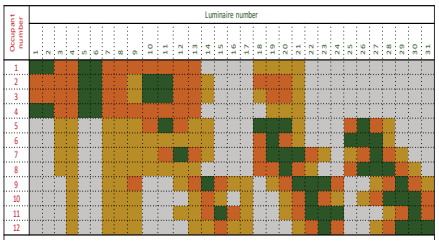

Figure 2. Control scheme per occupant

In order to understand how occupancy affects the lighting in each of the three zones, the chair sensor data for the relevant occupants situated in a single zone was combined.

DIMMING PROFILE

The dimming profile indicates the percentage dimming when the lights are on. A dimming profile was developed for each zone for every day of the work week from Monday through Friday, using the average illuminance from the zonal control schemes and actual occupancy data from the chair sensors.

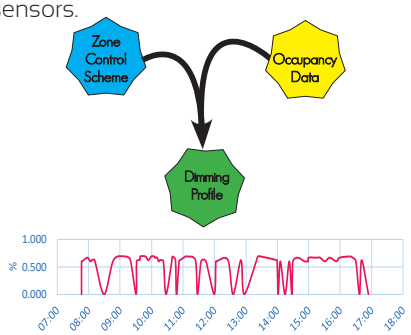

Figure 3. Dimming profile for a single zone

ENERGY SIMULATION

Energy simulations were completed for a reference case and a test-case. In the reference case, there is no dimming i.e. the lights are switched on at 07:00 and switched off at 17:00. In the test case, the lighting is controlled using the occupant-based dimming control strategy of the office. The dimming profiles are used in the simulation tool, IES-VE, to obtain the monthly and annual energy consumption for the open-plan office.

RESULTS

The estimated energy savings by using the occupancy-dependent control strategy as compared to the reference case is 36.4% in one year. The reference case's total annual energy consumption is 1.52 MWh while in the test case, 0.9667 MWh is consumed, as seen in Figure 4.

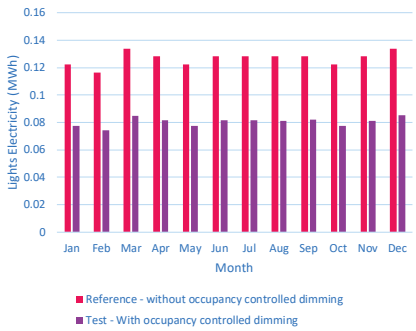

Figure 4. Monthly lighting electricity consumption for the reference and test case

CONCLUSION

The goal of this assessment was to estimate the potential lighting energy savings in an open-plan office when making use of an occupancy-based dimming control system.
Through an experimental approach, it was possible to use actual occupancy data. By using BES-software, the analysis was extended to obtain the energy consumption and savings for one year. ■

[1] T. Labeodan, C. D. Bakker, A. Rosemann and W. Zeiler, "On the application of wireless sensors and actuators network in existing buildings for occupancy detection and occupancy-driven lighting control," Energy and Buildings, pp. 75-83, 2016.

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

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Waste Heat Utilization System for a Data Center Using ATES

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INTRODUCTION

Nowadays, in times of globalization and informatization, it is taken for granted that internet access is available anytime, anywhere. And to do so, data centers (DCs) all over the world must process enormous computational workload related with our internet activities. Recent energy statistics indicate that the DC industry is responsible for 1.3 % of the world's and 2 % of the United States' electricity consumption. Particularly, all electrical power required by IT is converted to heat, which has to be mechanically removed by a cooling system. Specifically, almost half of the global DC consumption is assigned to the removing the dissipated heat from the electronics [1], while the heat is usually wasted to the ambient air.

However, the difficulty associated with recovering of waste heat from DC is the low quality of this heat and the heat transportation [1]. Although the typical mid-sized DC can dissipate around 1 MW of heat, which may cover the heating demand of hundreds of households, the temperature potential of the conventional air-based cooling system can be only up to 40 °C [2].

It is worth mentioning, that one of the incentives to investigate this specific case is driven by a possible attempt to build a DC on the university campus.

RESEARCH METHODOLOGY

Based on case study definitions, a certain framework was made. As the early project phase is essential for further development of the work the availability of data was identified. Key performance indicators were determined containing energy or carbon emissions metrics.

As in DC field, real experimentation is usually nearly impossible, numerical modelling is a suitable method for a feasibility study/an early design study of complex systems such as DC waste heat utilization.

CASE-STUDY DEFINITION FOR DC WASTE HEAT UTILIZATION SYSTEM

The case study conducted for this research is defined based on technical data of an existing aquifer thermal energy storage (ATES) system located at the Eindhoven University of Technology and the DC configuration, which follows the publicly available technical specification of IBM data center in Poughkeepsie, NY [2]. This DC specification represents a typical mid-sized DC, which may be deployed on the campus of Eindhoven University of Technology in the future.

Description of waste heat usage: application on the university campus

The ATES system provides heating and cooling to the connected campus buildings. Figure 1 shows the heat exported (heating delivery) and imported (cooling delivery) to the ATES system in last 10 years.

In the current situation, the ATES system supplies mainly cooling, which leads to the imbalance in the cold and hot clusters of the storage. The ATES system is kept in balance artificially by using cooling towers. If the outdoor conditions permit, two cooling towers, belonging to the ATES system, releases the surplus heat into the ambient air (see Figure 1 with a black arrow).

The amount of exported and imported heat can change in the near future (influenced by the Atlas building and two new residential buildings).

Assumed cooperation in actual situation

Currently, the ATES system operates during the year with less than half of the energy storage capacity. Thus, the capacity of the storage can be considered as unlimited as long as the yearly balance of the storage is ensured. As a result, it can be assumed that the ATES system has enough capacity to accommodate the mid-sized DC.

Even in peaks, the system does not exceed the whole potential capacity. The main barrier could be only continuous cooling demand of the DC leading to the aforementioned increase of imbalance of the ATES system. As it is undesirable to have an imbalanced system, the facility management oversees compliance about the amount of heat inserted into ATES by particular buildings and also temperatures of returning water. Such management is called in this article "ATES policy".

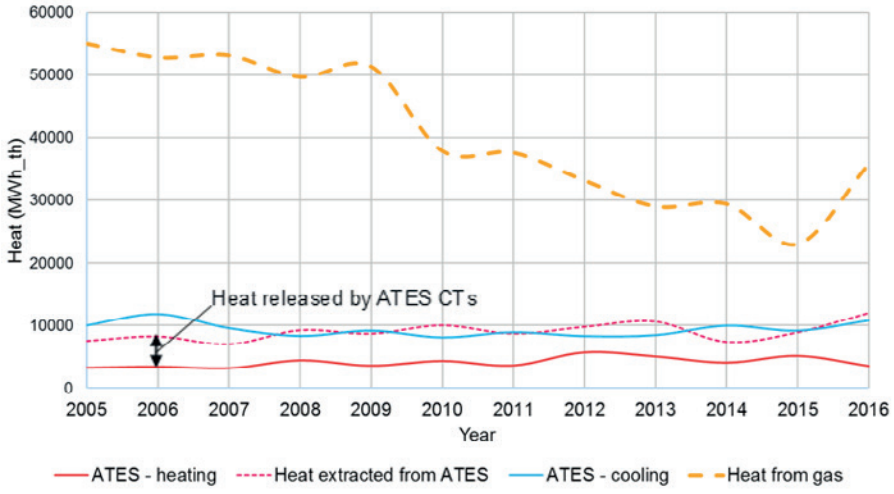

Figure 1. Eindhoven campus energy management

Table 1. Reduction in gas consumption

Source	Emission factor [kg CO_2/unit]	Adjusted emission factor [kg CO_2/kWhth]
Natural gas [1]	1.884 kg CO_2/m3	0.188
Electricity [2]	0.54 kg CO_2/kWh	0.135

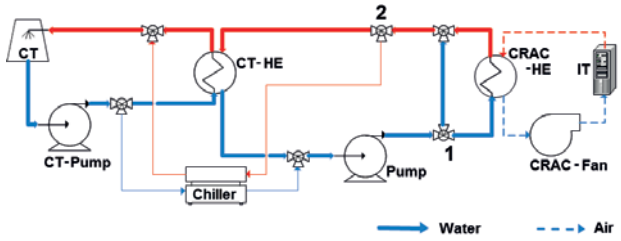

Figure 2. Schema of the conventional cooling system working in WSE mode

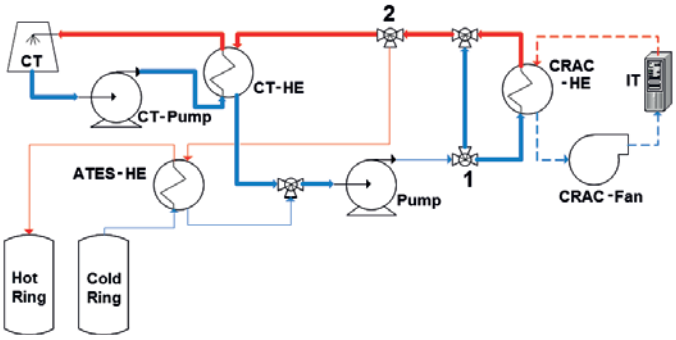

Figure 3. DC cooling system connected to ATES working in CT mode

Assumed cooperation in the future situation

In accordance with an ecological policy of the university, it is assumed that in future the ATES system would partly replace the use of gas for heating. It is assumed that gas consumption will decrease by 50 % (compared to the situation in 2015). This would result in more heat being extracted from the storage on campus than inserted to it, and in that case, the heat from the DC would become necessary to balance out ATES.

The motivation for a reduction in gas consumption described in Table 1 by the lower value of Adjusted emission factor for electricity against natural gas.

NUMERICAL MODELLING OF DATA CENTER

Regarding numerical modelling of the DC system, the DC environment is relatively complex system and therefore its modelling is conceptually divided into four "sub-models". Thus, the conceptual model of the DC environment consists of DC room model (zonal approach), DC cooling model, DC electricity delivery model, and control model. The existing ATES system is represented in the model as a temperature boundary condition of the modeled cooling system. The physics behind the ATES system is not considered in the numerical model.

Cooling Models

Two models of cooling infrastructure were developed, and it is schematically described in Figure 2 and Figure 3. The model with conventional DC cooling system was modeled to assess by comparison the benefit of DC cooling system connected to ATES system.

Model of DC with conventional cooling system

This cooling system represents the typical DC cooling configuration. This system can work in two modes according to external conditions – water-side economizer mode ("WSE mode") or in the "Chiller mode". Thus, once the ambient temperature of the air is under a certain value, then the cooling tower does not need the chiller to cool down the air and the system is able to work in "WSE mode" depicted in Figure 2.

Once the ambient temperature of the air is high, then the cooling tower of DC is not able to fulfill the cooling process and hence the chiller must be used (Valve "2" in Figure 2 switches).

Model of DC with cooling system connected to ATES

In a model of DC with a cooling system connected to ATES is in comparison with the previous model the chiller replaced by ATES. The cold ring of ATES was simplified and modeled with a constant temperature of water (7 °C).

The cooling system also works in two modes. In "CT mode" (described in Figure 3) when the ambient temperature is low (identical with "WSE mode").

Once the ambient temperature of the air is too high, the system switches into the "ATES mode" (valve "2" in Figure 3 switches).

SIMULATION-BASED ASSESSMENT OF WASTE HEAT UTILIZATION SYSTEM

Firstly, since there is no preferable operational strategy at this stage of the project, uncertainty study needs to be performed to provide the possible range of the waste heat potential for the given case-study.

Parameters that are subject to change are:

- Temperature of air in DC room
- IT workload
- Additional thermal capacity of the housed IT
- Thermal management: cold aisle with or without containment

Key performance indicators for DC waste heat utilization:

- Total DC electricity deman
- Carbon emissions
- The Power Usage Effectiveness (PUE)

Assessment of the cooperation of DC and ATES with respect to actual situation

The reason for partition of the simulation results into DC scale and then Campus scale is to gradually understand the topic. Firstly, it is important to understand the effect of certain cooling circuit elements or specific operational scenarios on the cooling consumption, resp. total energy consumption of DC. Only then it is possible to properly assess the whole waste heat utilization approach with emphasis on the reduction of a carbon footprint on a higher level like a university campus.

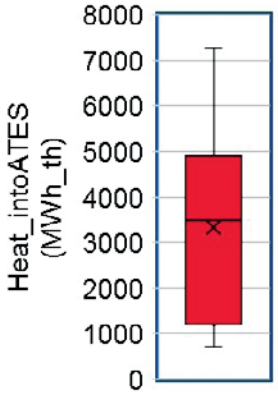

Figure 4. The range of heat inserted by DC cooling system into ATES system

1. It is assumed that 1 m^3 of natural gas provides 10 kWhth.
2. It is assumed that are used heat pumps with a coefficient of performance (COP) = 4.

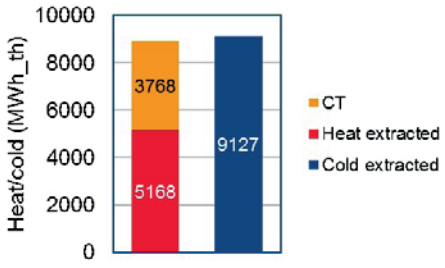

Figure 5. ATES load for reference year

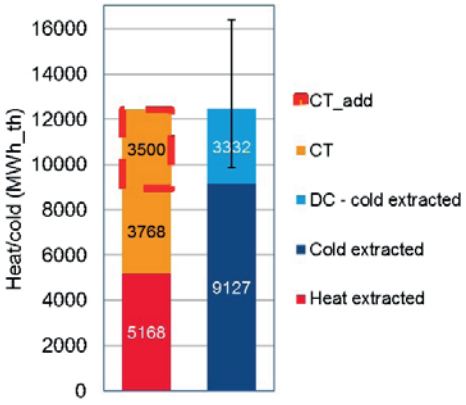

Figure 6. The theoretical use of ATES system in 2015 after connection of DC

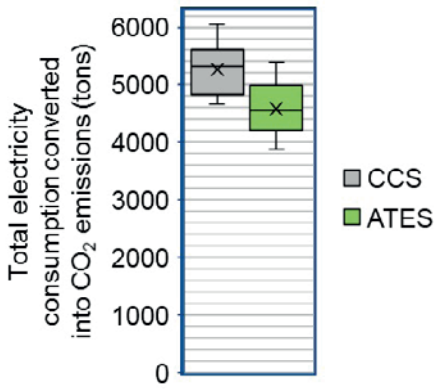

Figure 7. Emissions emitted by DC cooled by the conventional cooling system and ATES under "ATES policy" per year

Figure 4 describes the range of heat inserted by DC cooling system into ATES system (under ATES policy). Data which from that box plot was built contain cases from on the one side with a large cooperation DC – ATES for low DC temp. SP to on the other side with a low cooperation for high DC temp. SP.

Results at Campus scale

At first, ATES load for reference year (2015) is shown in Figure 5 (refer to data from [3]).

As mentioned before, ATES was used more for cooling of buildings (blue bar – Cold extracted from ATES) then their heating (red bar – Heat extracted from ATES) and hence, a significant amount of heat had to be realized by ATES cooling towers (CT) into ambient (orange bar) to balance out the system.

By connecting DC into ATES system, the undesirable imbalance would be significantly increased. In terms of feasibility, it is assumed that ATES CTs can release that excessive heat without any major problems. Because in last years the amount of heat released by ATES CTs has been varying greatly, while electricity consumption by ATES has stayed almost constant and the capacity of ATES system is not fully utilized by far.

Figure 6 describes the ATES situation that would occur if the DC would be connected to ATES system in the reference year.

In that case, paradoxically more heat would be extracted from ATES and consequently "destroyed" by ATES CTs then meaningfully used by the heating system of buildings in the campus.

Simulation results via carbon emissions:

Through carbon emission factor total electricity demand of both cooling variants was recalculated into CO_2 emissions. Further, values for both cooling systems were compared and put into campus context by comparison emissions that are released through gas and electricity consumption by particular buildings (refer to Figure 8).

The difference between average values of the conventional cooling system (CCS) and ATES variant in Figure 7 is [3] 630 tons of CO_2. This value corresponds to a black dashed line in Figure 8 leading to better insight what does this amount of carbon emissions can be compared with.

Assessment of the cooperation of the DC and ATES with respect to the future scenario

The reason for defining the future scenario rests on searching the case when waste heat from DC would become very needed on campus. This assumption is based on the effort of the university to become more sustainable. Which would result in a reduction of gas for heating within the campus and that heat from combustion of gas would be replaced by heat from ATES. This would lead to a situation that ATES system would be used more for heating than cooling of campus buildings, respectively the storage system would become imbalanced and would need some extra heat to balance out itself. And that heat would be provided by DC resulting in unlimited cooperation of DC and ATES in terms of heat.

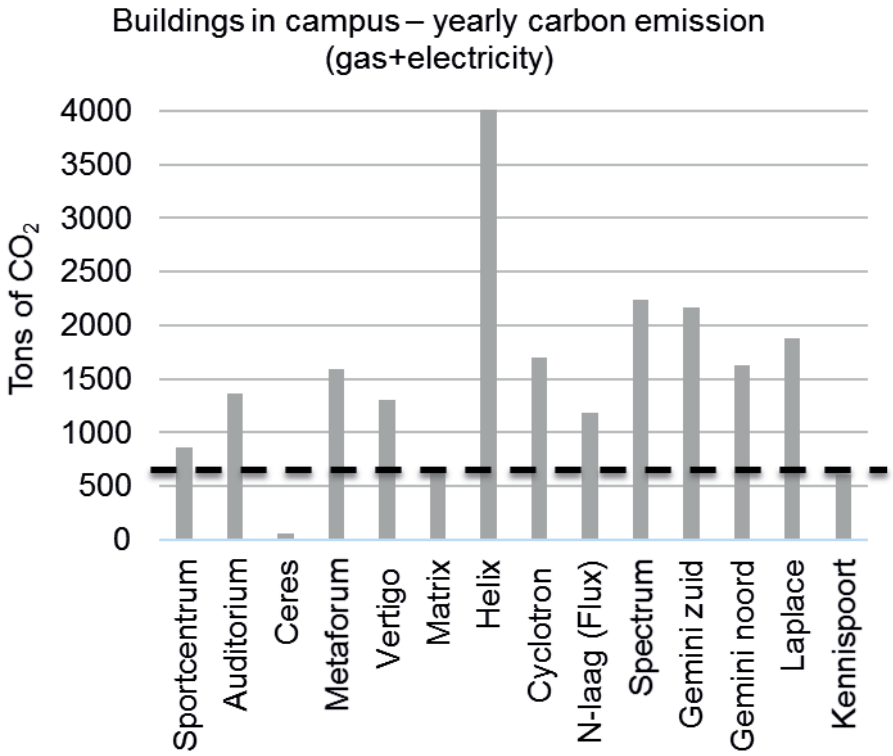

Figure 8. Annual carbon emissions by use of the particular buildings in the campus

3. According to [3], total CO_2 emissions emitted by university in 2015 were 25.500 tons of CO_2.

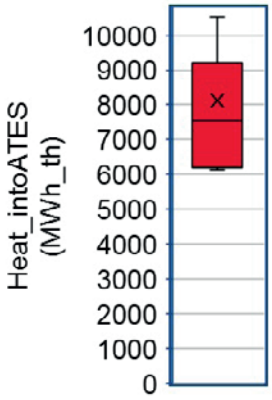

Figure 9. Heat inserted into ATES by DC without "ATES policy" per year

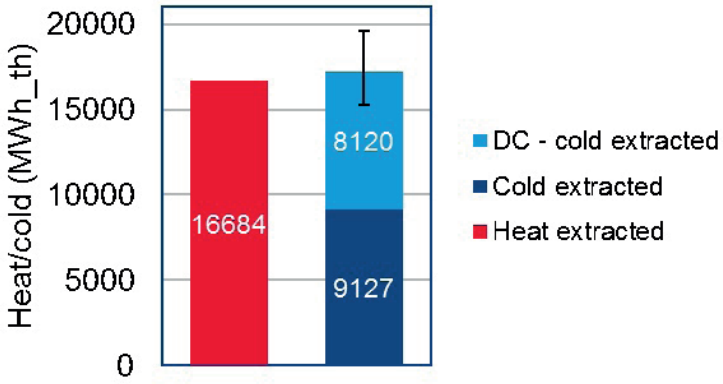

Figure 10. The theoretical annual use of ATES system in future after connection of DC into the system

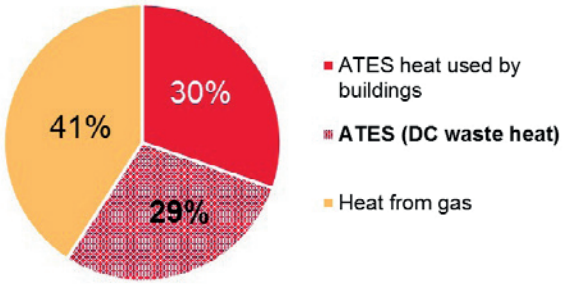

Figure 11. Sources of heat within the future scenario campus

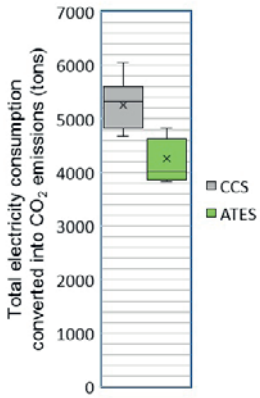

Figure 12. Emissions emitted by DC cooled by the conventional cooling system and ATES without "ATES policy" per year

Results at Campus scale

After simulating "100 % ATES" variant the amount of heat inserted into ATES significantly increased (Figure 9).

It is estimated that in near future the use of gas for heating reaches half the value and this missing half will be replaced by energy from ATES. This situation of potentially future ATES is shown in Figure 10.

Figure 11 describes heating demand of future campus where almost exactly half of the heat (29 %) provided by ATES would come from DC as waste heat. To put Figure 11 into context with Figure 10, this 29 % in Figure 11 corresponds to the light blue bar in Figure 10.

Simulation results via carbon emissions

In considered future campus scenario, the connection DC – ATES would be very beneficial for both sides (Figure 12 illustrates the reduction on DC side). This claim is supported through calculating the reduction of carbon footprint. The main reduction is aimed at a reduction in gas consumption.

The difference between average values of CCS and ATES variant in Figure 12 is 1000 tons of CO_2.

DISCUSSION

Usually, for DCs with air-based cooling, there is only a poor range of waste heat possibilities. Mainly space heating for the building nearby can be provided by DC requiring complex piping system. However, due to ATES, even mid-sized DC with air-based cooling can mean the significant source of heat for buildings across the campus as ATES in substance solves the mismatch in time between heat produced by DC and heating demand by buildings.

CONCLUSION

In this article, the convenience of cooperation of DC and sessional thermal storage was assessed and compared with DC with the conventional cooling system. In order to assess these two cases, the numerical models of these systems were developed using building energy simulation. The research aimed to quantify the waste heat utilization and reduction of CO_2 emission. According to this study, from 6 to 10 GWh of waste heat per year can be reused for given case-study. The cooperation of DC and ATES can reduce the CO_2 emission in the range of 550 to 730 tons per year (emissions released by the DC alone are not included).

The project showed that even mid-sized DC working with average IT load around 500 kW can in the future represent a strong heat supplier within the campus, balance out the ATES and significantly decrease the university carbon footprint. However, for the actual situation, the collaboration between DC and ATES would be more convenient for the DC side than for the campus side. But there might exist a win-win situation between DC and ATES side under certain ATES policy condition which was slightly investigated. Nevertheless, this should be more assessed by future work. ■

[1] Khosrow Ebrahimi, Gerard F.Jones, Amy S.Fleischer, A review of data center cooling technology, operating conditions and the corresponding low-grade waste heat recovery opportunities, Renewable and Sustainable Energy Reviews 31(2014)622–638.

[2] ASHRAE, 2008, High density data centers: case studies and best practices.

[3] M.M.W. Meulen, "Management review 2015 MeerJaren Afspraak Energie Efficiency TU / e Inhoudsopgave," no. maart, 2016.

Stage of afstuderen bij Nelissen ingenieursbureau?

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The indoor environment of energy efficient schools

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Supervisor
prof. ir. W. (Wim) Zeiler

INTRODUCTION

In 2007, a study by VROM was conducted to determine the quality of the indoor environment of schools [1]. The results of this research were concerning and as a response the RVO developed the 'Programma van Eisen – Frisse Scholen' [2]. This program consists of three classifications: A (excellent), B (good) and C (sufficient). In addition to a healthy indoor climate, energy efficiency is also important for the construction of new schools. In this study, the effect of the Program Fresh Schools and the relation between energy efficiency and the quality of the indoor climate have been researched.

METHOD

In this research, three schools have been assessed, concerning their indoor climate. All schools were selected from a list of the Top 15 Energy Efficient Schools 2016 of the RVO [3]. By means of measurements of one week per school, it was determined whether the schools meet the requirements of the Program Fresh Schools. According to those results, a classification was given. In addition, all schools studied in recent years by TU/e have been compared on indoor climate and energy efficiency.

RESULTS

The schools researched in this study show some deviations on individual parameters. For two schools the air quality forms a problem, with related health problems for children and teachers as a result (headache, fatigue, dry eyes). One school had problems with temperature, which were caused by malfunction of the heating system during the start of the heating season.

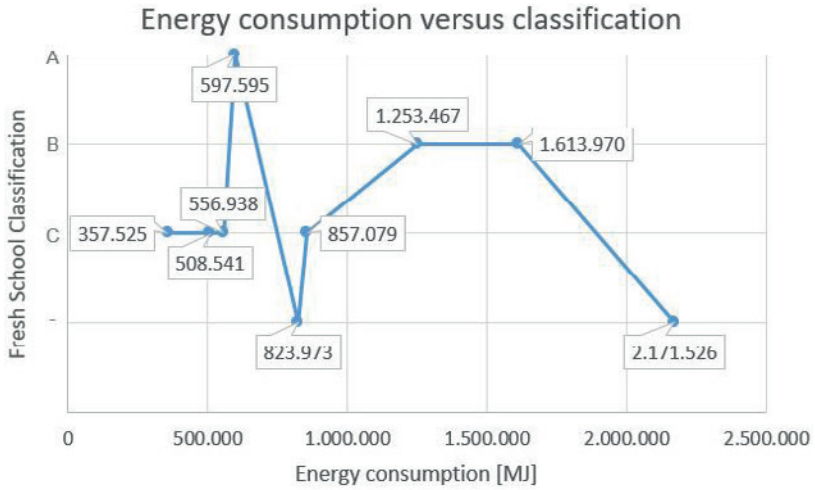

Figure 1. Relation between energy consumption and Fresh School classification

When looking at the results of previously researched schools, it turns out that CO_2-concentration remains a problem, whereby occurring concentrations can be up to 1800 ppm. Also the temperature often forms a problem, both high and low temperatures occur. Yet there are more and more schools with a Fresh School classification as starting point. However, there is no upward trend in the number of schools per year which actually meet the requirements for this classification.

In recent years, the EPC of newly built schools has been improved. It is expected that a high consumption results in a good quality. However, from Figure 1 it can be concluded that there is no relation between these variables. Finally, the relation between energy consumption for ventilation and the air quality, as well as for heating/cooling and the thermal comfort is considered. Herein no relation has been found either.

CONCLUSION

The three schools researched in this study comply with the Program Fresh Schools on several points, but have some problems with either the air quality or thermal comfort. Despite the increasing attention into the indoor climate of schools, no improvement has been shown over the years. Striking is that almost all schools do not meet the requirements for the intended classification. Against expectations, it can be concluded that no relation can be determined between the quality of the indoor environment and any other variable studied. For a higher succes rate for the Program Fresh Schools in the future, it is important to determine the reason for failure to meet the requirements. ■

Table 1. Comparison measured and calculated parameters of the Program Fresh Schools P95

	School 19	School 20	School 21	Requirements		
				Class C	Class B	Class A
Energy performance	-0,785	0,010	0,315	<0,7	<0,53	<0,35
CO2-concentration [ppm]	654	1620	1213	1200	950	800
Airspeed [m/s]	0,159	0,0995	0,102	<0,19	<0,16	<0,13
Draught rate [%]	11,3	5,94	6,00	<30%	<20%	<10%
Operative temperature [C]	20 – 21,1	19,7 – 23,2	21,1 – 23	19 – 25	20 – 24	21 – 23

[1] i. H. Versteeg, „Onderzoek naar de kwaliteit van het binnenmilieu in basisscholen," VROM, 2007.
[2] RVO, „Programma van Eisen Frisse Scholen 2015," Rijksdienst voor Ondernemend Nederland, 2015.
[3] RVO, „Top 15 energiezuinige scholen onderzoeksrapport 2016," 2016.

Atlas renewed: a challenge in sustainable renovation

Author
Peter van Mierlo
Valstar Simonis

For the renovation of the Main building (now named Atlas) at the TU/e campus, a design competition was tendered in 2014. The winning design was submitted by Team RSVP (Team V Architecture, Valstar Simonis, Peutz, and Van Rossum). The criteria on which the design was judged included architecture, health, flexibility and sustainability.

The sustainability criterion was measured using BREEAM, the Building Research Establishment Environmental Assessment Method, a method to ascertain the sustainability of building (designs). The method not only assesses energy use, but also looks at construction materials, water use and the health & wellbeing of the occupants, amongst others.

From the first moment it was already clear that the design exceeded the competition criteria of achieving a BREEAM score of 70% (or Excellent). During the preliminary design phase, as the plans were becoming more elaborate and detailed, the score was nudged gradually towards Outstanding, the highest level of

certification within BREEAM. With this in mind both the design team and the university put additional efforts in raising the sustainability even further.

These efforts eventually resulted in a score of 93.68%, a level unrivalled for renovation projects in the Netherlands. With this score the renovated Atlas building will also become the world's most sustainable education building, as well winning this year's BREEAM Award for Healthcare & Education buildings.

The renovation of the Atlas building proves that it is feasible to sustainably renovate a large (41,500 m²) and ageing building that has stood partly vacant into a pleasant, comfortable and inspiring work and learning environment.

DESIGNING FOR A SUSTAINABLE FUTURE

The new glass membrane façade with windows contains triple anti-glare glazing with internal sun screens. By using state-of-the-art materials, like a heat-reflecting coating on both the windows and the screen, this 'simple' membrane façade matches the insulation values of a 'double skin' façade. At night the internal blinds can be lowered, so that the insulation value of the façade is equivalent to that of an insulated cavity wall. The high quality façade reduces the need for mechanical heating and cooling whilst providing high comfort for the building's occupants.

The window concept with parallel opening windows makes maximum use of natural ventilation. Higher air flow around the entire perimeter of the window facilitates highly efficient natural ventilation and reduces draft. Fresh air is drawn in via the underside of the window while warm, stuffy air is expelled via the upper side of the window, thereby creating full circulation of air in the room. The windows can be opened individually by the occupants, and are also connected to the building management system. In fine weather they are opened at night by the building management system for a 'night rinse'; cooling and refreshing the indoor spaces with limited energy use.

Smart installation principles are used with a focus on energy consumption and creating a comfortable environment. Examples of this are demand-driven ventilation (based on CO_2 and temperature) and demand-driven, adaptable temperature control and lighting.

The building is connected to the existing thermal energy storage system of the campus, which enables the building to be heated and cooled sustainably. As the building will extract more heat than cooling it makes a positive contribution to the imbalance of the current thermal energy storage system.

Although the façade and building systems make a substantial contribution to reducing the energy consumption and awareness of sustainability, a large number of other sustainability measures have been implemented in the building, some of which have a significant impact on the environment. Amongst these is the reuse of large quantities of materials, including the entire foundations, the main load bearing structure and the supporting façade structure, leading to a considerable reduction of materials required, which in turn reduces flow of traffic and waste.

SMART ENERGY-SAVING LIGHTING (SEL)

The use of smart technology, like LED lighting with presence detection and daylight-dependent fittings, enables low energy consumption and excellent operation. The light fittings are installed in an intricate lattice pattern and are each equipped with a separate IP address and various sensors. This makes every fitting individually adjustable and the sensors individually readable.

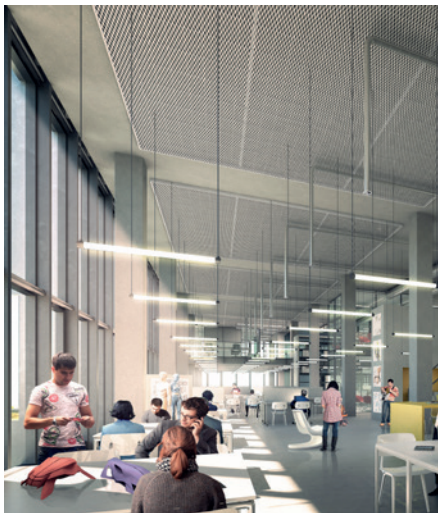

Figure 2. Open workspaces

The users of the Atlas building will be able to download a special application on their smartphone or tablet that will enable them to dim or brighten the light fittings in their vicinity to optimally adjust the lighting level to their needs. Alternatively the room controllers can be used for this purpose.

The light sensors in the light fittings are directly connected to the lighting control system, which enables the lighting strength to be automatically adjusted to the amount of incoming daylight. If the sun is shining brightly, then less artificial light is needed than when it is a cloudy day. Therefore the default setting for the lighting systems is a relatively low basic light intensity of 100 lux. If a presence is detected, the lighting strength automatically increases to 300 lux. Then the intensity can be individually adjusted up or down. When a person leaves the workspace, the connection with the smartphone or tablet is broken and the light intensity is again automatically reduced.

Motion sensors ensure that the lamps switch on/off based on the presence of people. If a room is empty for a whole day, facilities service is informed of this and the room will not have to be cleaned ahead of the next day. The climate control unit also responds to the presence/absence of the user. Where TU/e wishes, the climate control system (local temperature control) can also be adjusted in specific areas via the app. This creates a 'smart building', with considerable energy savings.

ATLAS AS A LIVING LAB

Through the initiative, in part, of the Intelligent Lighting Institute of TU/e, the building will act as a Living Lab for SAD-free (Seasonal Affective Disorder) research, among other things, to study how light can affect people's emotional state. Since the SEL system is an open system, in the future the TU/e will also be able to create new, project-specific applications to collect data, control systems and/or influence the behaviour of users (such as highlighting unoccupied workspaces to users, guiding users to unoccupied workspaces). The building also offers possibilities, in the staircases and on the roof to study building materials, PV systems and other building components in practice.

CONCLUSION

The project demonstrates that renovation offers real opportunities to convert old, vacant premises into high quality modern buildings fully compliant with the requirements of today and tomorrow.

The goal was to create the most healthy and comfortable indoor environment with the least possible adverse environmental impact. To achieve this, the multidisciplinary design team deployed the very latest innovations and state-of-the-art materials and techniques. For example, by equipping the building with Smart Energy-saving Lighting with individual IP addresses, combined with an open building management system to which new sensors and applications can be connected. This innovative and advanced lighting and climate system not only creates a comfortable place to work and learn but can also be used for research, for instance into Seasonal Affective Disorder. As a Living Lab for research the building encourages new developments in sustainable technologies and health. ■

Predicting the performance of ZigZagSolar using Daysim

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INTRODUCTION

Stricter legislation results in a need to create net zero-energy buildings. On-site renewable energy generation, such as the use of Building Integrated Photovoltaic (BIPV) panels, is a good solution to reach NZEB buildings. The ZigZagSolar energy harvesting façade is a BIPV system, which combines energy generation with architectural expression. It uses reflectors to increase the energy yield of the PV panel. Figure 1 shows the basic working principle of the ZigZagSolar façade.

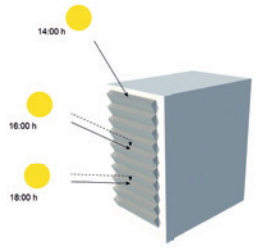

Figure 1. The working principle of the ZigZagSolar Façade

Due to the fact that the ZigZagSolar system is a relatively new product, there is still some uncertainty about its exact behavior in different conditions. The goal of this research is to get a better understanding of the behavior and performance of the ZigZagSolar façade system.

METHOD

The Radiance based daylight simulation tool Daysim was used for simulations. Earlier research [1] already has shown that Daysim can also be used for simulation of external irradiance distributions. The first step of this research was to validate Daysim by comparing simulation results with measurement data of a full scale setup at SolarBeat. In order to gain insight into the performance of the ZigZagSolar façade in relation to other BIPV systems, an application study with the Helix building at the TU/e campus was carried out. To study the effect of different climates, the building was tested for Dutch conditions (Amsterdam) and for Lisbon, Portugal. Several ZigZagSolar modules with different reflector angles were compared to other BIPV systems. Previous MSc projects ([1], [2]) all have shown that an increasing angle of the reflector could likely lead to more partial self-shading, especially near the fold where the collector and reflector meet. Two types of systems were evaluated: a single panel and split panel system. The single panel assumes that the lowest irradiance on a PV panel determines the performance [3]. For the split panel system, two separate rows of PV panels are installed. Shading of the back part of the PV panel will not influence the performance of the front panel, due to the fact that it is a separate string of solar cells.

RESULTS

The validation study showed that Daysim can accurately predict the performance and behavior of the ZigZagSolar system for both an annual and hour-to-hour basis. The relative deviation between model and measurement is less than 10% for 90% of the time. The results from the validation study therefore show that Daysim can be used confidently for further analysis of the ZigZagSolar façade system. The application study confirms that an increasing reflector angle leads to decreasing irradiance values on the PV panel. However, more panels can be placed vertically on the same surface due to smaller heights of each module, resulting in a higher overall irradiance yield of the whole system. Comparing the different modules with vertical BIPV shows that a too large angle can lead to a negative boost factor as depicted in Figure 2.

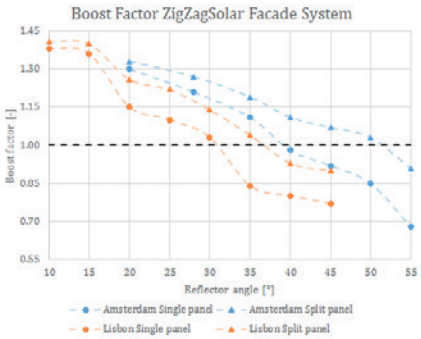

Figure 2. The boost factor of the system expressed as a comparison between ZigZagSolar modules and a similar amount of vertical PV-panels

At these angles, a similar amount of vertical PV panels installed on the façade results in a higher yearly irradiance than the ZigZagSolar modules. If a single panel system is considered, the reflector angle limit for Amsterdam is 35-40°, while the limit for Lisbon is 30°. Using a split panel system allows for a larger range of reflector angles: 50° for Amsterdam and 35° for Lisbon.

CONCLUSION

The results of this research have shown that the ZigZagSolar system has a lot of potential as BIPV system, but that certain limitations should be considered to optimize the performance of the system. Furthermore, using a split panel system instead of a single PV panel increases the potential of the ZigZagSolar façade, due to larger applicable angles of the reflector. ■

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Healthy environments; research and students' involvement

Author
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COORDINATOR HEALTH IN THE BUILT ENVIRONMENT

The TU/e has defined 3 strategic areas (SA): Energy, Health and Smart Mobility. The strategic area are chosen to concentrate the expertise at the TU/e in order to have power on societies and all have multidisciplinary perspectives to face the challenges of an urbanizing and ageing society. Well known is that the department of the Built Environment participates in the strategic area Energy and Smart mobility. Less known is that this department also participates in the Strategic Area (SA) Health [1] via the research track Health in the Built Environment. The SA Health is divided into different sub-areas from which the sub-area Participatory Health and Well-being is the most relevant for our department; the activities within Health in the Built Environment are connected to this sub-area.

Health in the Built Environment is aligned with the three key themes: "Quality of life", "Smart living environments" and "Sustainable transformation" that form the structure of our departments strategy further outlined in the Strategy for the Department of the Built Environment 2014-2020 "Building the future" [2]. All activities within Health in the Built Environment are connected to several other tracks within the department such as Smart cities and societies, Enabling vital and Healthy living and Sustainability. By this, the research track Health in the Built Environment reflects the multidisciplinary nature of our research that addresses the societal challenges.

The overall aim of the Health in the Built Environment is to target sustaining and facilitating public health and wellbeing while supporting individual citizens in their ambition of achieving and maintaining quality of life. Next to quality of life, other indicators of health in the built environment include but are not limited to mobility, vitality, and (work) productivity. Health-related research in the department stretches across the entire bandwidth ranging from individual occupants to entire buildings and urban environments. The research mainly focuses on identifying facilitators and hindrances in the built environment and examining the impact of (climate) changes on the indoor environment and health. On a high level, the research attempts to find solutions to:

- Support healthy living in urban areas
- Maintain or increase mobility and walkability of aging adults indoors and outdoors (urban planning and services)
- Create overall healthy indoor environments

The research on creating healthy environments looks at different building types such as hospitals, schools and office environments. The PhD's involved in this activity recently reported about their findings at the international conference Healthy Building 2017 (HB2017) held in Lublin, Poland. This conference was the next in line after the HB2015 conference at TU/e here in Eindhoven. The scientific chair back then was dr. Marcel Loomans from the unit BPS. The HB2015 theme was Stepping beyond traditional boundaries, (re) creating healthy buildings' [3]. Healthy buildings is an event of the International Society of Indoor Air Quality and climate (ISIAQ). Since 2016, dr. Marcel Loomans serves as president of this organization.

The built environment may support or harm the general health and wellbeing of individuals or a group of people. Environmental risks to health have been defined in the study of Prüss-Ustün, et al [4], as "all the physical, chemical and biological factors external to a person, and all related behaviors, but excluding those natural environments that cannot reasonably be modified". The included environmental factors mentioned are all related to past or ongoing research studies within Health in the Built Environment. The efforts focus on finding solutions to support or maintain the quality of life and health of individuals while they need to cope with challenges of life. This perspective is taken from the view on Healthy Environments as an environment in which the interaction between humans and their environment has a positive effect on their wellbeing, vitality, health and recovery when having a disease [5, 6]. This perspective has also been inspired by the view on health in terms of positive health as described by Machteld Huber and others. They re-defined health as the ability to adapt and to self-manage [7]. This view is aligned with the view of environmental scientists who see the health of the earth as the capacity of a complex system to maintain a stable environment within a relatively narrow range [8]. This view on health differs from the definition by the World Health Organization (WHO). According to the WHO definition, which is still the most prominent one referred to in science, health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity [9]. This view captured the world health status from that time with high health risks for citizens by infections. In most (Western) countries nowadays, the risk to become ill or disabled by an infection is minimized due to the use and provision of appropriate water- and waste management in cities.

In the program creating healthy environments we seek to find solutions for quality of life, vitality and better health. This requires exact knowledge of the underlying risks to health. On a global level, considering the world population, it is well established that men are more at risk compared to women. Similarly, this applies to ageing adults (contrary to the younger population). Risk is expressed as DALY (Disability-Adjusted Life Years) indicating the years of life lost due to mortality or life with a disability. Table 1 provides an overview of diseases or

injuries as well as main intervention areas relevant for the Netherlands [9]. The environment as a whole but specifically also the built environment is a determinant for health. However, one's health might also be influenced by the combination of environmental and social and personal factors. A typical social factor would be the availability of qualified staff in nursing homes. Personal factors include for instance digital literacy. The international Classification of Functioning and Disabilities (ICF) illustrates how different factors influence an individual's health, functional capabilities, daily activities and social participation in life and how these interacts [10]. If the built environment is seen as a determinant for health it means that interventions can be executed that may have a positive influence on health. This type of interventions are also referred to as non-pharmacological interventions. An intervention could take place in any part of the built environment within the continuum from home, hospital to nursing home. Research in this field can be two-fold: it may have an explorative character to find and explain causalities in the interaction between environment and health. But it could also be an approach for finding innovative design solutions for the built environment which will positive influence the health and/or well-being of an individual or society as a whole. In Health In the Built Environment, we actively pursue research related to all approaches in this area.

Table 1: Overview of diseases or injuries and main intervention areas (not shown are infections not relevant for the Netherlands) [9]

Disease / Injury	Main intervention area in the Built Environment
Infectious disease;	
Respiratory infections	Household and ambient air pollution, second-hand tobacco smoke, housing improvements
Neonatal conditions	Household air pollution, mothers' exposure to second-hand tobacco smoke, poor water and sanitation in birth settings
Non-Communicable diseases;	
Cancers	Household and ambient air pollution, second-hand tobacco smoke, ionizing radiation, UV radiation, chemicals, worker protection
Mental, behavioral and neurological disorders	Occupational stress; noise (for insomnia); bright lights, poor air quality and odours (for headaches). Physical activity fostered by supportive environments can reduce certain disorders.
Cataract	UV radiation, household air pollution
Hearing loss	Occupational exposure to high noise levels
Cardiovascular diseases	Household and ambient air pollution, second-hand tobacco smoke, exposure to lead, stressful working conditions, shift work.
Chronic obstructive pulmonary disease.	Household air pollution, ambient air pollution, exposure to dusts in the workplace.
Asthma	Air pollution, second-hand tobacco smoke, indoor exposure to mould and dampness, occupational exposure to allergens
Musculoskeletal diseases	Occupational stressors, prolonged sitting at work and poor work postures; need to carry large quantities of water over significant distances for domestic use.
Risk factors for non-communicable diseases in other areas but related to the environment;	
Physical inactivity	
Obesity	Workplace activity, prolonged sitting at the workplace, travel modes, transport infrastructure and landuse patterns, availability of suitable parks and open spaces
Obesity	Environmental factors favouring physical activity.

Many students have been involved in projects within the research programs of creating healthy environments. Currently the research groups, Building Lighting with prof Rosemann as chair, Building Acoustics with dr. Hornikx and Building Performance with prof Hensen are involved. The bandwidth of projects range from experimental studies in the lab, via field studies to simulation studies. A few examples of recent master projects and graduation theses underline the broad width of the research topics:

- Thermal comfort in hospitals from the perspective of nurses and patients;
- the design of an alternative ventilation systems in operations theatres, thermal requirements in the Neonatal Intensive Care Unit; or
- the impact of light on the visual performance for selecting medication

Research on the connecting link between the built environment and health will challenge your research skills but also ask you to consider ethical issues. The recruitment of participants, analyzing data and reporting results must be carried out in full accordance with the rules applicable in science and the ones related to the execution of projects involving humans. These were some of the topics addressed in the symposium Interdisciplinary human-related field research - how to make the right choice? organized at Healthy Buildings conference in 2017. ■

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[7] Rockström J, Steffen W, Noone K, Persson Å, Chapin AS, Lambin EF, et al. A safe operating space for humanity. Nature 2009;461:472-5

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[9] Prüss-Ustün, A, WolfJ, Corvalán, C., Bos R. and NeiraM 2016 Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks. World Health Organization, Geneva, Switzerland

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[11] https://www.tue.nl/healthBE

Office lighting conditions influencing human alertness

HEALTH IN OFFICES

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The transformation from individual offices towards office landscapes led to large variations in building parameters. Not all office workers are working close to a window (anymore), which might affect the lighting conditions they are exposed to. The amount and type of light our eyes (the intrinsically photosensitive retinal ganglion cells on the human retina) receive, influences the magnitude and direction of non-image-forming effects [1]. One of these effects is an increase in human alertness.

In order to investigate the influence of building parameters, specifically the distance to window, on luminous changes and subsequently the influence of these changes on employee's alertness, two field studies were performed (May 2016, the Netherlands). In study I, both influences were investigated whereas in study II the focus was solely on the impact of window distance on the luminous changes. Both lighting measurements and questionnaires (VAS) were applied.

Significant correlations ($p<.05$) were found between vertical illuminances and window distance and between correlated colour temperature and window distance. In both cases, this correlation was negative, indicating that a larger distance to the window resulted in lower illuminances and lower correlated colour temperatures. Furthermore, in study I, a correlation was found between vertical illuminance and subjective alertness for one out of the ten participants (see Figure 1).

These studies show that lighting conditions within an open-plan office environment change significantly due to window distance and that office worker's alertness may be influenced by these different lighting conditions. The low number of participants in study I only led to indications; the magnitude and direction of the potential relationship between office light and alertness needs to be confirmed in a more intensive future study.

Open-plan offices are often found to be uncomfortable or even harmful to employees [2]. We found that lighting conditions vary significantly throughout an open-plan office. These large differences may be negative for office workers situated further away from a window. Nevertheless, this variety can also be seen as an advantage for office workers because they can 'choose' their luminous exposure throughout the day. ■

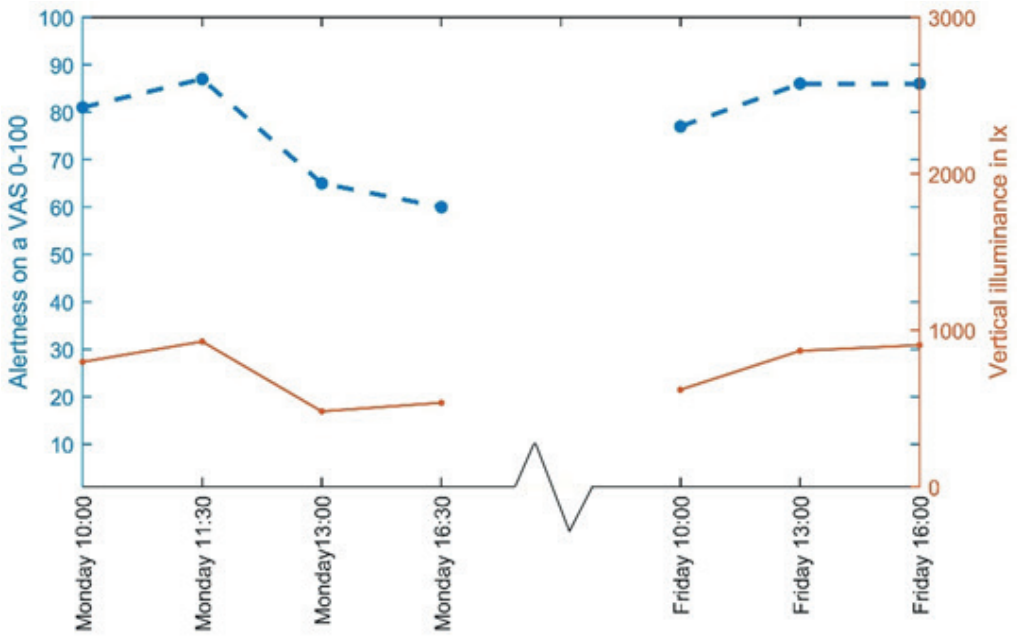

Figure 1. Relationship between vertical illuminance and subjective alertness for one participant (#7) for six measurement moments throughout the week

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[2] C. B. Danielsson and L. Bodin, 'Office Type in Relation to Health, Well-Being, and Job Satisfaction Among Employees', Environ. Behav., vol. 40, no. 5, pp. 636–668, Jan. 2008.

HEALTH IN OFFICES

The acceptability of luminous changes to open-plan office workers

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Occupancy-based lighting control has proven to save energy on lighting use; in particular, if it is applied at a high granularity, meaning at the desk level [1], [2]. With this type of control, lighting is switched off or dimmed each time an occupant leaves his or her desk. This results in a dynamic lighting environment, with several luminous changes throughout the day. In a large open-plan office environment, with multiple occupants, this can pose a possible source of distraction to the office workers. Just as noise, this distraction might negatively impact their work performance [3].

To determine whether luminous changes due to local lighting control are acceptable to open-plan office workers, an experiment was performed in an open-plan office (February 2016, The Netherlands). Dynamic lighting was experienced by the occupants (N = 9, all male, median age category 40-49) for two weeks. They were asked to keep a diary of all times they got distracted, including which environmental factor was predominantly causing it and how acceptable this was to them (7-point Likert scale). In addition, they filled in a questionnaire at the end of each week, assessing for all environmental sources how often they noticed it to change, how often this change distracted them, and, if so, whether the distraction was acceptable (again a 7-point Likert scale).

We found that artificial lighting did not distract users more than other environmental sources. Participants rated it on average just acceptable; similarly to sound, as can be seen in Figure 1, where the results from the diaries are shown. However, the spread of the scores is large, indicating individual differences: some users did regard the distractions posed by the lighting completely unacceptable. The results from the questionnaires showed the same general results, but had less spread.

Our study thus suggests that local lighting control is generally not considered distracting by occupants of open-plan offices, but that it applies as such to some users. However, as our study was of very limited size, more research is required on this topic to be able to draw a conclusion. ■

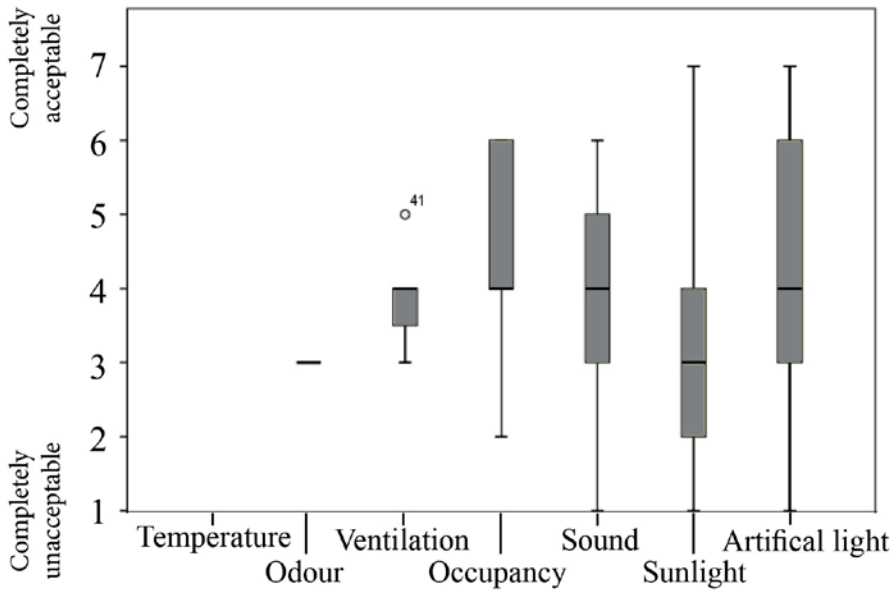

Figure 1. Boxplots of the acceptability scores from the diaries for each of the environmental sources

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[2] A. Galasiu, G. Newsham, C. Suvagau, and D. Sander, "Energy saving lighting control systems for open-plan offices: a field study," Leukos, 2007.

[3] S. Banbury and D. Berry, "Office noise and employee concentration: Identifying causes of disruption and potential improvements," Ergonomics, vol. 48, no. 1, pp. 25–37, Jan. 2005.

The acoustics of open-plan study environments

HEALTH IN SCHOOLS

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INTRODUCTION

An increasing number of students in higher education (post-secondary school institutions) spend a large part of the day in open-plan study environments (OPSEs). Research has shown that learning can be influenced by the physical environment where students perform their tasks [1][2] and that sound is one prominent dimension of this influence. However, the majority of research on noise, room acoustics and learning has been conducted in classrooms and in lecture halls, not in OPSEs, and has not been focused on students in higher education [3].

OPSEs are very similar to open-plan offices in terms of room acoustics, but the rich acoustic research on open-plan officies cannot directly be translated to OPSEs due to different activities, and different characteristics of the users in OPSEs. For instance, students are younger and not obligated to work for a full day in a specific OPSE. Therefore, the present study focuses on the effect of noise on students in OPSEs and especially in higher education.

NOISE DISTURBANCE IN OPSES

To gain more insight into the assessment of noise in OPSEs and to reveal the correlation between noise disturbance of students and the acoustic parameters of an OPSE, a field study was performed in five OPSEs in higher education in the Netherlands [4]. This study showed that more than one third of the surveyed students are disturbed by the background noise in OPSEs. This percentage might underestimate the actual influence of background noise on the disturbance because students may choose a different working place to avoid this disturbance. This survey showed that students are mostly disturbed by noise when performing individual complex cognitive tasks such as studying for an examination, reading and writing. In this study only weak significant correlations were found between the room acoustic parameters and noise disturbance of students, probably due to the limitations of a field study.

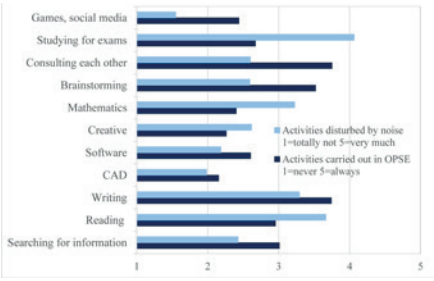

Figure 1. Activities carried out and bothered by noise in an OPSE [4]

PERFORMANCE OF TASKS IN OPSES

As a follow-up, experimental studies were done to find correlations between room acoustic parameters, sound sources and disturbance and performance of students for the most important student tasks in OPSEs. Computational modelling and auralization were used to simulate the sound scape of an OPSE. Sound scapes were composed by combining two different reverberation times with two different speech conditions. Students were asked to perform different tasks while exposed to these sound scapes through headphones or loudspeakers. Until now writing and collaboration tasks have been investigated. An unexpected result given literature results is the observation that the strongest negative effects on writing performance were found in conditions of high reverberation and high occupancy (many individual speech sources) while on basis of the literature, these conditions should have less effect because the intelligibility of the backgound speech is rather low [5][6]. Also in the collaboration experiment the participants experienced a long reverberation time as being more disruptive compared to a short reverberation time. The performance was slightly lower in the reverberant situation compared to the absorbent situation, although not statistically significant. Follow-up experimental research will be done to find the relation between background speech, room acoustics and performance and well-being for more tasks that are typical for students working in OPSEs.

More practical research is done by bachelor and master students on vegetation screens as one of the possible solutions to improve the sound privacy in OPSEs. This research has been presented at the Healthy Building Conference 2017. ■

[1] Tanner, C. K. 2000. "The Influence of School Architecture on Academic Achievement." Journal of Educational Administration 38: 309–330.

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HEALTH IN SCHOOLS

Classroom indoor climate and student thermal comfort

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Indoor climate quality (ICQ) – air quality and thermal environment – affects mental and physical health of occupants, especially for classroom teaching-learning process. Current thermal comfort standards often inaccurately portray student requirements , at least in part due to students having a transitional occupancy profile, moving across classrooms. To understand these transitional, student comfort needs, studies were conducted in Lecture room 7 of the Auditorium during two weeks of March 2016, involving continuous measurements of indoor thermal environment and subjective surveys at intermediate time points during classes. As the classes progressed, student thermal sensation changed even though indoor thermal conditions did not. Set-point temperature during the second week had been lowered by 1.5 °C. But, by end of the classes, thermal sensation votes were similar for both weeks. For nearly 20 mins post entrance, students retained a thermal memory of their last environment. They gradually adapted to the classroom's thermal environment, most of this adaptation taking place within the first 20 mins, similar to climate chamber studies. Immediately after entering the classroom, student thermal perception was primarily affected by where they were coming in from.

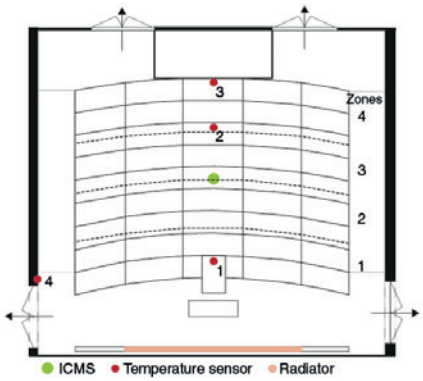

Figure 1. Classroom measurements layout

Energy consumption in educational buildings is also an important concern. Current standards endeavor to take care of both ICQ and energy concerns through prescriptive recommendations. The performance of an innovative conditioning system for school classrooms (airConomy®, from Eco Klima), combining ventilation and floor cooling/heating, was investigated through measurements in a full scale mock-up and in a classroom. The measurements showed that the airConomy® system employs a lower ventilation flow rate than current recommendations but achieves required ventilation levels, as shown from indoor CO_2 levels and ventilation efficiency measurements. The system also did not pose any issues of local thermal discomfort like draught and thermal stratification. On a further positive, lower ventilation rates meant the system used lesser energy than current, similar systems. The results of this study stress upon the advantage of performance based standards over prescriptive standards when moving towards innovative, low energy solutions for future buildings. Prescriptive guidelines can lead to innovative alternatives getting overlooked. ■

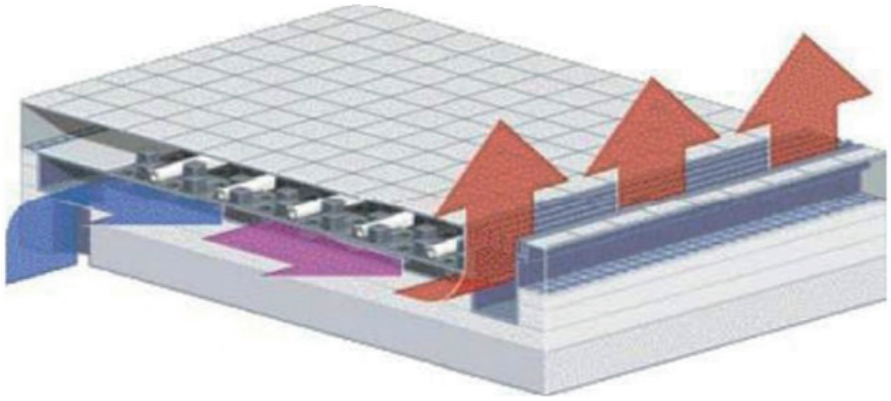

Figure 2. The airConomy® climate system

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Creating Healthy Environments Hospitals (CHEC)

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HEALTH IN HOSPITALS

One of the major societal challenges we are facing today is transforming healthcare so it becomes sustainable in terms of costs, availability and outcomes. Outcomes for professionals refer to comfort, well-being, work pleasure and safety, minimizing risks in care and appropriate care performance, resulting in improved staff retention and effectiveness. The project "Creating Healthy Environments Hospitals" (CHEH) aims at identifying environmental conditions which improve the staff retention and effectiveness. This project is part of the Spark Impuls program where the BPS groups "Building Performance" and "Building Lighting" closely collaborate with the Lectoraat "Technology for Healthcare Innovations" of the Utrecht University of Applied Sciences (HU). The two focus areas are Light (TU/e) and Sound (HU).

INTRODUCTION CHEC, LIGHT. MEDICATION ERRORS.

In hospitals medication follows a long route before it reaches the targeted patient. In this process (e.g. procurement, prescribing, transcribing, order entry, preparation, dispensing, administration, and monitoring of medications), human mistakes are easily made. Missed doses, missed medications or wrong medication are the primary errors [1]. These can result into a life threatening situation for patients. Human mistakes might originate from a too high workload, from distractions or interruptions by colleagues, or inappropriate lighting. The lighting environment impacts the visual performance as well as the non-image forming aspects like alertness. Medication errors are more pronounced during night shifts, when light levels are kept dim to enhance the sleep quality of the patients. Under dim light conditions it is more strenuous to read labels, check infusion fluids and to stay alert. This becomes even worse for nurses whose sight is deteriorated due to presbyopia and eye fatigue due to biological ageing. Therefore it is crucial to have a lighting situation that enhances the (visual) performance of nurses managing medication [2], [3]. In this initial research the lighting situation was measured in two hospitals (H1 and H2) in different wards (H1 standard, H1 IC, H2 A, H2 B and H2 C). Additionally, a survey about their light conditions was conducted among 32 nurses working at these wards. The data was collected with support of L. Mennen.

RESULTS AND DISCUSSION

An impression of a medication room is shown in Figure 1. The average lighting conditions are given in Table 1. According to the recommended values [4] the CCT and UGR are in all medication rooms according to the standards. The desk illuminance in the new hospital is a bit too low, as well as in the old, not renovated medication room.

Figure 1. Example of Medication room (H2 A). Preparation of medication takes place at the small desk at the left.

When comparing these values to the experience of the nurses (Figure 2) we can see that most are quite satisfied with the amount of light, although the nurses at H2 A tend to be less satisfied than at the other wards.

Table 1. Lighting conditions for different medication rooms

	Eavg [lx]		CCTavg [K]	UGR [-]
	Desk	Floor		
Recommended value	500	100		<19
H1 standard	397	325	2823	4-8
H1 IC	293	356	2967	
H2 A	195	315	2784	6-7
H2 B	521	773	3039	9-17
H2 C	839	483	3092	10

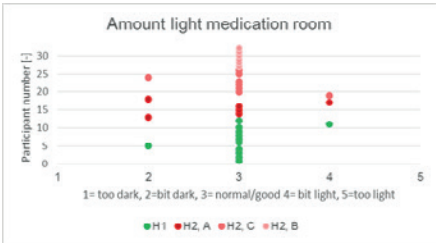

Figure 2. Example of Medication room (H2 A). Preparation of medication takes place at the small desk at the left.

CONCLUSIONS

Not all lighting conditions in the different medication rooms follow the current recommended value for hospitals although nurses are in general quite satisfied with the lighting condition. Expected is that the combination between small printed labels and dim light conditions will lead to fatigue and possibly errors. The next steps in this research is to determine the best lighting condition for preventing medication errors. The first step is to indicate the most suitable lighting related to the visual performance, the second will focus on the lighting condition to improve the alertness and well-being of hospital staff. ■

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HEALTH IN HOSPITALS

Effect of the sound environment in hospitals on occupants

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The influence of the auditory environment in hospitals on patient satisfaction, outcomes and sleep quality has been a topic of research since the early twentieth century [1]. However, a complete understanding of the influence of the auditory environment in hospitals has not yet been achieved. Looking into the literature on the sound environment in hospitals and its effect on healthcare staff, most studies focus on the high noise levels that are continuously present in intensive care units and during (orthopedic) surgery. The role of the sound environment in general nursing wards has gone unremarked, perhaps due to the absence of extreme sound levels in these areas.

We have learned from other research fields though, that sound intensity is not the only predictor for performance decrease or annoyance. Other aspects such as the predictability of sound, the intelligibility of speech and the source type are important to consider when we want to create healthy and comfortable sound environments [2].

The main topic of this project is to gain insight in the influence of the sound environment (and the role of room acoustics) on the performance of nursing staff. At the Healthy Buildings conference the results of a side-project were presented; related to speech. This topics will be addressed here briefly.

HEALTHY BUILDINGS: SPEECH PRIVACY IN MULTIPLE-PATIENT ROOMS.

Even though research has shown the multiple benefits of single-bed patient rooms in hospitals [3], the majority of rooms in existing hospitals are shared. To share a hospital room means to share sensitive and information with total strangers which may cause uncomfortable situations for both patients and healthcare professionals. Furthermore, the awareness of other ears in the room could even withhold a patient from sharing important information during visiting rounds [4].

A possible solution is the use of local soundmasking systems combined with a good room acoustic design. A pilot study was conducted to gain insight in importance of speech privacy in multiple-bed patient rooms in a Dutch hospital from both patients' and professionals' perspectives. Additionally the impact and acceptance of a local soundmasking system in a 4-bed patient room was investigated. See Figure 1 for layout and measurement positions.

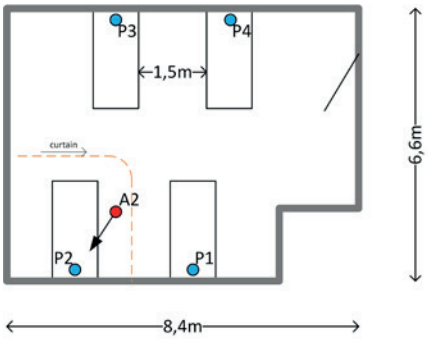

Figure 1. Layout of the room and measurement positions

Room acoustic measurements were conducted to determine the physical effect of the system on speech intelligibility. Subjective measures included interviews with patients experiencing the system and the wards' staff. A questionnaire was used to gather information on people's need for speech privacy in the ward.

The results indicate that patients as well as healthcare professionals acknowledge the need for speech privacy in multiple-patient rooms. The local soundmasking system which was installed significantly reduced the speech transmission index (STI) as can be seen in Figure 2, but leaves room for improvement. Based on the interviews it was concluded that implementing local sound masking in multiple-bed patient rooms is promising and further research on both the perception of the patient as the acoustic properties will be conducted. ■

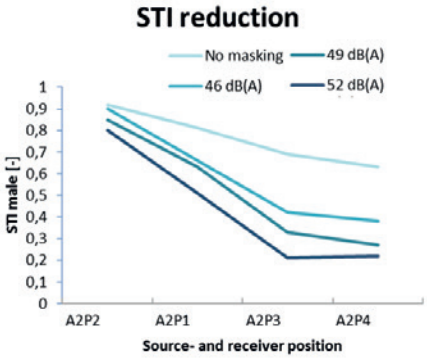

Figure 2. STI reduction for each source-receiver position in different masking levels

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Stichting Promotie Installatietechniek (PIT)

De Stichting PIT zet zich in voor promotie en innovatie binnen de installatiebranche. Wij financieren projecten die in technisch, economisch of wetenschappelijk opzicht vernieuwend zijn. Dat doen we voor organisaties die zich zonder winstdoelstelling bezighouden met onderwijs en kennisontwikkeling in de branche. Denk bijvoorbeeld aan universiteiten en onderzoeksinstituten.

Zo draagt Stichting PIT bij aan het genereren van nieuwe kennis en innovatieve ontwikkelingen waarvan de gehele installatiebranche kan profiteren. Daarbij moet altijd sprake zijn van substantiële cofinanciering. Zo waarborgen we dat er binnen de branche draagvlak bestaat voor onderzoeken en projecten die door de Stichting financieel worden ondersteund.

A new wind tunnel. In our Department. What? Why? How?

Author
prof. dr. ir. B.J.E (Bert) Blocken

Don't say wind tunnel to an atmospheric boundary layer wind tunnel. The TU/e currently has three wind tunnels. A large one called Goliath in the Department of Applied Physics (test cross-section 0.8 x 0.5 m²), a smaller one in our Department (test cross-section 0.5 x 0.5 m²), and the baby wind tunnel, used for demonstration purposes (test cross-section 0.2 x 0.2 m²). The Goliath wind tunnel is a typical aeronautical wind tunnel. The new wind tunnel (WT) will be an atmospheric boundary layer wind tunnel (ABLWT), with test cross-section 3 x 2 m² and test section length of 27 m. The total length of the ABLWT is 46 m (see Figure 1). An aeronautical WT reproduces wind flow high up in the atmosphere, where the mean velocity profile is considered uniform and turbulence is low. An ABLWT reproduces wind flow in the lowest part of the atmosphere, near the surface of the Earth, where the mean velocity strongly increases with height and turbulence is high. In an oversimplification, one could state that an aeronautical WT is used to physically simulate airflow around objects high up in the sky (airplanes, helicopters, etc.), while an ABLWT is used for objects mounted on the surface of the Earth (buildings, ships, etc.).

WHY A NEW ABLWT IN OUR DEPARTMENT?

There were several compelling reasons to establish an ABLWT in our Department and University. First, as a research-intensive country, it is almost inconceivable that no university in the Netherlands had an ABLWT. Second, since the shutdown of the TNO ABLWT in Apeldoorn, the Netherlands only had two ABLWT facilities left: one at DNW-NLR in Marknesse, and one at Peutz in Mook.

Third, the ABLWT is intended to reinforce the international position of the Department of the Built Environment and of the TU/e in the field of urban physics and wind engineering. So far, most of the work done in this field in our Department consisted of either numerical work (mainly CFD) or field measurements, or a combination of both. For wind-tunnel experiments, we always had to visit other universities and research institutes, which is costly and less practical. Thanks to the new ABLWT, the TU/e will be the only university in the Netherlands with such a facility, and the Netherlands will again have three ABLWTs to support Dutch research and innovation

HOW WILL IT BE USED?

The TU/e ABLWT will be used for research and valorization in six focus areas (see figure 2): built environment, maritime technology, sports, vehicles, air quality and wind energy. The facility has been specifically designed to allow high-quality testing in each of these areas and will be unique in several aspects. The test section is 27 m long, as opposed to most ABLWT facilities in the world that have a test section length between 8 and 15 m. This large length allows testing of air pollution spreading over a very long distance upstream or downstream of cities. It also allows analysis of several wind turbines positioned behind each other. Further, it allows simultaneous testing of 4, 6, 8 or 9 cyclists behind each other in a team time trial.

CONCLUSION

A new state-of-the-art ABLWT has been designed and constructed at the Department of the Built Environment @ TU/e. The ABLWT allows to expand research and innovation at TU/e and beyond. ■

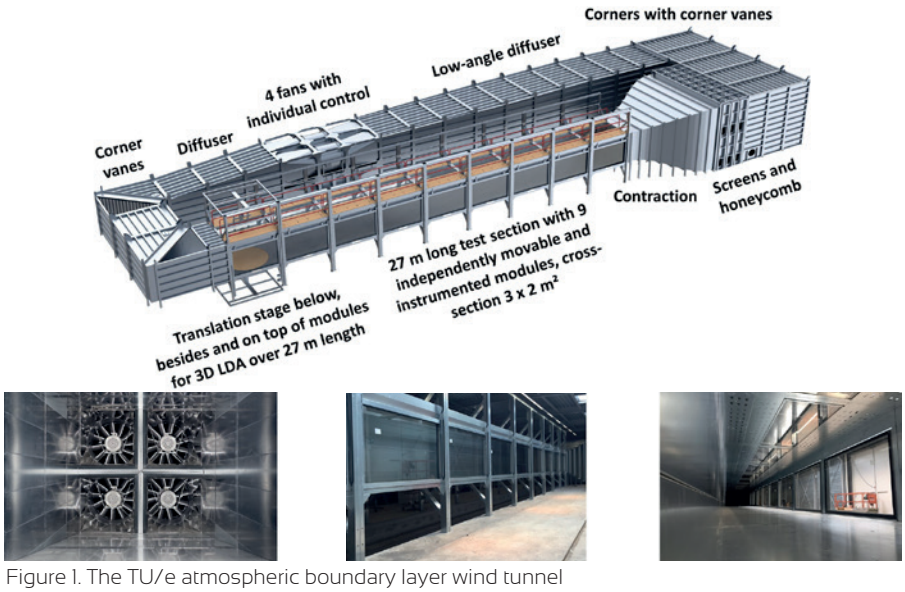

Figure 1. The TU/e atmospheric boundary layer wind tunnel

Figure 2. The six focus areas of research and valorization for the TU/e atmospheric boundary layer wind tunnel

Mollier, Building services & Datascience

Author
B. (Barry) Tuip

In 2004, I started my career as a bachelor student Building services. We were the last ones, the stop of our bachelor program was announced during our introduction week.

Since the introduction week I had a great time in Eindhoven! Mollier was like a group of new friends and with our own space and activities at the TU/e, studying became like a new hobby for most of us. During my study, I was part of the 11th board of Mollier (external relations) and I organized several study trips and activities. The study trips might be the best memories of that time. Not only the faraway trips to Dubai, Shanghai or Malaysia, but also the Eurotrips with our own touringcar were a great way to travel through Europe, visit interesting companies and have karaoke party's in the bus!

As a student, I started working at Deerns in Eindhoven once a week. A great opportunity to get already some working experience while studying. For my graduation project, a decided to look for a company where I could help fixing a very big problem in our business: most buildings don't perform as they should.

At Strukton Worksphere, I started with some analyses of building performance, based on data of indoor climate conditions, energy consumption and BMS data. The combination of the insights from this data were very helpful to get a full view of building performance, and help colleagues to find and fix problems at our customers. We started with the use of Excel, but the 2009 version was only limited to 32K lines so my Matlab skills from the university we very useful at that time (we're still using Matlab btw).

Figure 1. 11th board of Mollier. From left to right: Sander ter Mors, Mike van der Heijden, Mark Niesen and Barry Tuip

Figure 2. PULSE team at Strukton Worksphere

In 2012, Strukton Worksphere started with a big innovative project, now called Strukton PULSE. The objective of PULSE was to get our company more data-driven and to become best of class in the way we operate and maintain the buildings of our customers. I started to work on the data analysis part of the project which has now, 5 years later, developed to our own big data platform, a new department with over 10 employees (of whom four are former Mollier members).

We use PULSE for all kind of automated analysis like: fault detection, energy management, comfort analysis and predictive maintenance. Predictive maintenance is becoming a key element in our business: predicting equipment failure and required maintenance to prevent these failures.

This also introduces a new kind of knowledge needed in the field of building services: datascience. Combining our knowledge and experience with IT specialists who know how to process data, use machine learning techniques to discover new relations, and build models to predict building and equipment performance. In the end, I hope this might help us get a little bit closer to my objective I mentioned before: making buildings perform as they should!

Last but not least, my newest job which I practice for over 8 months now is also really great, amazing, gives me a lot of energy, but is also quite a challenge sometimes: taking care of our son Jax who was born in April this year!

I wish all the students at Mollier all the best with their studyies, we will catch up at the next activity of Schoone Leij or Mollier! ■

heijmans

START JE CARRIÈRE BIJ HEIJMANS!

Wil jij zien op welke wijze Heijmans bouwt aan de ruimtelijke contouren van morgen? Ben jij nieuwsgierig naar welke spraakmakende en innovatieve concepten Heijmans ontwikkelt en realiseert? Volg ons dan op Facebook, Instagram, LinkedIn en Twitter en schrijf je op onze website in voor onze nieuwsbrief 'het Beste van Heijmans.'

techniplan adviseurs bv
RAADGEVEND INGENIEURSBUREAU

www.techniplan.nl

Ga jij de uitdaging aan om ontwerpvraagstukken over energiebesparing, duurzaamheid en een comfortabel binnenklimaat in gebouwen integraal aan te pakken? We zijn op zoek naar enthousiaste stagiairs, afstudeerders en nieuwe collega's die hierover met ons willen nadenken! Bij Techniplan Adviseurs lever je een bijdrage aan duurzame en innovatieve bouwprojecten en werk je integraal aan de advisering op het gebied van techniek in gebouwen en de gebouwde omgeving. Ook zijn er mogelijkheden voor een duaal traject, waardoor je al tijdens je studie praktijkervaring kan opdoen.

Geïnteresseerd? Neem dan contact op met Esther Gerritsen (tel: 010-4562311).

Low-frequency impact sound transmission through floors

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ir. T.B.J. (Theo) Campmans

INTRODUCTION

In recent years discomfort due to neighbor noise from adjoining appartments has been increasing. Urbanization leads to more multi-family buildings and more people living together in older renovated or new innovative buildings. Several field studies performed on traditional heavyweight buildings and innovative lightweight buildings show that impact sound is found to be very disturbing, especially in the low-frequency range, and for lightweight constructions. With the upcoming market of lightweight building techniques and stricter regulations on low-frequency sound it is necessary to improve the reduction of impact sound transmission.

LOW-FREQUENCY SOUND

Sound below 200 Hz is generally regarded as low-frequency sound. Furthermore, acoustics in the lower frequency range behaves differently than high-frequency sound in buildings. Generally, at higher frequencies, conditions of the sound fields in rooms and vibration fields of constructions are assumed diffuse, which means that practically equal conditions are present at every location. In other words, the pressure would be equal everywhere in a sound field. However, low-frequency sound fields cannot be assumed as diffuse and exhibit modal behavior, especially in small rooms.

Modal behavior is governed by eigenfrequencies that are the frequencies at which a construction easily vibrates and radiates sound. The eigenfrequency for simply supported plate constructions can be obtained by equation 1.

$$f_{lm} = \frac{\pi}{2}\sqrt{\frac{Eh^2}{12\rho(1-\nu)}}\left[\left(\frac{l}{L_x}\right)^2+\left(\frac{m}{L_y}\right)^2\right]$$

Equation 1. Eigenfrequency for simply supported plates, which depend on the material properties; Young's E-moduls (E), density (ρ), and Poisson's ratio (ν) and on the geometry; length (L_x), width (L_y), and the plate thickness (h).

PROBLEM STATEMENT

Modal behavior results in a non-diffuse sound or vibration field that has a spatial distribution of pressure or velocity of amplitudes and equilibrium. In practice modal behavior is a problem for designers, since at one point in a room the acoustics can be considered good, while at another point it can be considered bad. For instance, when a person sits at a desk in a room (s)he can hear the sound of a radio softly, instead while standing (s)he experiences the sound more loudly. When designing it is difficult to take this unequal sound field into account.

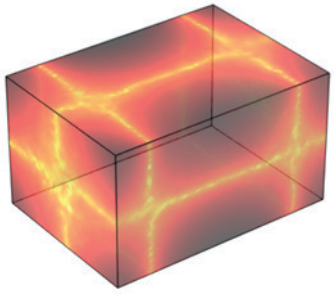

Figure 1. Non-diffuse sound pressure distribution in a room with a lower sound pressure level (light) and a higher sound pressure level (dark)

AIM AND METHOD

The aim of this research was to study the influence of different geometrical configurations and material properties on the impact sound transmission of a floor. The objective is to gain insight in the modal behavior of floor constructions. This is done by characterization of the modal shapes and a parametric study into the influence of the floor properties. This study is done for both a plate floor and a beam floor, where the plate floor is approached as a reference and to determine the plate's influence. Prior to this research, a literature study and a verification study were performed.

Research is done with the use of finite element method (FEM) software COMSOL to numerically model the floors and their impact sound transmission as shown in Figure 2. The use of a numerical method allows for readily applicable changes in geometry or material properties, as well as the boundary conditions. This makes it more effeciently to investigate different models in comparison with setups of experiments.

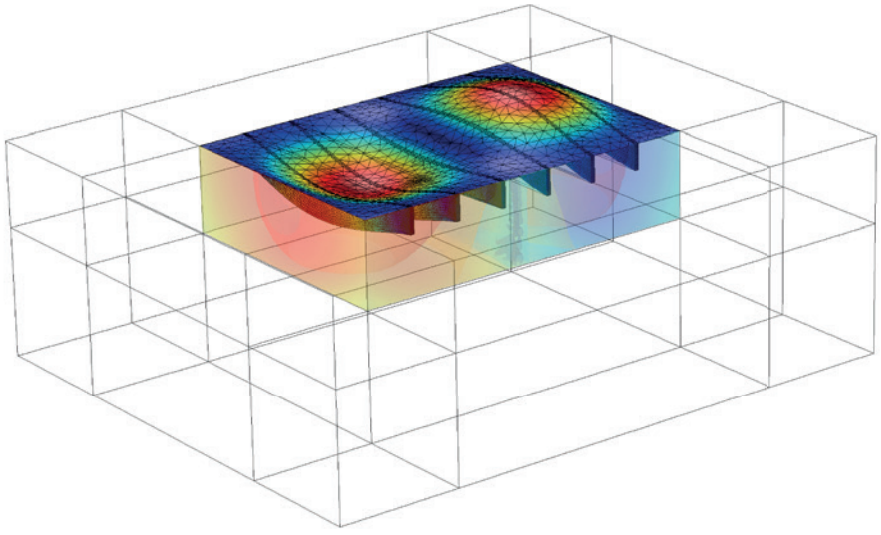

Figure 2. Representatation of the final FEM model with overlayed resulting vibration field and sound field (transparant). The vibration field shows the modal shape belonging to the second eigenfrequency of the beam floor as well as the resulting sound radiation

CHARACTERIZATION METHOD

To understand the vibration behavior of floors, different modifications of a floor construction have been investigated. In these modifications, different elements of the floor construction have been decoupled and different boundary conditions are applied to them. By blocking the degrees of freedom or changing the stiffness the plate, beam and coupling elements exhibit different translation and rotation. This methodology allows for analysis of the wave behavior of the floor construction and its separate elements. The methodology for the configurations is derived from research into vibrational behavior of wooden floor from [1]. The structural mechanics module from COMSOL is used to determine the eigenfrequencies and modal shapes of the different floor configurations using the eigenfunctions. The goal is to identify characteristic modal shapes and deduce their origin.

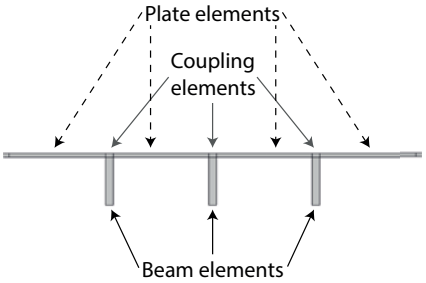

Figure 3. Representation of the geometrical model and its separate elements that can be fixed or otherwise constrained

The geometry of the floor construction is chosen as simple as possible in order to gain insight in the wave behavior, resulting in a top board lying on three equally spaced beams. On the sides the board is constrained, which means only the board and three beams are able to displace. Thus only the plate and three beams are modeled. The connection between board and beams are made using three elements, which will be called coupling elements, that divide the board into four plate elements.

CHARACTERIZATION

The characterization study is done for a 2D configuration first, subsequently a 3D configuration is investigated. Figure 4 shows the modal shapes for the 2D configuration were the coupling elements are fixed. As can be seen this results in vibrations, occuring only in a single element. Only a plate element displaces in-between two coupling elements, or it is possible that a beam element displaces. These are the core characteristic vibrations that can occur in floor constructions. However, in practice waves can propagate within the floor and are not restricted by the coupling elements. Instead, modal shapes occur such as seen in figure 5 that represents a more realistic floor. Waves travel through the whole floor and result in plate and beam displacement.

Figure 4. Modal shapes for a 2D beam floor with fixed coupling elements

The eigenfrequencies of the floor seem to follow three specific ranges which can be assigned to specific modal shapes. Modal shapes that exhibit a wave motion with the entire floor belong to the first group of eigenfrequencies. Shapes are determined by the motion of the plate element and the beams follow the plate rotation. Due to this behavior and the free rotation at the coupling element the beam eigenfrequency is significantly lowered and occurs at the end of the first group where it is a combination of a plate and beam wave motion. The second and third grouped eigenfrequencies consist of half and whole wavelengths that fit between the beams. Intermediate forms are restrained and do not occur causing the jumps in eigenfrequency groups.

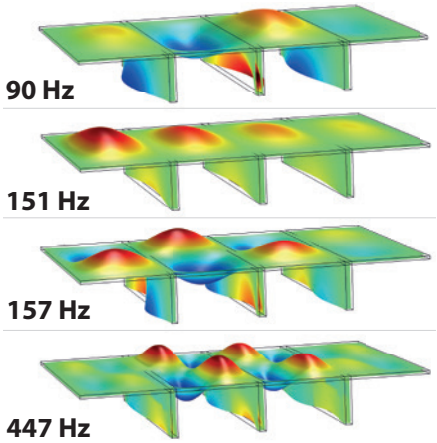

Figure 6. Modal shapes for a 3D beam floor with all side edges clamped

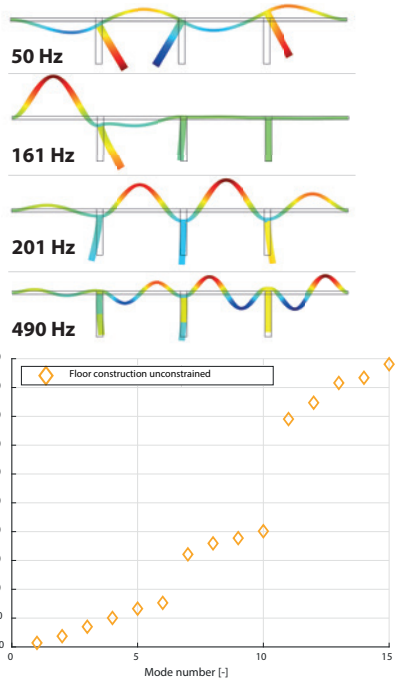

Figure 5. Modal shapes for a 2D beam floor with only the side edges fixed and all the eigenfrequencies for the considered floor

A similar study is done for the 3D floor configuration and figure 6 shows the uncoupled floor. Results from the parametric study will be compared with this investigation to examine if it is possible to characterize the modal behavior of the floor. The first eigenfrequencies exhibit wave behavior belonging to the entire floor. As seen for 90 Hz both the beams and the plate elements displace, while the dominant motion occurs in the beams. For the higher frequencies the modal behavior shifts towards dominant plate displacement in-between the beams. Except when the beam eigenfrequencies occur, which can be seen at 157 Hz, there both the beam as well as the plate elements displace.

Figure 7 shows the consequences of the 3D model; a broader range of eigenfrequencies since wave-motion in the depth direction of the floor can occur, which is applicable to both the

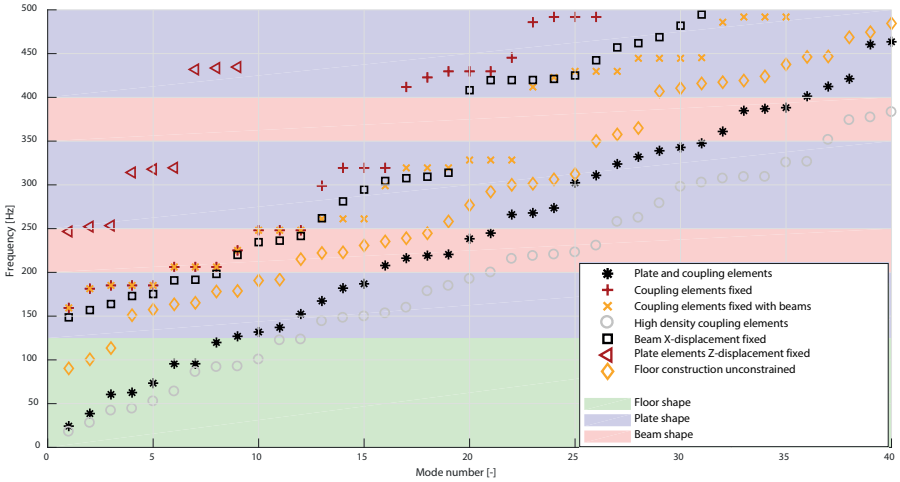

Figure 7. Eigenfrequencies and their distinct modal behavior of all modifications for the considered 3D beam floor

plate elements as the beam elements. It should be noted, that modal shapes are not purely exclusive to the plate or beam elements rather they often occur in both elements. In particular at the floor shape region the floor does not behave as a whole such as in the 2D configuration, but rather the modal behavior occurs as a mutual wave motion, coupling the beam and plate elements. This sort of behavior also occurs at some higher frequencies.

PARAMETRIC METHOD

A powerful source of insight into a model is examining the behavior of its outputs as you systematically vary one or more of its inputs. This method is called model behavior analysis. Each input that you vary systematically is called a parameter, thus this method is commonly known as parametric analysis. First is described which parameters are investigated and how they are assessed.

The eigenfrequencies and their modal behavior are the base of impact sound transmission and are directly derived from the wave equations. It is from the equation for the eigenfrequency that the variables applied for the parametric study are chosen. These variables influence the impact sound transmission since they are present in the eigenfrequency and other equations relevant to the transmission. The eigenfrequency equation for solids shows three types of categories; geometry specific, material specific, and source specific. Length, width, thickness are geometry specific, and respectively stiffness, density, and Poisson's ratio are material specific, while excitation location and strength are source specific.

By varying these variables as the input of the validated model the changes in radiated power and sound power level are investigated. A reference model is chosen to represent a case that is expected to be neither heavyweight nor lightweight for comparison with the parametric cases. The results of the parametric study are presented as modal shapes, vibration fields, and sound power levels. Graphs and tables are presented to compare the parametric range of the variables. In this article only one parametric study will be presented as example for the explanation of the method and results.

A first step is the determination of the influence from the parametric variables on the eigenfrequencies and their respective characteristic modal shapes. These are compared with the identified frequencies and shapes in the characterization study. In addition, the frequency response of the floor, its velocity field, is compared with the modal shapes to investigate the distribution of the excitation energy. This is done with normalized and average values to provide a clear overview for the different parameters and their values. Finally, the radiated sound power is analyzed with respect to peaks and magnitude. The sound power level per frequency is provided to accurately analyze the sound radiation of the floor. These results are then summarized in a single number rating or octave band values.

RESULTS PARAMETRIC STUDY

An eigenfrequency graph shows the obtained frequency and the amount of modal shapes that will determine the impact sound transmission. Plotting the found eigenfrequencies against the parametric quantity shows the effect of changing a material or geometry. The obtained eigenfrequencies up to 200 Hz are shown in figure 8 for the parametric of the density from the plate. It can be seen that with increasing density the eigenfrequencies will lower and more modal shapes will occur within the floor. In general, this implies there will be more sound radiation frequecies and thus more sound power level peaks.

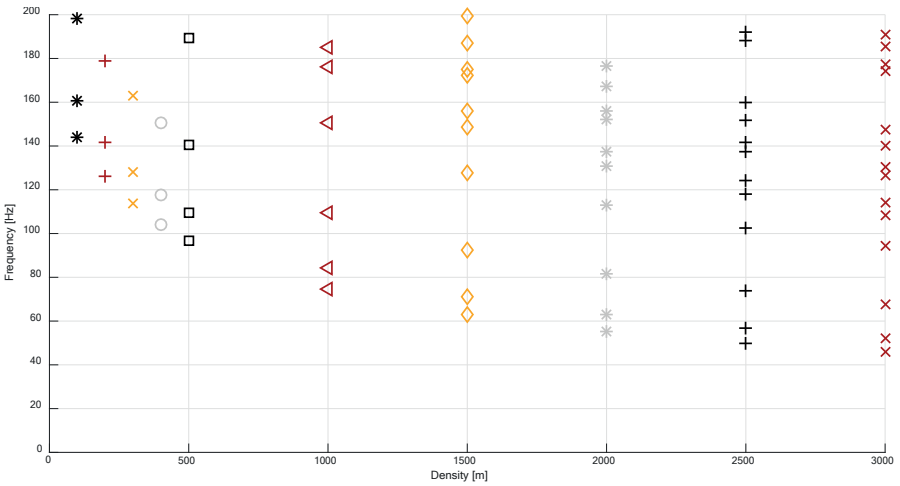

Figure 8. Eigenfrequencies of a beam floor for the parametric range for the density of the plate

These eigenfrequencies have appurtenant modal shapes that will govern the excitation admittance and velocity field. Figure 9 shows the average of the normalized modal shapes belonging to the found eigenfrequencies of the floor. The average shows that considering the frequency range of 1 – 200 Hz the shape functions have higher values in the light colored areas. These areas more easily admit energy by impact forces and similarly vibrate more easily when the floor is excited. The resulting velocity field after excitation on the surface of the plate averaged over the same frequency range. Comparing the velocity field with the averaged normalized modal shapes, a similar pattern can be seen, separated in single regions and more attenuated away from the excitation.

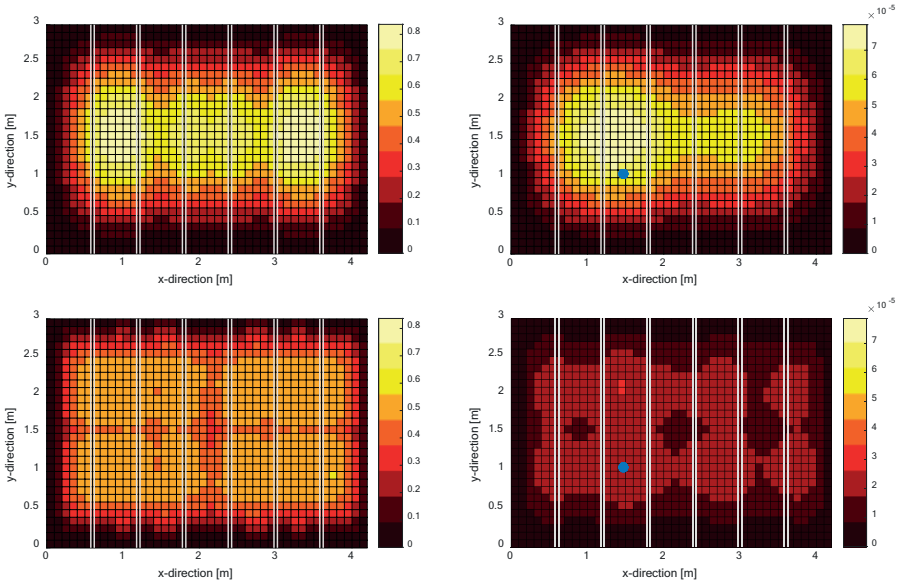

Figure 9. Average of the normalized modal shapes displacement [-] (left) for the found eigenfrequencies for a beam floor with a density of 100 and 3000 [kg/m3] for the plate elements and the corresponding velocity fields (right) with excitation (blue dot).

The lightweight situation surface velocity is completely governed by the first three modal shapes in the chosen frequency range, the mode belonging to the plate elements dominates the floor behavior. Eventually when the plate mass increases the dominant behavior shifts to the beam and plates as found in the characterization study. The heavy weight plate shows a more uniformly distributed modal shape and velocity field, even though the vibrations mainly occurs in-between the beams. Furthermore, it is seen that the magnitude of the surface velocity is much lower.

The radiated sound power level is shown in figure 10. Analysis of the sound power level clearly shows that the peaks are related to the eigenfrequencies of the floor. It is this pattern that results due to the modal behavior of the floor; namely from excitation to vibration and eventually to radiation. The magnitude of the peaks show the influence of the excitation location and floor impedance. For the parametric investigation of the density from the plate elements it is seen that the sound power peaks shift to lower frequencies with increasing density. Subsequently, more peaks will be in the frequency range, however, the magnitude of these peaks is lower.

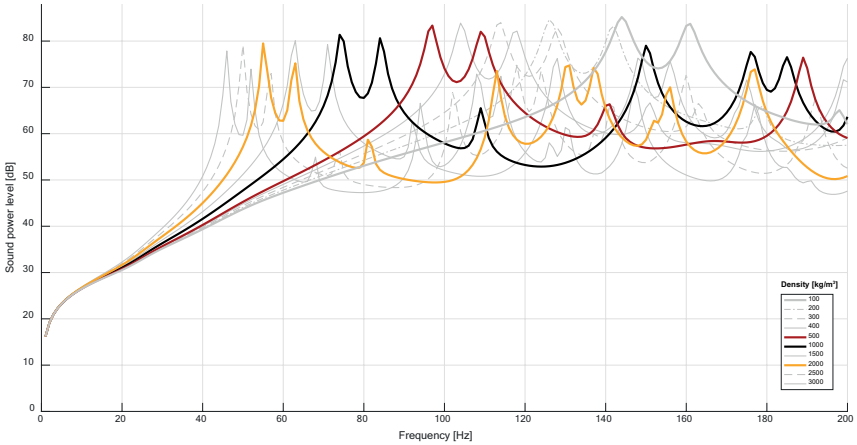

Figure 10. The radiated sound power level of a beam floor on the parametric range for the density of the plate elements

When the single number rating is investigated (presented in [2]), it is found that higher density plates for a beam floor have lower sound radiation. This implies, although there are more modes that can radiate sound, that the floor impedance is higher. A more practical conclusion from the parametric study into the density of the plate element is that the rate of decrease for sound power lowers slightly with an increasing mass. This is to say, increasing the density of a lightweight plate has more effect than increasing the density of a heavyweight plate.

These were only a summary of the results of the parametric study into the density of plate elements at beam floors. In the same way, all modifications for the plate floor and beam floor are investigated and analyzed in more detail, which led to more findings.

FINDINGS

Two floor configurations have been investigated, namely a plate floor and a beam floor. First the modal behavior of the floors are characterized. Second, the geometry, material and source properties have been studied by a parametric method to investigate their influence on the modal behavior and impact sound transmission.

- Eigenfrequencies that are found can be categorized in different regions. Examination of the displacements, the modal shape, belonging to the computed eigenfrequencies show groupings by beams, plates or the floor as a whole.

- The first few eigenfrequencies exhibit purely global behavior but are governed by the floor geometry. When eigenfrequencies become of a higher order the global behavior becomes supplementary to the local behavior. Local behavior will occur at higher frequencies when wavelengths are able to fit between beams. Wave motions are present in the plates, and the beams will act as boundaries.

- The general behavior with relation to global and local displacement are present in any floor and it is the ratio of stiffness and mass between plates and beams which determines the occurrence of local and global vibrations.

- The geometry of the floor has the largest influence on the impact sound transmissions as it influences the floor as a whole by defining the dimensions of the elements. These dimensions influence the eigenfrequencies at their base since waves of half a wavelength must fit in these dimensions.

- Secondly, a change in the dimensions causes a change in the stiffness and mass of the element, further affecting the modal shapes, while also determining the floor impedance and radiation. In general, larger dimensions result in less eigenfrequencies that will radiate sound, in addition larger dimensions have a higher mass and greater stiffness admitting less energy. On the other hand, a larger floor area or plate area leads to more eigenfrequencies and a higher sound radiation.

- The above conclusions are applicable for the most part to both the plate floors and the beam floors, and respectively the plate elements and the beam elements. This means a similar influence is expected, only the extent of the effect differs. Furthermore, for beam floors these effects seem to be dependent on the ratio of plate and beam properties for the mass and stiffness.

- The modal shapes are the significant factor in the impact sound transmission for every investigated parameter. Even though the floor impedance and radiation factor play a large role in the sound transmission, it is always in conjunction with the modal shape if a force is admitted and if it has a resulting velocity.

RECOMMENDATIONS

All in all this was an extensive research with a broad scope and many variants. However, still many assumptions and simplifications had to be made. This results in new opportunities for further research:

- Eigenfrequencies and modal shapes, and thus subsequently the impact sound transmission, are very dependent on the boundary conditions. During this research idealized conditions such as a fixed surface or simply supported edges are applied. However, in practice many different types of connections are present which will have a particular influence. An explorative investigation could be done towards the magnitude of influence for these boundary conditions.

- The most important conclusion of this thesis was that the impact sound transmission is very dependent on the mass and stiffness in relation to the ratio for the plate and beams. Where the plate element in this study is eventually still considered thick, further research could indicate the quantitative relation between the plate and beam for the impact sound transmission. ■

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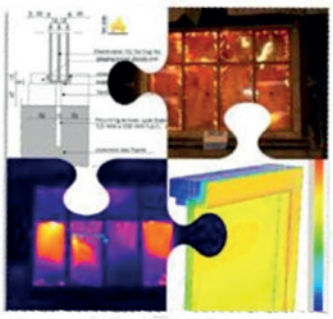

Examples of student research projects:

- Experimental research on fire and response of structures and separation constructions under fire conditions
- Mathematical simulation of fire and response of gasmass, building occupants and constructions
- Probabilistic approach of fire safety objectives in relation to rules and regulations

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Expert class FSE – Next Generation

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On Thursday, September 14th, the annual expert class FSE – Next Generation took place at the TU Eindhoven. A group of 40 people visited the event and the audience consisted of professionals in the field of fire safety engineering and (recently graduated) students. The highlight of the afternoon was the announcement of the three nominees for the IFV-VVBA Thesis award of 2017.

In the first half of the event two presentations were given by professionals in the field of fire safety engineering. Dr. ir. Ricardo Weever, professor Fire Service Science at the Dutch Fire Service Acadamy, started with a presentation about the importance of research in the field of fire safety engineering. It is essential for the fire services to understand what is happening in case of a fire in order to choose the right approach of the fire. Several research methods can be helpful to a better understanding of fires, Weever mentioned fire modelling, fire investigations, business intelligence and full-scale experiments as possible methods and gave some examples of these methods.

The second presentation of the afternoon by ir. Ruud van Herpen FIFireE was about a probabilistic approach to achieve fire safety objectives. In general, regulations of the Dutch Building Code are applied to assure the fire safety objectives are met. However, these regulations are based on the standard fire curve and standard boundary conditions and therefore a more project-specific approach leads to a more realistic safety level. By applying extensive fire modelling and taking uncertainties into account in boundary conditions a failure probability analysis can be performed. With this analysis, the minimum required fire safety measures can be determined to assure safe evacuation and prevention of fire spread.

After the coffee break, five students presented their graduate projects. The students were running for the IFV-VVBA Thesis award which is given to the most innovative, expressive or relevant Bachelor- or Master thesis in the field of fire safety science. In total 16 theses were submitted and during the expert class three students will be nominated for the National Congress of Fire Safety & Science (November 8-9) where the ultimate winner of the thesis award will be chosen. The winner of the thesis award will receive a check of €1200, - which should be spent on education or knowledge broadening in fire safety.

Figure 1. Expert class FSE - Next Generation on September 14th

During the presentations of the students a wide range of subjects was treated. Technical subjects such as numerical simulation of external flames in ventilation-controlled fires by Reem Shakerchi. But also subjects which focus on human behaviour, Lisan Bomhof examined the association between experience and situation awareness of Dutch duty officers in the fire service. These two examples imply the wide range of research that can be done in the field of fire safety. After the student presentations, the three nominees were announced and the expert class had come to an end.

The nominees are:

- Sami Takieddin, University of Ghent
  A Numerical Investigation of Spray-Plume Interactions
- Paul Hoondert, University of Technology Delft
  State of the art fire safety concept for evacuation of different types of vulnerable patients in Dutch hospitals
- Cindy Veerman, Saxion University of Applied sciences
  Smoke gas explosions

The final winner is chosen on November 9th during the National Congress of Fire Safety & Science. All 16 submitted theses can be found on the website of Fellow FSE (www.fellowfse.nl).

FELLOWSHIP FSE

The fellowship FSE at the TU Eindhoven provides supervision of master and graduation projects within the field of fire safety engineering. Also, the fellowship can bring you in contact with professionals and help you to do fire experiments. For more information visit the website. ■

Cycling aerodynamics

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ir. T. (Thijs) van Druenen

Supervisors
prof. dr. ir. B. (Bert) Blocken

INTRODUCTION

This year's three major European road cycling races have already passed and since long time we have even beheld a Dutch winner for one of them. In May, Tom Dumoulin won the Giro d'Italia. His quest to this trophy will have required years of intense coaching, training and sacrifice, and for time-trial specialists like Dumoulin this will have included hours in a wind tunnel searching for the optimal aerodynamic position and racing strategy. The athlete's clothes, equipment, and the bicycles they ride have all been developed from an aerodynamic perspective. Indeed, it has been shown that over 90% of a cyclist's resistance at professional racing speeds is attributable to aerodynamic drag [1]. Given this high proportion of the aerodynamic drag, and the often small winning margins in elite cycling, a detailed understanding of aerodynamic interactions has the potential to be the difference between winning and losing.

In our research group, led by prof. dr. ir Bert Blocken, we try to understand the complex flow-field around a moving cyclist. The variable three-dimensional geometry of the human body, the variable racing environment, and the non-linear interactions inherent to cycling flows, make the nature of cycling flow fields very complex. The aerodynamic drag of a cyclist originates from viscous drag, which is caused by skin friction in the boundary layer on the cyclist's surface, and pressure drag. Over 90% of the resistive aerodynamic force is caused by pressure drag. The magnitude of the pressure drag is proportional to the pressure differential generated between the high-pressure stagnation regions located on the front surfaces of the cyclists and the low-pressure wake areas, which result from flow separation around the body and bike of the cyclist. Therefore, the larger gains can be achieved by investigating cyclist positions, equipment, and strategies that reduce this pressure differential.

INVESTIGATING CYCLING AERODYNAMICS

Methods of investigating cycling aerodynamics include wind-tunnel experiments, computational fluid dynamics (CFD) simulations and field testing. Because of their accuracy, repeatability and amount of control, wind-tunnel experiments and CFD are preferred over field testing. With the new wind tunnel nearly up and running, this will allow us to greatly extend our research. The long test section of the newly built wind tunnel allows testing up to 9 consecutive cyclists behind each other, with each one being measured simultaneously. The most common measurement performed with cyclists in the wind tunnel is the time-averaged aerodynamic force measurements. Usually, the goal is to measure the effect of different rider positions and cycling equipment configurations. Currently, there are no wind-tunnel standards developed specifically for tests concerning cyclists. This is one of the reasons published and unpublished results show a large variation in drag measurement results. There is a considerable amount of factors making wind-tunnel testing less straightforward as it may seem at first sight: boundary layer development, keeping a steady cycling position, repeatability, atmospheric conditions, wind-tunnel type, blockage effects, buoyancy effects, Reynolds effects, freestream flow quality (e.g. turbulence intensity), force measurement system, test methodologies, pedalling etcetera. All of these factors make wind-tunnel experiments concerning cycling aerodynamics a great challenge.

With advances in meshing methods, increases in computing power, advances in turbulence modelling and prediction of flow separation, CFD is now capable of being another tool for investigating cycling aerodynamics. As CFD provides whole flow-field data, it can gain a more detailed view on the flow characteristics around a moving cyclist. By combining CFD results with wind-tunnel experiments, results are validated. Strong correlations have

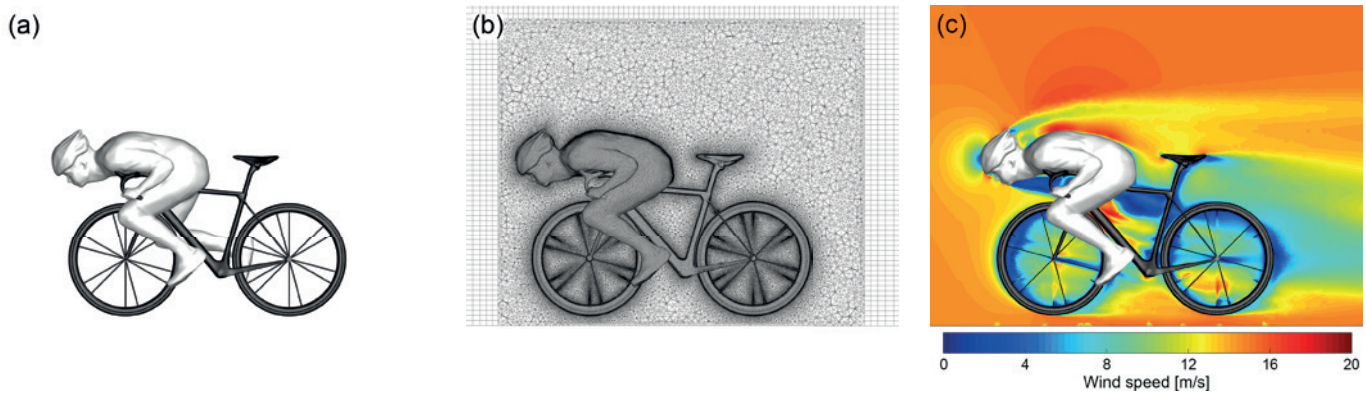

Figure 1. The application of 3D-scanning in CFD, from (a) scanned geometry to (b) high-resolution mesh and (c) contours of velocity magnitude in vertical section

Figure 2. Geometries of trailing cyclists in wind tunnel (source: Bart van Overbeeke Fotografie)

been found with experimental results. In general, the urban physics group of prof. dr.ir Bert Blocken has a lot of expertise in the field of CFD. Already, some of this expertise has been applied in cycling aerodynamics, as shown by the following examples: A couple of years ago, Thijs Defraeye took the first steps by testing different turbulence models on cycling geometries [2], and more recently Yasin Toparlar and Bert Blocken used CFD to evaluate the influence of a following car [3] and motorcycle [4]. Here, the aerodynamic effects of a close trailing vehicle were found to be significant enough to influence the outcome of the race. These findings were shared with the UCI, but not taken into account in recently enhanced regulations.

Developments in 3D-scanning techniques now allow us to quickly capture the variable three-dimensional geometry of individual cyclists. In a recent study, in which different descent positions are analysed, the 3D-scanning technique was extensively applied. Figure 1 shows the workflow of one of the investigated descent positions. The cyclist and equipment are scanned and smoothed out during post-processing of the scans (see Figure 1a). The resulting geometry is then converted into a high-resolution mesh consisting of, in this case, 27 million cells (see Figure 1b), serving as input for the actual CFD simulations. Figure 1c gives the resulting velocity contours on a plane through the centre of the cyclists.

TEAM TIME TRIAL

Currently, several parallel sport-related studies are being carried out in our group. Paul Mannion investigates the flow field around para-cyclists (e.g. hand- and tandem cyclists). Among other topics, Fabio Malizia studies the effect of crosswinds on cyclists. One of my own current projects focusses on the aerodynamic forces acting on cyclists during a team trial. In a team time trial, teams of 6 to 9 cyclists, depending on the type of event, try to reach the finish in the fastest time. For each cyclist, the aerodynamic drag is dependent on his position in the paceline. When riding in a group, the leading cyclist can experience a drag reduction up to 5%, while for the following cyclists a drag reduction up to 49% is reported [5,6]. To benefit from this drag reduction equally, cyclists rotate their positions during the race. A cyclist who has been in the leading position for a while rotates to the back of the formation, and the cyclist in second position takes over. So far, little is known about the flow field and aerodynamic forces acting on the cyclists during this rotation. Therefore, a variety of strategies is observed in elite team time trial events. For example, differences in longitudinal and lateral displacement distances between the cyclists are noticed, as well as the time a cyclist has to spend in the leading position, before rotating back to the end of the formation.

WIND-TUNNEL MEASUREMENTS

In this study, CFD simulations are performed to investigate the aerodynamic forces acting on the cycling team during this rotation, and wind-tunnel experiments are carried out for validation. A team of 6 cyclists is considered, which is typical of team trial events during UCI Road World Championships. The wind-tunnel measurements were performed in the Wind Tunnel Laboratory at the University of Liège in Belgium. Four cyclist geometries are placed in line (see Figure 2). The blockage ratio is kept below 3% by scaling the cyclists down by a factor 4. To ensure Reynolds number similarity with the (full-scale) CFD simulations and with reality at 15 m/s cycling speed, the wind-tunnel tests were performed at 60 m/s. This required the models to be reinforced with vertical bars in the wheels. Corrections were made to remove their contribution to the aerodynamic resistance. Using an elevated setup with a sharp-edge horizontal plate, the development of the boundary layer was limited. The drag force was measured using a force transducer and air temperature and speed were recorded for correction of the drag.

CFD SIMULATIONS

In addition to the wind-tunnel experiments, CFD simulations were performed for validation purposes. The 4 cyclists were placed in a computational domain, and a uniform velocity of 15 m/s was imposed, equal to the wind-tunnel experiments. The grids were based on an intensive grid-sensitivity analysis and grid generation guidelines in CFD. A high resolution of cells was used in the boundary-layer region of the cyclist, with the wall-adjacent cell centre point at only 10 μm from the body surface. In this way the dimensionless wall unit

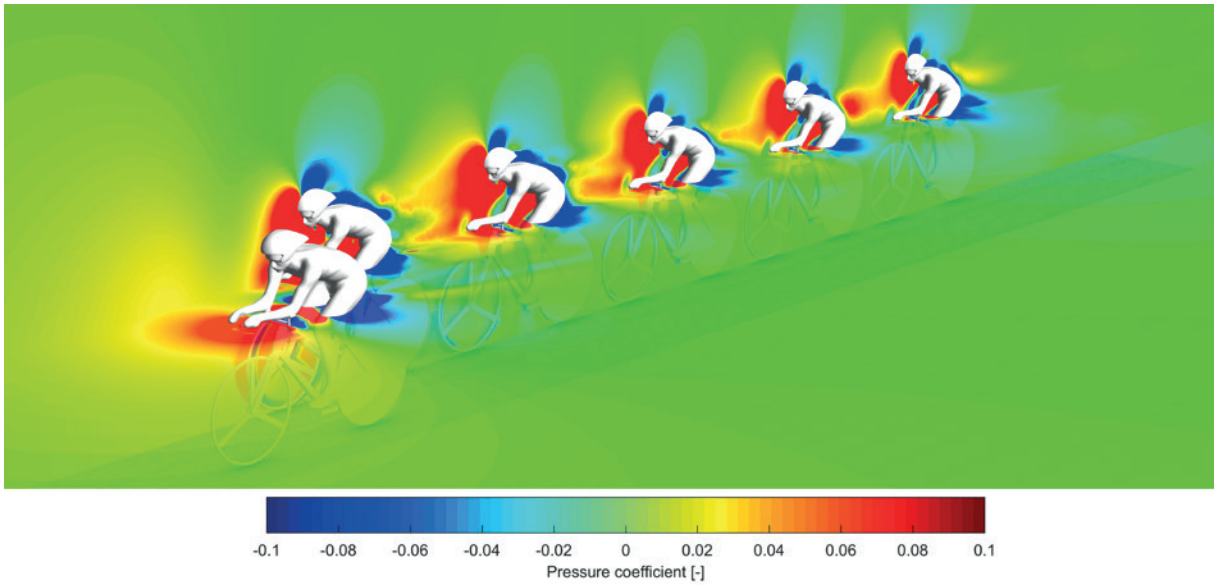

Figure 3. Instantaneous pressure coefficient in a vertical and a horizontal (transparent) plane, for a specific moment during the rotation

y* was kept below 1. The number of prism layers is 40 and the growth ratio between the layers is 1.1. Further away from the body, a maximum cell size of 0.03 m is used, resulting in meshes consisting of approximately 100 million cells. Different turbulence models and settings were tested before satisfying validation results were obtained. For cyclist 1 (leading), 2, 3 and 4, a minimum deviation of only 2%, 2%, 6% and 3% respectively was found between wind-tunnel experiments and CFD simulations, which is considered a very good agreement in the field of CFD. Additional wind-tunnel measurements were performed using only 3 cyclists, but with a larger separation distance, and a similar agreement was found. The same settings and configurations are then used for the actual study. Here, 6 cyclists are considered, which is typical for team time trial events during UCI road world championships. The cyclists are positioned 120 mm behind each other, and a lateral displacement of 200 mm is used for the returning cyclist. To provide flow field information and drag values during the complete rotation, 13 simulations are conducted. Later, more lateral displacement distances will be considered.

For a specific moment during the rotation, Figure 3 shows the instantaneous pressure coefficient in a vertical and horizontal (transparent) plane. As the returning cyclist moves to the back of the formation, he influences the flow field and aerodynamic forces acting on the total team. At the moment of writing, not all simulations are yet completed. However, already some interesting results are obtained. For example, when the returning cyclist is parallel to the first cyclist in the paceline, the drag of both cyclists will increase by around 10%, which will result in a delay for the total team. Goals of this study include determining the optimal lateral displacement distance for the cyclist as he moves back to the end of the paceline, and analyse flow fields and drag values for improving team time trial strategies.

FURTHER RESEARCH

For this team time trial, cyclists with equal body characteristics are considered. Of course, in reality this is not the case. Due to differences between athletes such as limb length and diameter, torso shape, diameter and position, hip angle, muscle definition and size, the drag for each athlete differs at each position in the team. A deviation of 1.6% between 4 riders was found [5], which is a significant margin in elite races. Therefore it is suggested that specific team testing may be necessary to properly optimize performance of a pursuit team, rather than relying on general values. This is where the 3D-scanning technique comes in. For investigating team dynamics and optimizing strategies, a team of elite cyclists is scanned (Team LottoNL-Jumbo) and a high-resolution mesh is created for each individual cyclist. A large set of CFD simulations is carried out, in which different combinations of cyclist are investigated. In addition, individual and team aerodynamic characteristics are combined with individual power production to determine the optimal cyclist combination and racing strategy.

Increased computational resources, and developments like 3D scanning, will create more possibilities of investigating cycling aerodynamics by CFD. In the near future, dynamic simulations with pedaling cyclists and rotating wheels will probably provide even more insight into the complex flow field around cyclists. In addition, the newly built wind tunnel will rapidly extend our opportunities, which will definitely lead to more interesting research and results. ■

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Strukton PULSE: Data-driven Building Management

Author
ir. D.Y.H. (David) Al Juma

On average, we spend 90 percent of our time in buildings (extensively mentioned in our field). Most of the time, we take many aspects within our buildings for granted. In other words, we want these buildings to be comfortable and safe. We also assume that these buildings – where we live and work – are sustainably built, maintained and future proof. These assumptions are not as obvious as they seem to be. In order to create an optimal and highly integrated building management, the Strukton PULSE platform has been developed. This platform is based on the Big Data and IoT (Internet of Things) combined with Strukton Worksphere's building management and maintenance expertise. Interested? Read the following paragraphs about the most innovative platform in its domain: PULSE.

PULSE ANALYTICS

In order to reach these objectives, several crucial steps need to be taken into account. First of all, PUSLE Connect facilitates the collection of data from the building management system, sensors, energy meters and other devices. These sensors and devices generate a lot of data. By implementing PULSE Connect these data can be accessed. After importing these data, the data points are coded in accordance with our self-developed coding system. Since these data have different sources, our coding system creates order, uniformity and offers the opportunity to process the data in the same way. After the coding process, generic and project specific algorithms are coupled and activated for the related components and processes.

The next step is analyzing the outcomes of the implemented algorithms in PULSE Analytics. As can be seen in Figure 1, PULSE Analytics consists of four modules: Installation, Comfort, Energy and Maintenance.

PULSE ANALYTICS: INSTALLATION

Within the PULSE Installation module, the usage of different components is monitored. The monitoring focusses on the usage of a component per period. Furthermore, the amount of switches is monitored. By doing this, the waste of energy by unnecessary usage time and unnecessary wear caused by a big amount of switches or usage time is directly noticed.

Figure 1. The main dashboard of PULSE where the performance of a building is assessed

Within the building management system, the installations are regulated by a lot of setpoints. Within PULSE all these setpoints of the different components are illustrated, controlled, monitored and deviations in these setpoints are compared to the actual values and automatically communicated. This ensures quick and more addressed actions. Additionally, the performance of a certain component is shown as the availability per period of time. This enables quick analyses on the performance of the installations.

Within the premium version of the installation module, self-developed algorithms will take over control and continuously monitor the performance of the installations and automatically generate fault detection and dispatch messages. This results in preventing failures and solving problems in an early stage. Figure 3 shows an overview of the premium version of the installation module of PULSE where several performance indicators are assessed by pre-defined limits. The total score of a component is obtained from the underlaying individual score of each performance indicator (PI).

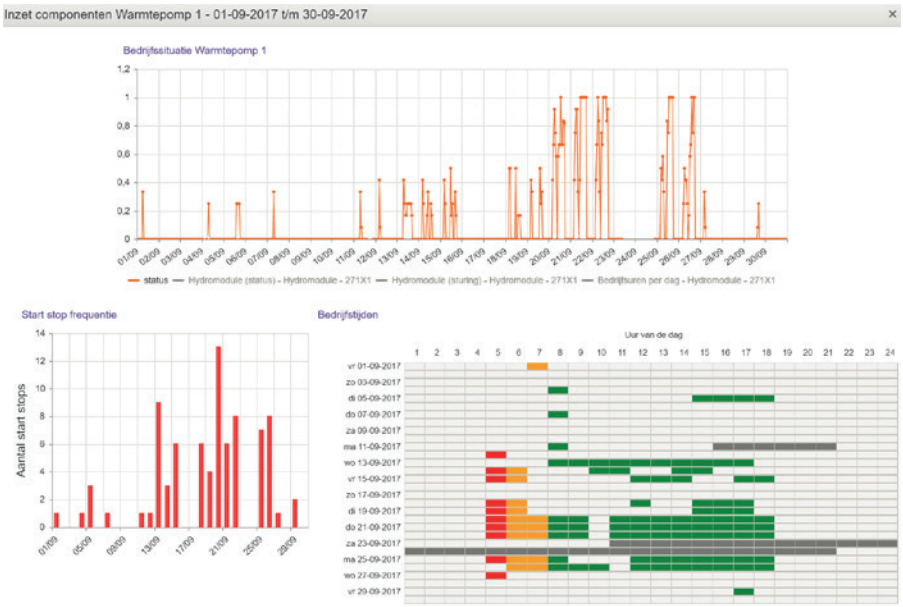


Figure 2. An example of the PULSE Installation module

PULSE ANALYTICS: COMFORT

The PULSE Comfort module offers a continuous insight, control and the availability to monitor and adjust the indoor climate of a building or room level. All available data points related to indoor temperatures, humidity and air quality are illustrated. The outcomes of these data points are monitored and assessed by pre-defined requirements on room levels. Deviations can directly be noticed and each data point can be analyzed in detail. Data of different occupancy measurement systems can be integrated to make full analyses of comfort related to the occupancy in a room.

PULSE ANALYTICS: ENERGY

The energy module monitors the energy consumption or generation based on live and historical data for all kind of energy sources: electricity, gas, water, PV panels, storage systems etc. Smart algorithms are developed to be able to perform interesting and useful analyses; for example, relating the energy consumption to the outdoor temperature or the occupation of a building/room. Furthermore, it is possible to show the energy savings and to continuously monitor the defined energy savings goals.

A relatively new innovation is a self-learning model based on artificial intelligence to predict future energy consumption per data point. The predictions and insights (output) of this model are based on inputs related to human activities within a building, outdoor weather conditions and historical energy data. After a learning period, the output can be seen as a reference model. By comparing this actual energy consumption with the reference model, potential energy savings can be detected and achieved energy savings can automatically be calculated.

PULSE ANALYTICS: MAINTENANCE

Using the maintenance module, the most suitable maintenance moment for a certain installation component can be predicted. The main objective is to prevent failures, increase the availability and lengthen the lifetime of a component. Maintenance data is combined with the technical measurements on (sub)equipments to find relations for feature failure prediction. The accuracy of predictive maintenance is continuously increasing as the algorithms are becoming more advanced and more training data is available. In the maintenance module, building operators can analyze the predicted maintenance moments to the planned ones in order to optimize the maintenance planning.

PULSE: DISPLAY

Last but not least, PULSE Display is a narrow-casting solution to inform

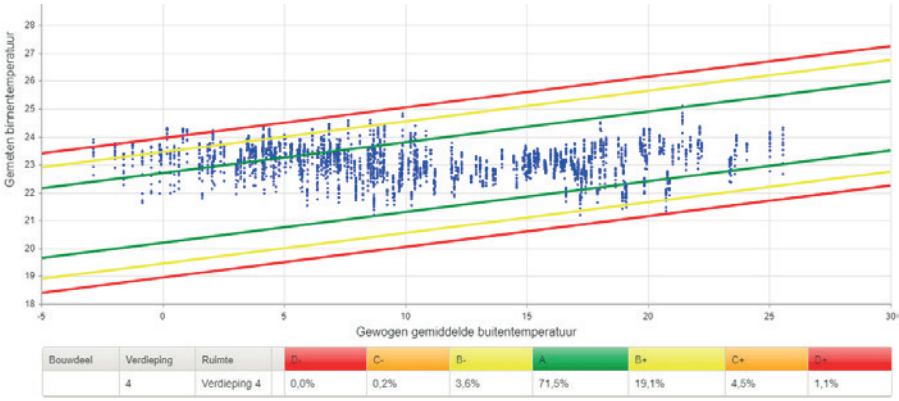


Figure 3. The distribution of indoor temperatures in relation with the outdoor temperatures and assessed by the ATG method

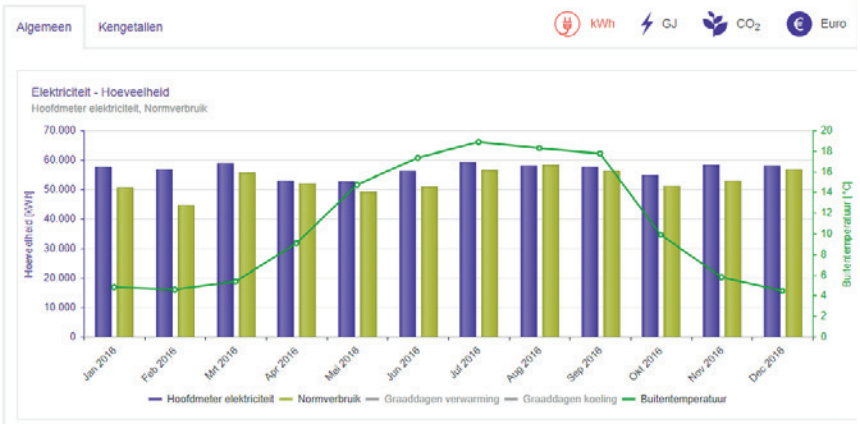


Figure 4. Actual and reference energy consumption in kWh

building occupants about sustainability and other diverse topics. Data from PULSE platform are used to make building occupants aware of the actual energy consumption and their influence on the consumption. This can lead to energy savings and more awareness of the importance of sustainability. That is also why this solution can lead to higher building scores according to BREEAM.

To conclude, within PULSE data from different sources are collected in order to be able to create an integral overview for an optimal exploitation and maintenance of a building. At the one hand, energy consultants can get detailed insights in the functioning of the installations, for example. Furthermore, potential energy saving measures can be related to the effects on the indoor comfort. At the other hand, the effect of changes in the installation can directly be related to energy costs and the frequency of maintenance.

With PULSE, Strukton created a new and innovative approach of building exploitation and maintenance which is fully different compared to conventional ways and aspires to create perfectly functioning buildings. To emphasize this, a PDEng trainee (mathematics and computer sciences) is added to the team to expand our expertise on predictive maintenance. We are still building on our technicians but nowadays they are supported by smart systems, consultants and data scientists. ■

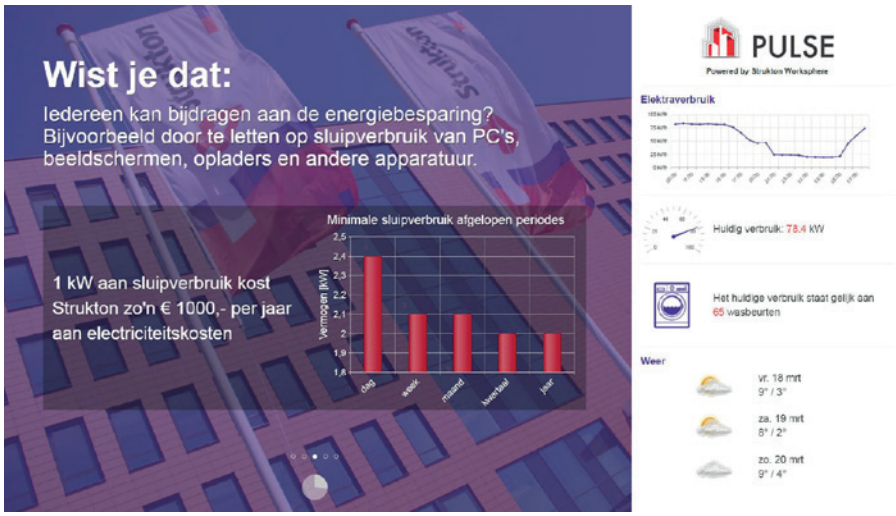
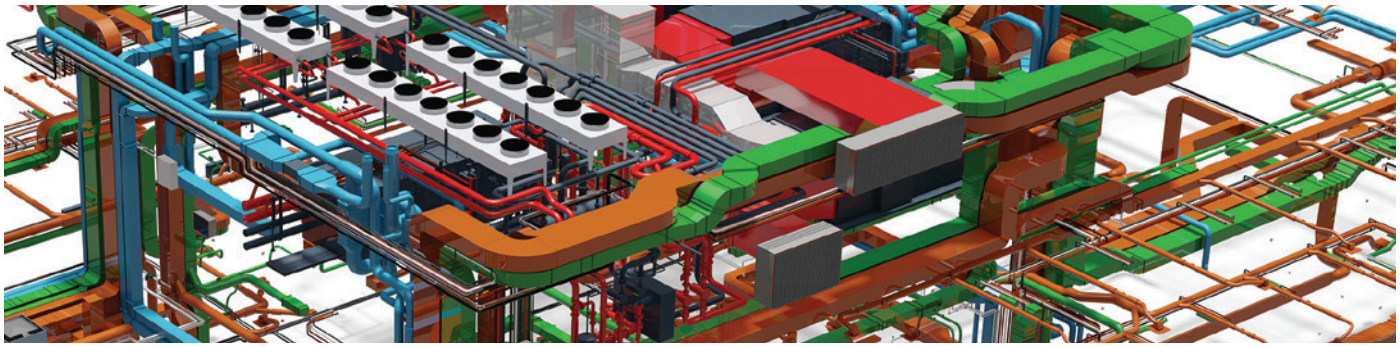


Figure 5. An example of PULSE Display module



Deel je onze passie?

Wij hebben passie voor installatietechniek. Omdat klanten (zoals TBI, Engie en Unica) met onze design software prachtige 3D-modellen maken. Het resultaat: spraakmakende gebouwen in binnen- en buitenland. Als product manager, software engineer of BIM-consultant ben je meer dan een klein radertje in het grote geheel – je doet ertoe vanaf de eerste dag.

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Municipal Solid Waste Incineration bottom ash components

Author
K. (Kim) de Boer

Supervisors
Dip. Min. K. (Katrin) Schollbach
P.M.F. (Perry) van de Wouw MSc

BOTTOM ASH

In the Netherlands a person produces about 600kg of household waste a year. To deal with these large quantities it is incinerated in waste-to-energy plants. This way energy is produced and the volume of the waste reduced by up to 90% at the same time. Bottom ash (BA) is part of the residue of that is produced with this process. It is usually heavily contaminated with chlorides, sulfates or heavy metals.

But it is possible to treat the BA and make it fit for the same application purposes as virgin resources in the production of building materials. This study is looking into the application of bottom ash in concrete as natural aggregate replacement. By using BA instead of landfilling it, the mining of raw materials and the concrete CO_2 production footprint, can be reduced. Before bottom ash components can be used as aggregates in concrete, they need to be crushed and pre-treated to generate a clean fraction with good properties.

There are many factors that determine the quality of concrete aggregates such as size, strength, porosity, composition and the ability to react with cement in unintended ways. And because BA is a very inhomogeneous material it is necessary to look at many different samples to get a good overview. This generates a large amount of data with many potential variables that influence the properties. For this reason statistical analysis is used in the project to sort and group BA according to its properties and find correlations that might otherwise go unnoticed.

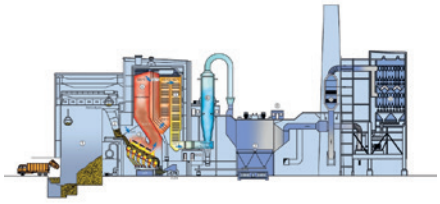


Figure 1. Municipal solid waste incineration process (Source: Wikimedia Commons)

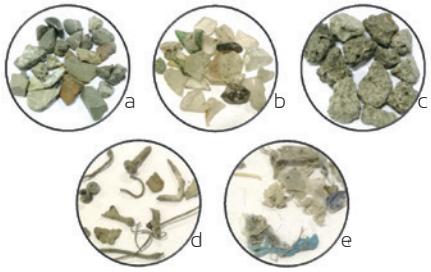


Figure 2. Sorted BA components: (a) Refractory, (b) Glass, (c) Slag, (d) Metals, (e) Unburned organic.

XRD MEASUREMENTS AND REACTIVITY

In addition to the previously measured data, XRD (X-Ray Diffraction) measurements are done. These measurements give information about the mineralogical composition of the samples. The output of these measurements can then be used together with the data clustering for comparison.

The reactivity of the different components will also be measured. The powder of the sorted and milled BA fractions is mixed with calcium hydroxide and water and then stored for a certain amount of time. Then, the reaction is stopped using ethanol and the reactivity of the material can be determined based on the reduction in calcium hydroxide because it reacted with the BA.

DATA CLUSTERING /PRINCIPAL COMPONENT ANALYSIS

With the values determined, the data analysis can start using both data clustering and principal component analysis. It is done making use of 2 programs: X'Pert HighScore Plus and Origin 2015. In the clustering, the following properties are taken into account: the chemical composition, the loss on ignition, the specific density (intact and milled), the water permeable porosity, the maximum water absorption, the leaching of Cl^- & SO_4^{2-}, and the aggregate crushing value.

CONCLUSION

From this study can be concluded that there are some clear groups, mostly the same materials are clustering together when all the known characteristics are taken into account. The clustering also seems to be very size dependent. In the future, it will be interesting to look at this while making different combinations of component characteristics. ■

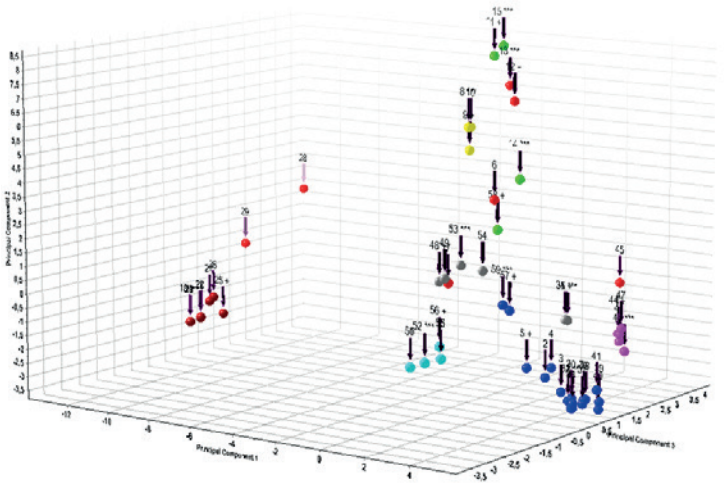


Figure 3. Result of principal component analysis using HighScore

[1] http://www.civilengineeringforum.me/production-fly-ash/

The Hamburg-Copenhagen Urban Challenge

Author
R.N.P. (Remco) van Woensel

Quite a while ago, I received an email from the faculty stating that they had the opportunity to send one student to Denmark for the DTU Summer University Programme of 2016. As the name implies, this is a summer school at Danmarks Tekniske Universitet, which is situated in Copenhagen. Well actually, it is situated in Kongens Lyngby, but nobody knows where that is, so it's easier to just say Copenhagen (as Kgs. Lyngby is only 10km away). Luckily for me, there was only one week left until the subscription deadline of the DTU at the time the email was sent to us. I was the only one who responded at such short notice, meaning there was no lottery required and I was the one who could go to Denmark the following summer.

The DTU Summer University Programme consisted of three weeks. I subscribed for the course 'Sustainable urbanisation from a practical case perspective', a multidisciplinary group project where we were going to investigate an urban area and develop a plan to make it a sustainable neighbourhood. I was assuming that this course would take place at the DTU campus, but about a month before I departed to Denmark, I was notified that the course was renamed 'Hamburg-Copenhagen Urban Challenge'. Suddenly it was a collaboration between DTU, Copenhagen Business School (CBS) and HafenCity Universität Hamburg (HCU), meaning the first two weeks of the course were going to take place in Hamburg and the final week in Copenhagen and Kgs. Lyngby. This meant a lot of extra travelling, paying for two accommodations at once (as I already arranged a room in Denmark for the entire period), but also an amazing time which was well worth the additional effort and costs.

Before the course started, I had to go to Denmark for a two-day introduction at DTU. During my stay in Denmark I had a student room at DTU Campus Village, which consisted of blocks of shipping containers that were renovated to function as student accommodation for exchange students. This meant I was surrounded by other exchange students and therefore it didn't take long before I made some friends to hang out and explore Copenhagen with. The first day of the introduction was mainly about how everything was organised at DTU. During the second day, we did some sightseeing in Copenhagen. Now that I got to know Kgs. Lyngby and Copenhagen a little, it was time to go to Hamburg.

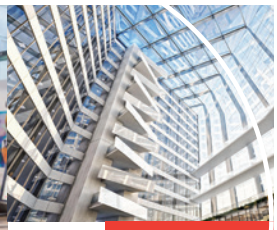
Figure 1. DTU Campus Village

The first part of the course focussed on the district HafenCity, which was still in development. The programme of the course was really packed. Every morning we had lectures from guest speakers that were involved in the development of the area or we went to visit projects. The remaining part of the day was for group work. The only free time we had left were the evenings and the weekends. Since half of the group was from DTU or CBS, there were enough people that wanted to see the city and have fun during the time we were there. This meant exploring Hamburg and having drinks almost every night.

Figure 2. Model of development plan of HafenCity

After two weeks the entire group travelled to Denmark for the last week of the course. The programme was structured similarly as in Hamburg, but now the area of interest was Nordhavnen. Here the people from HCU were the ones that wanted to explore Copenhagen so again we went out for drinks and to go sightseeing almost every night. In short, my time abroad was definitely a great experience during which I learned a lot, met new people and had a lot of fun. ■

Figure 3 . Nordhavnen



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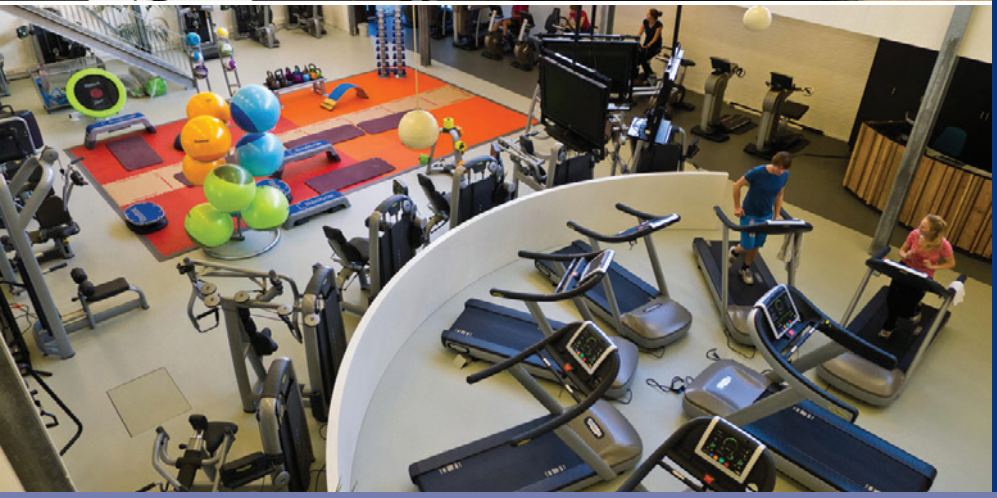

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VIRTUe: Raising sustainability awareness in Dubai, UAE

Author
VIRTUe

VIRTUe is a student team at the Eindhoven University of Technology that will be participating in the current and in future Solar Decathlons. The Solar Decathlon is an international competition in which multidisciplinary student teams from all over the world will compete to build the most innovative and sustainable home. Founded in the United States in 2002, this competition now occurs across the globe. The first edition that VIRTUe will participate in is the Solar Decathlon Middle East 2018 (SDME) in Dubai, a diverse Arabian city is known for its hospitality, but also for its impressive development. To answer the needs of Dubai, VIRTUe will present LINQ (Figure 1), an innovative way of living that will connect technologies and people within the home.

The Solar Decathlon, created by the U.S. Department of Energy, is an international competition in which universities from all over the world compete to design, build and operate a grid-connected, solar powered house. During the final phase of the competition, teams assemble their houses which are then evaluated for their energy efficiency and comfort conditions among other things. For the Solar Decathlon Middle East 2018, a total of 250,000 visitors is expected. The Solar Hai, one of the largest solar parks of the world, will be next to the Mohammed bin Rashid Al Maktoum Solar Park.

Cities are enormous contributors to the depletion of our environment: 75% of the world's CO_2 emissions from human activity originate from urban areas, as well as about 75% of resource consumption [1]. Next to this, cities cope with relatively more social problems such as increased loneliness, depression [2] and crime rates [3] compared to rural areas. We believe that smart technology, combined with sustainable building and city planning, can help solve these problems: a smart home and a city done well can provide better communication, awareness and functionalities [4], facilitating a change from the bottom up.

LINQ is a concept that not only represents the house that VIRTUe is going to build at the Solar Decathlon Middle East 2018 but it also represents a bigger idea of connecting people and technology within and around the house.

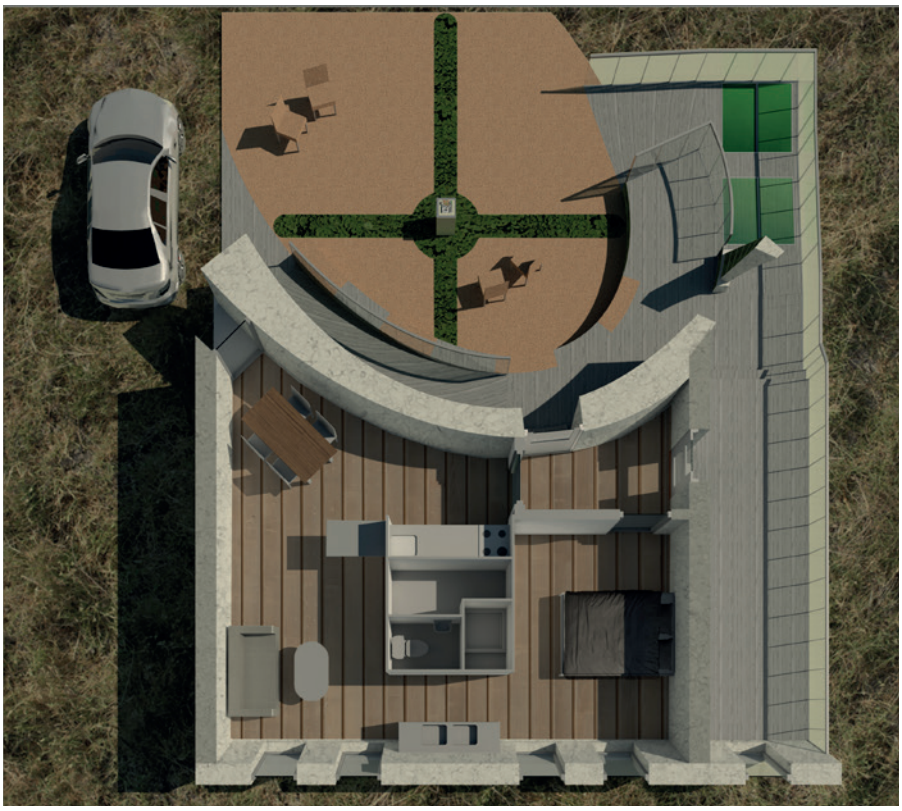

Figure 1. LINQ, an innovative sustainable home

PEOPLE TO PEOPLE

One person alone is not going to make the difference on the field of sustainability. With a group of people it is much easier to find motivation, increase smart use of energy and make use of shared equipment. To encourage sustainable behavior and social interaction the users should be placed in a non-invasive smart environment with shared spaces.

TECHNOLOGY TO TECHNOLOGY

The world is full of smart technologies that make more efficient use of the energy they get. By linking these devices together and operating them from a central system, energy supply and demand can be regulated. This decreases peaks of energy use and reduce the need for energy storage.

PEOPLE TO TECHNOLOGY

Both people and technology can be connected with each other by a smart system whose interface enables communication between user and technology, allowing them to learn from each other. The system will understand the preferences of the user, and the user learns about sustainable energy use by the system. LINQ connects people, technology and people with technology.

Making up over 90% of the population, the target group of LINQ is expats in Dubai. Expats are often couples or couples with children, and usually return to their home country after several years of living and working in Dubai. LINQ will use most of the time it has to teach its users about sustainability. When users move back home, they will take this knowledge with them, and inspire even more people in their surroundings. This way, the users can spread valuable insights regarding sustainability, learnt in Dubai, all over the world.

Taking the current situation, the concept of LINQ and the target group into consideration, the idea to combine multiple houses into one apartment complex with shared spaces was intriguing. The benefits of an apartment complex instead of single housing are beyond counting.

PASSIVE DESIGN STRATEGIES

To lower the energy loss towards the outside, may it be the heat in the Netherlands or the cold in the UAE. The apartments can provide shade for each other. They can also reduce the urban sprawl, a phenomenon that is not unfamiliar in Dubai and many other cities that undergo fast development.

WATER MANAGEMENT

The water grid can be connected, decreasing water loss. Sharing the same water circulation system provides increased opportunity for water cycling.

ENERGY MANAGEMENT

The use of shared solar panels is cheaper. Energy peaks can be decreased in a more efficient way.

SOCIAL ASPECTS

One of the most important advantages is that the users of the apartment complex can easily use the same shared spaces and shared equipment. In addition, it enhances the spirit for sustainability by working together.

Every apartment contains all the basics needed for a complete living experience. By adding shared spaces that provide more luxury to the living conditions, the users tend to make use of these spaces. The shared entertainment room can be used to invite the family over. The shared kitchen can be used to host regular dinner parties, for instance with other inhabitants of the apartment complex. The shared garage can store and charge shared electric cars. The shared city farming can be used to grow vegetables. Each LINQ complex can cover and can be specialized to the needs and preferences of the users.

One of the apartments will be built for the Solar Decathlon Middle East 2018. Next to the realized apartment, a section of the neighboring apartment will be visible to show that LINQ is part of a bigger picture. Small additions are made to comply with the public tour of the Solar Decathlon. These will be easily recognizable as separate elements. The additional elements are also used to for extra energy production.

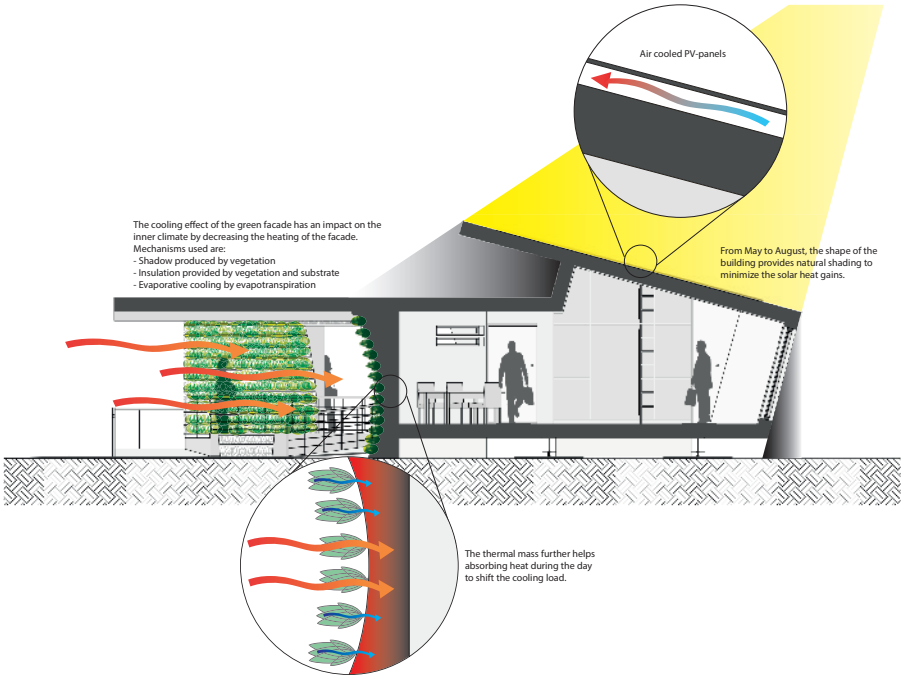

Figure 2. Bioclimactic drawwing with a cross-section of LINQ

TILTED

Both the south wall and the roof are tilted to provide shade on the south wall, which is vital for reducing solar gain and optimizing the angle of the thin film photovoltaic panels towards the sun. In addition, it gives the apartment a strong architectural expression.

LIFTED APARTMENT

The apartment is lifted with the use of a stabilizing structure, giving it the impression that it hovers above the ground. Detaching it, and thus hinting to the visitor that this apartment is actually located on the top floor.

STABLE CORE

The cores play a vital role in the apartment complex, stabilizing the building and connecting the apartments to one another, transporting electricity and water. During the Solar Decathlon this core is load bearing, which significantly speeds up the building process and increases building comfort.

SHARED SPACE

This outside area will demonstrate the green atrium and the use of shared spaces. Oriented towards the central square of the Solar Decathlon, this area will be most vivid and visitors can use it to meet each other and share their ideas about a sustainable future.

NET ZERO WATER SYSTEM

This system will be located in the core. By the use of membrane biotechnology this machine will recover fertilizer nutrients, renewable energy and drinkable water from wastewater produced by the apartments.

DOUBLE CURVED WALL

In this view the double curve in the north wall is clearly visible. This wall is a 3D printed concrete wall that provides both space and nutrients to the vegetation inside the wall.

CITY FARMING

To give an impression of the shared spaces we will convert a section of the partially built apartment, on the east side of the plot, into a shared space for city farming.

WINDOW TO WALL RATIO

Because of the tilted wall, this wall is better visible in this plan view. Due to the shade created by the tilt of the wall, it is possible to have a larger window-to-wall ratio.

PARKING AREA

On the west side the parking area is visible, normally located in the garage, this area gives the opportunity to show the world the future of mobility and houses working together.

TAILOR-MADE

The elements that are needed to make the apartment accessible during the SDME are created with luminescent solar concentrator panels, or LSC panels. The transparent panels refract specific colours in the spectrum of sunlight in such a way that the light reaches the sides. Here, the light is converted into energy by solar cells embedded in the panel frame.

Figure 3. A rendering of LINQ

TRIAS ENERGETICA

In order to keep our project as sustainable as possible, we have adopted the trias energetica as our leading strategy: First, we will try to minimise the demand for energy, for example by using passive strategies. Then, the energy we do use, should be sustainable, hence we use solar energy. Finally, if there is an energy demand that is absolutely necessary, but cannot be satisfied with renewable energy, non-renewable sources shall be used as cleanly and efficiently as possible.

From a building physics and services perspective, we at VIRTUe have high ambitions in our design where we want to create a sustainable, net-positive energy and self-sufficient system that is durable and flexible. The climate of Dubai is a challenging environment to achieve so, however, as a smart and collaborative team we are, nothing is impossible. The opportunity set for us here is unparalleled, since the knowledge we have gained as students in this technological university and the mentoring we receive from the leading world-renowned experts is applied without any limitations. The support from the TU/e and industry partners has helped shape our concepts into realization. No precedent exists to this kind of project in the TU/e and we are excited and lucky to be part of such a competition.

VIRTUe is a multidisciplinary student team of the Eindhoven University of Technology located in the Netherlands. The majority of the team consists of students and faculty advisors related to the TU/e. To complete the multidisciplinary aspect of the team and cover the vast diversity of the challenges of the Solar Decathlon, VIRTUe not only recruits members from within the TU/e, the team also consists of students from Wageningen University & Research and Fontys University of Applied Sciences. VIRTUe was officially established as a student team since January 2017. It thereby contributed to the community of student teams at the TU/e. A community in which science, business and innovation come together. Several noticeable teams within this community are Solar Team Eindhoven, Team FAST and InMotion. Being a student team in Eindhoven opens the door to collaborations in a network which promotes innovation and entrepreneurship.

The establishment of this team ensures Dutch participation in present and future Solar Decathlon Competitions. The current and first team of VIRTUe is participating in the Solar Decathlon Middle East 2018 which will be held in Dubai in November 2018. By participating in the Solar Decathlon Competitions, VIRTUe raises awareness for sustainability within the Built Environment. With the use of a human-centered design which includes both the environment and the occupant as deciding factors we not only raise awareness but also create an attractive product which changes the perception of sustainable living. For more information about VIRTUe, visit: https://teamvirtue.nl/. ■

[1] Miller, G. T., & Spoolman, S. (2012). Living in the environment: principles, connections, and solutions. Belmont, CA: Brooks/Cole.

[2] Karmakar, M. A., & Raychaudhuri, S. (2015). Loneliness & Depression: An Urban Syndrome?

[3] Victimsofcrime.org (2014) Urban and Rural Crime. Retrieved May 15, 2017, from http://victimsofcrime.org/docs/default-source/ncvrw2014/urban-rural-crime-statistics-2014.pdf?sfvrsn=2.

[4] Edwards, W. K., & Grinter, R. E. (2001, September). At home with ubiquitous computing: Seven challenges. In International Conference on Ubiquitous Computing (pp. 256-272). Springer Berlin Heidelberg.

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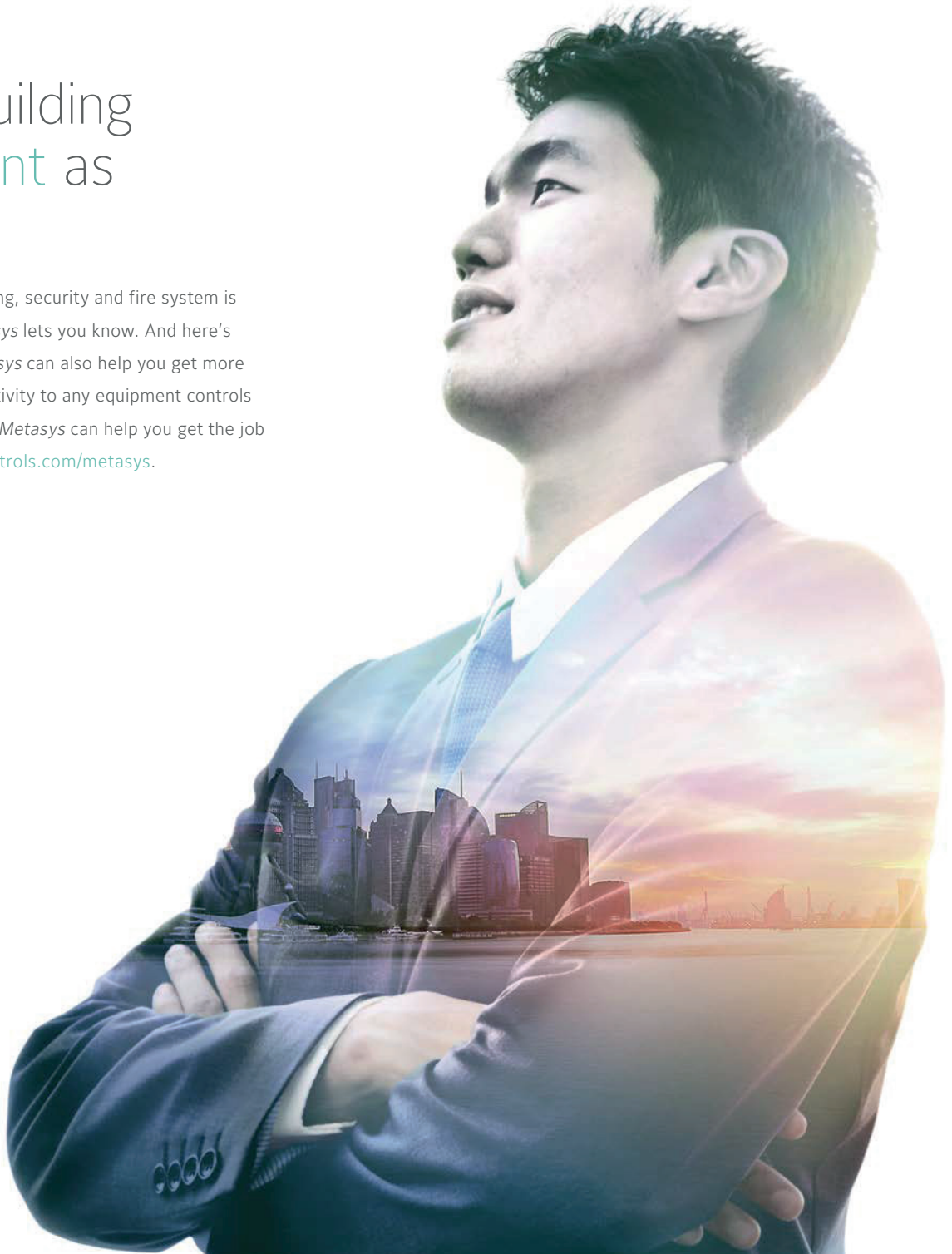

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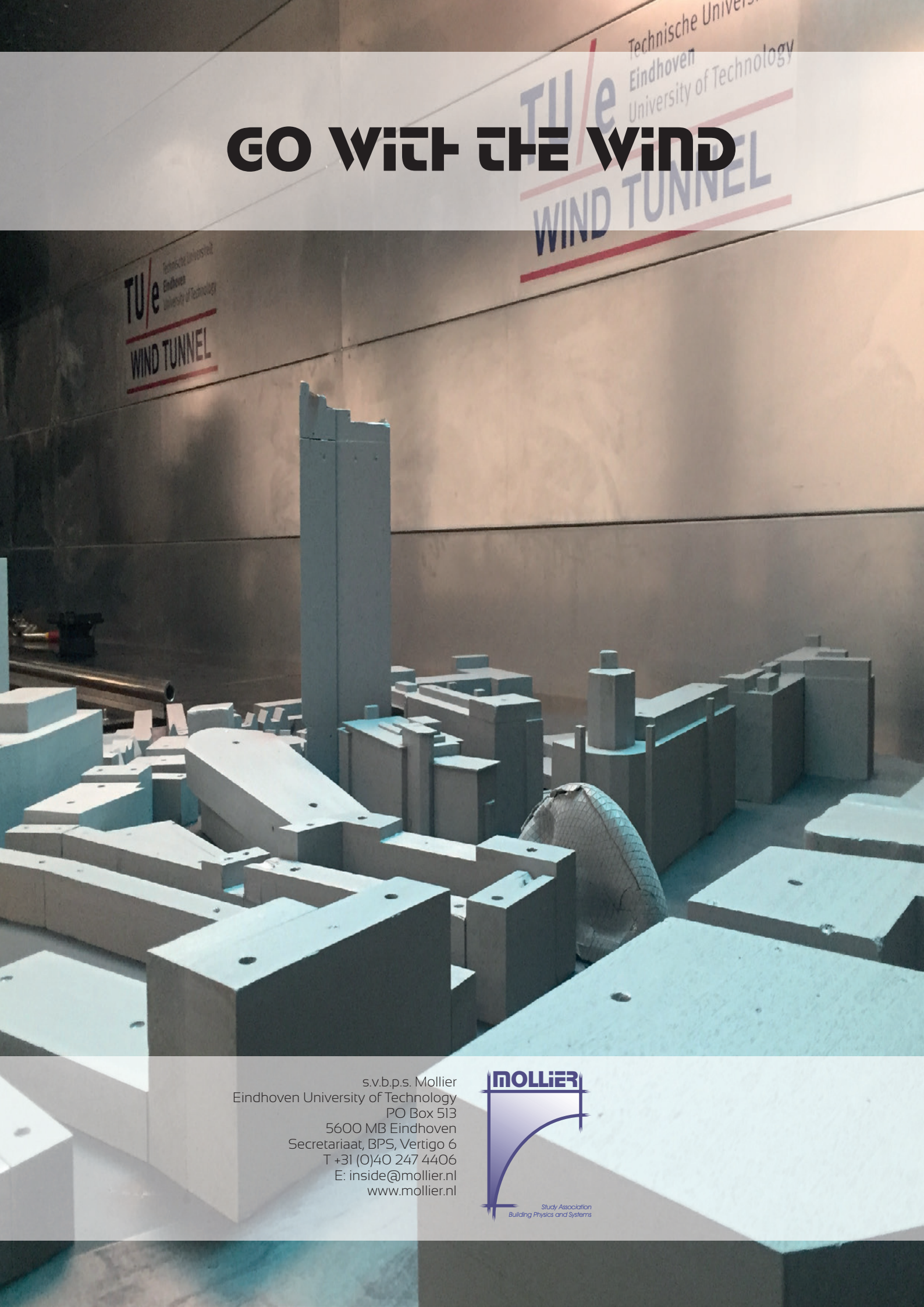

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