### Built Environment

eindhoven university of technology

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As Dean of the Department of the Built Environment, I am proud and honoured to be again the one to write the preface of the new yearbook. Many of our graduates, along with a team of student assistants, have worked very hard to make this beautiful book together with editor Jos Bosman and graphic designer Jac de Kok. This new Built Environment showcases all the beautiful work done by our graduates during the academic year 2012/2013.

Three new themes define our strategy 2020 that has been recently launched. It is possible to recognize them already in three graduation projects that are published in this yearbook:

**Sustainable transformation** is of key concern when trying to redevelop empty buildings. Sjoerd Raaijmakers has developed a module that on its own can be implemented in any building (pp. 106-108).

**Smart living environment**: Hanneke Godfroij has done research into the possibility of *variety is the spice of life – adaptive façade for energy neutral living*, in which she investigates whether concepts as Passive Building are the satisfying solution for our energy problem. She finds the solution in the adaptive façade that has a function as a skin. Like people and animals the skin of this façade is able to sweat, shiver and exuviate (pp. 118-120).

**Quality of life**: Wenlei Ma has investigated the possibility of how to reintroduce wheat straw as a building material. The starting point of the research of her graduation studio was *beauty and thinking about making* as a core value for improving the quality of life (pp. 101-103).

Elphi Nelissen
dean, department of the built environment
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In 1986 an advertisement by the architecture firm Wiel Arets appeared in the second number of the journal *Wiederhall* (a Dutch journal with a German name that appeared in English language) consisting of a relatively narrow, upright rectangle with the firm’s name in an otherwise empty upper portion and a lower portion filled with a partially transected building perspective drawing. It is a particularly exact drawing, literally architectonic, which unequivocally manifests the ambition of the will to build. In that same year the fashion shop in Maastricht was completed which a year later appeared on the cover of *Wiederhall* 5. The name of the firm had in the meantime changed into *Wiel Arets’ Idea*. Since that time the architect has continually hammered home that ideas are the essence of his architecture. The result is principally valued for its meticulous execution.

After being in business for only three years, in 1989 his work was considered so impressive that Arets was awarded the Maaskant Prize for young architects.

Establishing his own style and signature in such a short period of time is an impressive achievement. His choice for three industrial products played a role in this: glass bricks, Wagenfeld’s round, matte-white glass wall fixture (diameter 300 mm; *Van Lien industriële verlichting* type IND), and Andy Warhol’s sunglasses. He had a photo portrait of himself made by Kim Zwarts, wearing the

Located in the center of Rotterdam, the B’ Tower is composed of three distinct volumes of retail and residential program, and is a contiguous extension of Marcel Breuer’s 1955 ‘Bijenkorf’ department store. Standing at a height of 70 m, its plinth encompasses retail while its subsequent volumes are composed of 54 studios and 24 apartments, respectively. In the mid-1990s the city of Rotterdam mandated that a portion of newly built structures in its center incorporate housing; intrinsically, the B’ Tower is one of the first of these, seeking to impart and sustain an urban vibrancy within this rapidly restructuring district.

Adjacently sited to a pedestrian promenade, the tower’s retail and lobby are accessed by foot, while its residential program provides additional entry options for automobiles and bicyclists. Specially designated elevators enable this automobile entry, rising four stories to an elevated park that offers direct access to the building’s core. This two-story and 64 space car park allows for views onto the city’s surroundings beyond a ribbon of transparent glazing, disclosing the first of many cinematographic experiential sequences within this hybrid tower.
Warhol shades. Zwarts also took all the photos for the book that appeared on the occasion of the Maaskant Prize. In one photograph these same sunglasses are portrayed as a symbol; it is this photo which for Kenneth Frampton remains the key image that defines his fascination with Arets’ work:

“Arets represented the pharmacies of his early period as though they were symmetrically framed stills taken from the film by Chantal Ackerman. These images insisted on the hardness of the things themselves and the absence of the human subject. In a monograph published on the occasion of the Maaskant Prize, this idiom attained its apotheosis in a photograph entitled Apotheek, wherein interpreting translucent and transparent surfaces were overlaid with an image of spotlights reflected in a black table top and a sheet of glass. On the glass lay the architect’s dark glasses casually poised like the signature of a film director.”¹

It was with three products – glass bricks, wall fixtures and sunglasses – that Arets was able to manifest his attitude toward design more than any other architect of his generation in the Netherlands. In 2007 WAA (Wiel Arets Architects) designed their own variant of the Wagenfeld fixture for Italian manufacturer Alessi (Alessi dOt.it Lamp). One can be found today on the walls of his Amsterdam consulting room. This type of wall fixture has become a design icon and has become the unofficial trademark of WAA. The highpoint off this trajectory to

Foreseeing a possible future conversion of use, the tower was developed so as to allow for the transformation of its residential units, which currently function as short stay apartments, into cooperative housing. The ground floor retail space is multi-storied in height, exposing itself to the adjacent pedestrian promenade, and columns within each corner of the tower allow for completely flush glazing. The upper storied residential volumes feature generously sized balconies, each admeasuring 4.8 x 2.2 m, providing the tower’s residents with outdoor entertainment space able to accommodate a six-person dinner party table.

A collectively balanced heating and cooling system is embedded within each floor slab, together with electrical and IT solutions, regulating the flow of ventilation to and from the tower at all times. Energy for heating is circulated throughout each slab by way of the area’s central ‘district heating’ system, while cooling is collectively created within a central device before its distribution. This holistic approach to the interior climate allowed for the seamless integration of the heating, cooling, electrical, and IT components, which service the tower’s environmental needs without dictating its design.

rotatie-as: zijvlak van rugleuning ca. 7° gedraaid t.o.v. verticaal vlak

rotatie-as: zijvlak van zitting 7° gedraaid t.o.v. verticaal vlak
date is the its use in the B-tower in Rotterdam where the fixture is installed in the middle of the bathroom mirror. Use of the same type of fixture for a quarter-century indicates accuracy of an initial choice as well as insight into how the making of such choices is a factor of resolve and demonstration of character. Arets believes in “good choices” and that once you’ve found something really good you should never give it up. This is literally the case with the wall fixture. The choice for glass brick also determined his signature, but this form of signature only defined the starting trajectory of making him famous. This too – becoming famous – is something Wiel Arets understands like few others. The glass bricks form an important element in the first phase of his work. This quality could be translated as an alabaster skin to a great many other possible material applications which could also atmospherically serve the same perception spectrum. The sunglasses were sufficient to define a signature once. Their use was a reminder of the beginning of a director’s attitude which, according to Frampton, seemed to possess a lasting narrative (thanks to the staging of the architect by means of his photographer, to whom he gave direction just as a director does to a cameraman, thereby here too giving ample space to his way of doing maximal justice to camera use).

Since the construction of the AZL building in Heerlen, Wiel Arets Architects has also designed furniture, produced by Lensvelt. According to the information Arets published in his autobiographical references, the acoustic cabin is a goldmine, as many thousands are sold.

Interior living spaces are outfitted with kitchens designed by WAA in collaboration with Alessi and Valcucine, with all remaining residential furnishings, with the exception of the Vitra couch, designed by WAA in collaboration with Lensvelt. All bathrooms are equipped with the WAA designed Il Bagno d’Oro bathroom series fixtures produced by Alessi, Laufen, and Oras. Unique to the uppermost and cantilevered volume’s residences are façade facing bathrooms, allowing one to soak in the oversized bathtubs while overlooking the skyline of Rotterdam below and beyond.
What is striking is that Wiel Arets has grown within the organization of WAA into the role of director of the design with idea. He creates scenes and roles in which those who work for him contribute the best they can to his story. Generally, comparison of what they do under their own name and what they have made for the firm is in WAA's favor. Arets seeks to keep WAA as a laboratory which stands out by refinement. His own form of refinement develops ceaselessly. The B-tower in Rotterdam is proof of a development in design attitude that moves towards the position of Mies van der Rohe's generic architecture. In a 21st century version. For Arets it represents a major achievement in his career to ‘follow up’ Mies as dean of the architectural department of ITT in Chicago, because he has taken Mies as a mirror from the beginning (as a major role model in the diary reference series, of both his graduation project and of the Maaskant prize publication). Mies has for Arets a mental and physical nearby presence, as he explained, when Stanley Tigerman asked him why he came to Chicago to lead a faculty, when he has so much interesting work in his office to be realized.

Arets: “Mies was born 11 kilometers from the place where I was born.”

Tigerman: “Really? That close to Aachen?”

Arets: “Yes, I’m very close to Aachen. I was born in Heerlen, which is a city where the coal mining industry was happening. Mies left at the beginning of the flourishing of the mining industry. After that the area became very rich, became very exciting. Because it is where Holland, Belgium, and Germany
are next to each other. But there is also lots of Spanish and French influence.”

Tigerman: “But then you went to school in Eindhoven?”

Arets: “I went to school at Eindhoven University of Technology”

Already during his studies in Eindhoven Arets developed an attitude and style of working which later made him famous. Various professors and co-workers did feed his passion for architecture. Assistant professor of architecture Hans Tupker drove him and his fellow student Wim van den Bergh to Paris in order to introduce them to Japanese architect Tadao Ando. In concert with both Arets and Van den Bergh, William Graatsma produced a book and an exhibition on architect Peutz. The text Arets contributed to the catalog (and which appears in English in this annual’s appendix) is an example of the art of interpretation learned under the tutelage of Prof. Geert Bakaert (the author of the first essay in the Peutz book). The graphic designer who produced the book on Peutz with Graatsma (and this annual) was immediately impressed by Arets’ will to build, sufficiently so to give him and van den Bergh (they worked together at the time) the commission for the expansion of his own house. The design for this very first assignment provided for the use of glass brick; alas, it was not completed for client reasons. Yet the book on Peutz and this design nonetheless demonstrate the self-confidence with which Arets had already demonstrated his professionalism as a student.

In our fluid society, where Internet and new technologies are playing an important role, we have to define new criteria for what is our public and private realm or domain. We have to rethink all of our infrastructure as well as mechanical transportation by airplane, boat, train, car and new, yet to be developed transportation systems, and make clear choices. The airport will connect main points at a greater distance from one another (within 288 minutes). Fast trains have to connect cities and major locations (within 72 or 288 minutes). The smaller cities and villages are connected by local public transport and road systems (within 72 or 288 minutes). The car will become a vehicle that we will use only on specific occasions, when computers can control it on electronic highways. Finally, we have to economize our means, to make clear decisions about how the unconscious city could be developed, and how the ‘New Map of the World’ should look like in our new global strategy.

Rob Willemse graduated cum laude from Eindhoven University in 2001, shared an Archiprix first prize, and immediately after graduating started working at Wiel Arets Architects in Maastricht (NL) where he worked for over ten years. He then purchased his own commissions that he realizes at the office of Lars Dreessen, who worked as well previously at Wiel Arets Architects. Rob Willemse reports here on this reference WAA experience in practice.

In a society full of negativity, one must dare to dream. This takes nothing away from the idea that in practice making dreams a reality in architecture means principally dealing with rules, money and time. Development plan rules, reasonable well-being demands, cadastral limits, location logistics, attendant archeological finds, and last but not least development instructions determine the rules under which a project may be completed. If the rules are not adhered to then the necessary permit will not be granted and the project will not be completed.

Development cost estimates must demonstrate whether the project is economically feasible. Construction can only take place within these budgets and only then can one speak of a project. Every month a design team works on a project or a contractor continues to work costs fistfuls of money. Time is a global and determinative factor.

These last two factors – money and time – make projects possible and offer work to architects. Simultaneously these factors lead to an increasingly complex incipient project organization in which there is increasingly less work for architects (and other architectural advisors).

To illustrate this point a number of projects with diverse (sometimes complex) project structures for which I was responsible as part of my architectural practice (2001 - 2012: Wiel Arets Architects; from 2012 as Dreessen Architecten) are detailed below. Each project is illustrated by a conference table as they appeared during an important part of the process with the client(s) on the left and the architects and advisors on the right. The names of the firms are abbreviated as WAA and DA.
The structure of the Sport Campus Leidsche Rijn project - a high school with a gymnasium – can be termed traditional. On one side of the table we find the project manager, representing the client, supported by other representatives of, for example, the end user(s). On the other side of the table the architect forms a design team along with a structural engineer and a architectural and technical advisor. The project manager functions as the delegated client and their direct communication with the client and ample decision-making powers is of great importance to the process.

In the structure of the Anna van Bueren project, a high-rise with 400 student rooms above university lecture halls, a restaurant and a library, included the developer, the end user and the contractors on the client's side of the table. This project was underway when the 2008 economic crisis hit. The risks of the project were reconsidered by the developing restaurant and a library, included the developer, the end user and the contractors on the client's side of the table. This

The assignment for the Regiocentrale Maasbracht was obtained by means of a tender to a “DBM contract” (design-build-maintain) in which a combination of contractors register with a large institution, in this case Rijkswaterstaat (Dutch Ministry of Waterways and Public Works). The architect works for the contractor, but is seen by the Ministry as having a leading role over many aspects. The architect also focuses more on the end user. The contractor is sometimes placed literally between the two to guard the budget as this can also strongly influence the design and realization process and the quality of the result. What is special about the design process is also the verification procedure in which the client is notified in writing that all requirements (a list with hundreds of items, sometimes literally copied from the client's original order) have been fulfilled.
The international competition for the prestigious ICC (International Criminal Court) saw submissions from hundreds of reputable architecture firms from across the globe. Wiel Arets Architects was one of three finalists. These three architecture firms were invited to work out their designs in functional, constructional, technical and budgetary detail. There were a great many meetings, tests and much deep thinking. This included the formulation of complete contract documents. The meetings took place in the company of many experts who represented and assisted the client. This process was done in parallel with three architecture firms.

In the design and realization process of the PM Residence in Valkenswaard the client and architect sit evenly matched at the table. We see here a productive process in which the architect learns about the client’s specific wishes while the architect provides information to the client about the possibilities and limitations of the project as clients are not usually familiar with professional architecture. The architect guides and coordinates resulting in a design to specification, one achieved relatively quickly, that fits within budget, and above all is unique and personal.

The Rabobank Parkstad project, renovation of the bank’s main offices in Heerlen, had essentially two clients: the project client was owner of the building which was to be rented to the bank. Yet the bank is simultaneously a client as regards its completion. It goes without saying that the needs of these two clients – although they sat on the same side of the table – were not always the same. By recognizing and understanding these needs constructive and dynamic solutions can be found. As architects we help give form to the how these are thought through at every level down to those who plan the interior design such that a representative from the end users is able to contribute their part thus creating a broad level of satisfaction among users.
In the processes described briefly above we confirm a number of things. The number of initial and watchdog participants on the client’s side of the table is many times the number of advisors on the other side, including the architect who must ultimately deliver the design process. The essential nature of the client, that without them no project is possible at all, appears to be decisive. When we examine the process costs of these pairs, there is less budget for building quality and expert advice for others, including the architect.

When clients and contractors are responsible for guarding the budget within a construction team the architect has taken away from him an important instrument for the production of a qualitatively high-quality building: responsibility for the construction budget. Insight into the factors that determine the cost of a development plan can permit the architect to optimally tune design and quality. This insight is not often remembered by the architect in a development plan.

The architect is also deprived of other advice-related tasks – or does the architect let this happen? The contracting parties commonly have at their disposal drawing rooms, specialists, development cost experts who can perform this work. Because they find themselves on the client’s side of the table, it seems only natural that this work comes to them. Their interests differ from those of the architect, however.

The contribution of expertise and the broad discussion platform used in similar processes can indeed reliably lead to better results. Optimalizations made out of budgetary necessity can easily lead to a better design. Open, transparent communication with an understanding for everyone’s interests – within reason – is a key to successful architecture.

In this the architect can play a decisive role. Only with a complete architectural concept, one which includes function, engineering, budget and rules, will he be able to hold his own against so many on the other side of the table. The architect depends on strategy, experience, consequence and his belief in dreams.
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new alliances for a legible landscape

stijn kuipers

the development passports
daily regional system: a system approach

Today’s urban design and planning is less about master planning. It is about a multilayered approach, about signaling issues and chances. It is the spatial construct of socio-economic alliances. In this project no master plan is designed, but rather a system that creates conditions, sets frameworks and draws opportunities. It shows how new economic combinations and opportunities could enhance the quality of the landscape. Sustainable development is in this case the combination of regional demand, local challenges and strengthening the landscape identity. Different urban methodologies are used to construct a framework that holds multiple scenarios; from traditional morphological research to networking with actors and hotspots. The result is twofold: a framework and a collection of probable projects.

transforming landscapes in a high-tech region

The region Southeast of Brabant, marketed as Brainport, is profiling itself as a world-class high-tech innovation hub. Powered by high-tech companies like Philips and ASML the region of Brainport was elected as the “smartest region in the world” in 2011. One of the policy key points to maintain and expand this position, is the quality of life that the region has to offer to its (future) employees, since prognoses indicate a shortage of qualified employees. The only truly unique quality of the region, besides perhaps the industrial heritage, is the strong intertwining with the countryside. However, the qualities of the countryside are not yet fully exploited. Spatial planning policies have a strong tradition in separating city and countryside, as such the current building activities are very traditional. New housing rather takes place in the form of village-like extensions than, for example, the transformation of derelict farms. If Brainport wants to be world-class and unique it will have to find a more innovative way to produce living and working environments.

The countryside itself is in transition from an industrial landscape optimized for production, to the post-agricultural landscape. This means that urban functions and activities are becoming more dominant and less space remains for traditional agricultural activities. Farmers leave or stop because they lack space for extension. Although the development of nature becomes more favored, the public bodies as traditional funders will step back as result from the economic recession. The countryside has in multiple ways a lack of economic drivers. Previous studies that have been done always focus on how the countryside can be used for a better Brainport, but the reversed question is never asked: how could the transforming countryside benefit from Brainport?

The evolving question has a threefold nature where above issues are combined: how can we at the same time; 1) strengthen the identity of the fragmented landscape; 2) apply new economic drivers that match the ambitions of Brainport and 3) improve the local situation?
urban economies in a traditional landscape: metropolitan rurality
Not all areas are suited for urban economies. The metropolitan landscape is well connected, has rich cultural heritage, is close to the city and not dominated any more by large scale agriculture. These are the areas where we can let go the traditional separation between city and countryside. The current restriction in development only obstructs the area in becoming a grown-up post agricultural landscape. Strengthening the landscape by development instead of prohibition is what needs to be enabled. Spatial language of the metropolitan countryside. Allowing new developments to strengthen landscape needs a set of spatial rules. Extensive historical and (geo)morphological research into the different types of landscape reveals a strong vertical orientation. Each type of landscape was formed by a different logic. This logic is translated into a zoning plan. Every zone has a different character according to the landscape typology. For the developments it means that every zone holds different kinds of functions, sizes and amounts of nature. For example: in the nature zones 80% of the development will be forest, while the active zones will be used for farmers offering recreational facilities like camping, restaurants or a winery.

The use of the different ‘development passports’ will ultimately lead to a re-establishment of the different landscape typologies that once made a clear structure in the area. Instead of treating the whole countryside as an area where construction is virtually prohibited, allowing certain developments will enhance the characteristics en thereby the identity of landscapes.

promising concepts: arrangements
As argued earlier, urban design is not just about space, it is a (socio)economical arrangement. To show how we can solve local issues, produce landscape and stimulate ambitions of Brainport, a set of arrangements is developed. New economical concepts that have a strong bond with the landscape, combine new functions, and help to improve local challenges. Interventions in infrastructure create the conditions for the concepts to work. Examples are: a wellness centre with water retention basins and water treatment combined, small townships that have high-tech housing and working and produce recreational infrastructure, or a new care estate with lots of recreational forest, a revalidation centre and elderly housing.

design example: the agro-hub
Another example is the Agro-hub. It offers a sustainable alternative for farmers wanting to expand their business, but lack more space and should otherwise move to another location in the Netherlands or Europe. They can expand or move to the Agro-hub, while other areas will get more space for nature and dwelling. The Agro-hub is a collection of different functions which use local cycles of food and waste. Food for pigs is locally produced and enriched with waste from the brewery and bakeries in the region. The manure of the pigs is food for the fish farm and fuel for the biomass installation. Both the pigs and fish are processed on location. Transport is thereby reduced to a minimum: pigs can even walk from farm to farm to abattoir. The Agro-hub offers a public attraction where people can see where their food comes from. At the same time it enhances the industrial, utilitarian character that this type of landscape has. A new connection to the canal gives a new function and meaning to the derelict water system from the industrial era.
brainport in the ‘battle for talent’
Southeast Brabant, one of the most important economic driving forces of the Dutch economy, is facing a major challenge. The international competition between high-tech regions is fierce and businesses are constantly tempted to move elsewhere because of large (tax) benefits, a lower regulatory burden and attractive partnerships. Attracting and retaining high-tech businesses is essential for the regional economy; high-tech businesses not only create a lot of jobs themselves, they also create employment in the rest of the production and distribution chain.

In comparison to other high-tech regions, Brainport as a business location has a number of strengths and weaknesses. One of Brainport’s weaknesses is the lack of adequately trained staff. Businesses in the Eindhoven city region (SRE) are having trouble to find the right employees, resulting in a large loss in revenue (Provincie Noord-Brabant, 2013). Brainport Development, the executive organisation of Brainport, sees a link between this problem and the residential environment: “De leefomgeving is een belangrijke vestigingsfactor voor kenniswerkers” (Brainport Development, 2012). The ambition to provide an ‘internationally competitive service level with regard to education, culture, sport, recreation and housing’ exists, but the interventions needed to achieve this goal are not concretized.

network of villages in a historical landscape
Despite this, Southeast Brabant, which is roughly made up of the North Brabant part of the Kempen area, has a large number of distinctive regional characteristics. One of these qualities, frequently mentioned in literature, is the landscape that serves as the basis of the present high-tech economy (Hauben et al. 2007). An agricultural landscape, dating back to the middle ages, which for centuries has been closely linked to the people who settled in the area.
Re-using this landscape, which over time got detached from the economic reality of villages and cities, to strengthen the economy of the region, creates possibilities for sustainable development of Southeast Brabant as a knowledge region. Not only the underlying landscape, but also the regional structure on top of it has specific qualities. A relatively large number of the regional residential and work spaces are not located in the central city, but in the surrounding villages. This decentralised organisation can be seen as a disadvantage (concentration of people and activities in a larger city would give Eindhoven a more metropolitan character), but is at the same time one of the unique characteristics of Brainport. It can give the region a ‘village’ quality: a small-scale, informal twist to a highly dynamic high-tech economy. An informal, scenic ambiance, a region of small-scale villages, connected to a strongly layered landscape.

This network of small settlements in the landscape has changed significantly over time. The industrialisation and, in particular, the following suburbanisation of the 20th century, led to a major spatial and economic transformation and the development of a wide range of villages, landscapes and the transitions between them.

Returning to the exact medieval situation is neither possible nor desirable. The present economy, population growth, demands and wishes are essentially different from those of one hundred and fifty years ago. The present-day landscape, often seen as charming and idyllic, was at that time a landscape of extreme poverty and hard work. Instead of trying to return to the medieval landscape, recovering some of the lost qualities of the landscape seems a more realistic and useful way to revitalise the interconnectedness of the village and the landscape. Along with adding new patterns and occupations, this contributes to both the creation of valuable villages and landscapes that can play a key role in the improvement of the residential quality of Brainport and cushioning the gap left by the retreating agricultural sector. The natural guardian of the landscape, the farmer, is faced with increasing difficulties to survive in the globally competing agricultural market.

the intermediate zone
Especially the village outskirts, where most village-country issues show up, offer reasons and possibilities for interventions. The outskirts of the villages have, in many places, been transformed from finely-meshed, informal transition zones into hard edges, preventing village and countryside to interact in any way. Reintroducing an informal, finely-meshed, irregular zone around the villages can strengthen the village character, improve the spatial and economical link between village and country and, at the same time, provide new guardians of the landscape.
Not any design or development method is suitable for the reintroduction of this intermediate zone in every location. Highly dynamic areas require a different programme to areas in the sheltered parts of the region, different types of outskirts and landscapes ask for different approaches and also the local issues that can be addressed differ from one location to the other. Therefore, in this study, three cases (Nuenen-West, Gemert-Zuid en Reusel-Zuid) are taken as an example, each of them with their own landscape and village outskirts, a specific landscape, their own issues and a suitable development method.

residential landscape nuenen-west
For Nuenen-West, an area with a large housing programme, a residential landscape was drawn up in which the housing programme is used to restore old landscapes and create new ones. The carrying capacity of the landscape is used for housing and related facilities and facilitating the development of a finely-meshed, scenic intermediate zone.

waterland gemert-zuid
The southern part of Gemert has severe water-related issues. Especially in winter, with heavy rain, the greatly narrowed river is unable to carry all the water through the village. The development of a wetland area, in which water storage, nature and agriculture are alternated with infrastructure and housing, alleviates the water problem, while, at the same time, restoring the connectivity between village and country.

initiative park reusel-zuid
Reusel-Zuid is a perfect example of many villages in the sheltered parts of the region: low dynamic villages with a stagnating or declining population and economy, often inhabited by a close-knit community. For Reusel-Zuid, a finely-meshed transition zone between village and landscape has been designed in the shape of an initiative park, where local initiatives of enthusiastic residents find their place.

references
In 1888, famous urban designer Joseph Stübben complained that there were no coherent streets in the north-south direction of Cologne’s inner city and that, for this reason, traffic had to be directed along the banks of the Rhine. The Prussian regime did not have the means to change this: the law of that time did not allow for large-scale redevelopment. The change in the urban structure only materialised in places where owners were motivated to cooperate and willing to invest in a change that benefited the public space as well. It is therefore interesting to examine how the larger-scaled new buildings in the city came to be and how this enlargement of the grain within the urban fabric is linked to the emergence of a new cityscape, with new streets and squares. The impression of the somewhat ‘spontaneous’, often diagonal sequence of squares in Cologne’s inner city seems to have been continued in the second half of the 19th century, during the process of grain enlargement. The middle class’ interest in a possible scale enlargement (for, for example, hotels or the first big stores in the inner city) went hand in hand with the design of new squares or passages. The development around the cathedral, the so-called clearing, was a driving factor of a process in which the authorities got more options to conduct urban planning if business owners saw their own interests served. Hereafter, government buildings, such as the courthouse, were also given their place, forming an east-west axis: the Königsstraße with a view of the cathedral and directly behind it, the railway bridge over the Rhine, with the new squares around the cathedral making this continuity experienceable for pedestrians.

1945
The result of a complete bombardment of Cologne’s inner city during the Second World War, which spared the cathedral, made planning a north-south connection possible for the first time. The reconstruction plan was made under the direction of Rudolf Schwarz, respecting the logic of the old fabric, including the grain enlargement of the second half of the 19th century. An existing large urban element, the opera, was relocated to the inner city. The old building could have been restored, since the façade had survived the war well enough, but Schwarz considered it a good tactical urban planning move to replace the logic of Stübben’s time, during which the opera, next to the city gate, formed the monumental end of the east-west axis to the Heumarkt and the Deutzer Brücke over the Rhine, with the modernist logic of a traffic road with an adjacent community centre, in the very heart of the inner city, which he divided into four sectors. The new opera, designed by Riphahn, has been designed as a solitary building in green surroundings. This green area was part of a diagonal park sequence (instead of a square sequence): from a green area next to the cathedral, via a museum framed by greenery, which Schwarz himself designed, to the opera in the park. The courthouse, which was restored, is the fourth large-grain element determining the location of the new north-south street. Schwarz made sure that all restorations carried out in the inner city were based on the principle of soberness: all historical particularities, such as corner towers, were omitted. The courthouse was also restored in a greatly simplified manner, but retained its gabled roof. All other restored buildings (e.g. the Dom-Hotel) were given flat roofs. Riphahn’s opera expresses the effect of the reconstruction on what was left from the pre-war period: with two wings receding upwards, the building responds to the monumental character of the cathedral, of which the towers point upwards, and, in addition to that, the imaginary spiers have been cut off flat, as is
the case with the majority of reconstructed buildings. The impression of this ‘cut’ can be described as the epistemic trauma. This is a characteristic of modernism. It is the impression of the shock resulting from the alternation between the 20th century logic of experience and the 19th century one.

1970
After the Nord-Süd Fahrt had been completed, famous Cologne photographer Chargesheimer published a book with photographs of the new inner city, all made at half past five in the morning, without traffic or people in the streets. The book immediately makes clear that in the wake of Schwarz’ planning, something completely different from just a new logic, with the opera as a solitary building depicting the ideal of a democratic sense of community, has emerged: the traffic space is a harsh world in which a building very different from the opera steals the show in an unexpectedly alienating way: the archives building of WDR as a modernist city gate above the motorway. With these photographs and the memory of what was there before the Nord-Süd Fahrt passed through the inner city, a counterculture cultivated the melancholic feeling, evoking the negative side of the epistemic trauma. The pop group BAP sang about it in the Cologne dialect in their song Unter Krahnenbäumen.

1995
Photographer Wolfgang Vollmer again took photographs of all locations Chargesheimer photographed, with similar photo equipment. The astonishing result: hardly anything changed in most locations.

2020
For a future vision for 2020, the agency Albert Speer und Partner made a plan for changing the entire inner city of Cologne (a comparison shows: largely in other locations than the ones photographed by Chargesheimer). Regarding the Nord-Süd Fahrt, the abstract gestures of buildings above the road are wished away, but, because of WDR’s ownership, are not elaborated further (WDR did not cooperate with Speer’s planning, which was based on the cooperation of owners; the plan was an initiative of the board of the Chamber of Commerce). A rather large transformation was proposed around the opera, which brought forth a contest and a winning design. This procedure had to be cancelled, due to a widespread protest by the people of Cologne, who wanted to keep the modernist building as it was. The building is currently being renovated.

The study carried out shows that the part of the development in Cologne over which Speer had no control has a very different urban planning logic to that of building block, street and solitary building (on which both Schwarz’ and Speer’s plans were based). This different logic was identified by Colin Rowe as the composite building block. The area this other logic (than the one of solitary buildings and building blocks) takes up in the inner city proves to be enormous. This insight is the most important result of the conducted study. The possible interaction with the proliferation of the composite building block logic is the subject of the two plans presented here. The insights gained will be shared with WDR, being the most important owner, the Chamber of Commerce and the department of urban planning.

jos bosman
overview of the existing urban fabric with two new designs
1. velika iliev
2. sven jansse
At first sight, St. Andreas seems to be standing strangely in its urban surroundings. It doesn’t seem to have space to breathe in this densely built-in environment, among buildings of a similar scale and next to a main traffic axis. When looking at the historical development of this urban environment in morphological terms, only little has changed. However, many transformations in the built environment have occurred; with regard to volume and scale, a big change has taken place. Post-war development under Rudolf Schwarz’ supervision took place on the basis of a maximum height for the built environment around churches and the goal to create more space around churches. This resulted in a flat roofscape and churches which could be seen from a great distance. A good example of this is the development around Cologne’s Cathedral, which urban setting was redesigned to make the cathedral to stand free in a big elevated square. For Camillo Sitte, an Austrian urban planner who wrote the book ‘der Städtebau’ in 1889, the idea of a church standing in the middle of a big square was too modern. He believed it would cancel out all the artistic effects a church could have on its urban surroundings. According to Sitte, a church should be approached in two ways: once from a big space and once from a narrow street, from the back of the church. The church will be perceived twice, in two different ways (Sitte, 1889).

The research question with regard to this topic is: how should the urban tissue around St. Andreas Church in Cologne respond to its environment and how can a building be a part of that?

It is important to know how the city of Cologne thinks about the urban setting of a church. Günther Sellen of Cologne’s Heritage Protection mentioned: “All churches in Cologne have a ‘Schauseite’, which is not the front portal, but the choir. To Catholic ideas the choir is the centre of the church, which therefore always should be uncovered” (Sellen, 2013).

The artistic effects of a church suddenly appearing in its built environment (Sitte, 1889), is completely opposite to the open built-up post-war structure of Cologne (Schwarz, 1950), which is again somewhat different from the aim of Cologne’s Heritage Protection of having a freestanding choir (Sellen, 2013). An attempt to bring these in agreement was made by means of a photograph from 1970, taken by the famous photographer Chargesheimer, that served as an argument and plot for a design. This picture perfectly fits all three above mentioned points of view, resulting in a master plan that adopts Schwarz’ modern structure and offers a sublime, artistic view of the choir of...
flirt with the church, model of the designed building

St. Andreas Church. The master plan is the answer to the first part of the research question.

The second part of the research question, i.e. how a building can be part of that master plan, was answered by making a comparison between two German terms for the English word ‘experience’: Erfahrung and Erlebnis (Walter Benjamin, 1940). Erfahrung is an experience that requires tradition or routine to be able to notice things you did not see at first sight. Erlebnis is a sensational experience, which will be undergone in a powerful manner the first time, which, upon repetition, will become less powerful.

The design for a building with live-work apartments and a public grand café, situated between the choir of St. Andreas Church and Cologne’s Cathedral, consists of three stretched volumes, with narrow alleys between them: a dense urban setting within a plot. By looking through all three apartment volumes, it is possible that, during your daily routine, you suddenly perceive part of the richly textured façade of the church. The triviality of your daily routine is in a big contrast to the volatile appearance of the church; Chargesheimer’s picture has been turned into a more sublime experience: an Erfahrung.

This will be a very different experience to the Erlebnis of the monumental, wide views and the static activity of dining in the grand café, which volume penetrates all three apartment volumes perpendicularly, creating a view from church to cathedral.

The way this building makes the churches flirt with it, is the same kind of flirtation Camillo Sitte admires in churches within a dense urban environment. This makes the design a good example of the merger of urbanism and architecture.

references
former street façade (above, chargesheimer, 1970) and current street façade (underneath)

building block in situation
a. according to sitte 1889
b. according to schwarz 1950
c. according to sellen 2013
d. new intervention
the new WDR-office

sven jansse

Being the most striking example of the composite building block in Cologne, the WDR complex plays a prominent role in the spatial perception around the Nord-Süd-Fahrt: the Archivhaus welcomes the motorists from far away with its imposing stature and the Funkhaus regularly opens its doors at the Wallrafplatz for small-scale concerts. The latter was built in 1948, as one of the first reconstruction projects, in the same location where a hotel used to be before the bombings. This first WDR building successfully served as a catalyst for the revitalisation of public life and the complex was soon expanded to the west. In the decades that followed, the WDR complex was shaped to look like it does today, every building in the block responding to the local context in a specific way, while also dealing differently with the pre-war urban structure that was the most important basis of the reconstruction led by Rudolph Schwarz.

Although the people of Cologne are slowly coming to accept the Archivhaus and the Nord-Süd-Fahrt as symbols of the modernism during the times of the reconstruction as part of the present identity, a lot could be improved with regard to the urban embedding and the architectural quality of the building block. The large-scale infrastructure for motorised traffic crowds out pedestrians and the closed and inaccessible skirting makes the block a blind linear barrier. The abovementioned specific responses to the context therefore turn out to be little more than an abstract morphological gesture.

The badly functioning part of the WDR complex will be replaced by a building ensemble consisting of four buildings that is largely confined to an elongated building envelope of two hundred by thirty metres. In this way, the linear character that was already present in the existing building block is strengthened, while at the same time, free space is created where it was previously taken up by the context-oriented buildings. By freeing up this space, a historical link is made to Rudolph Schwarz’s strategy, according to which important buildings should have space. Partly due to the firm anchoring by means of underground television studios, this large-scale ensemble interacts with the freestanding Dom on its plateau of car parks. In order to further strengthen this, a large part of the flat roof of the new WDR head office serves as a distant square for the impressive cathedral.
The four new buildings each represent an existing WDR building. By respecting the contours one time (Archivhaus) and abstracting the principle of a head building the other (Filmhaus), a whole is created that both evokes memories and introduces a new typology. By replacing a composite block that was created in phases in one go, the population of Cologne will again be confronted with a new reality; a third layer is, as it were, added to the stack of morphological structures already present. The ability of the city and its residents to include this dynamic of change in the city’s character, is one of Cologne’s main strengths.

The restraint that had high priority during the reconstruction period is in contrast with the often unexpected and sometimes even surreal use of materials that can be seen in the city centre. This seemingly playful use of materials is continued in the new design: the massiveness of the concrete structure is stressed, concealed or contrasts with the unorthodox materials such as translucent plastic sheet material, glass blocks or oversized vents (2).

The architecture of the ‘Silent architecture’ series by Simon Ungers teaches us that in the use of simple geometric shapes as a guideline for a design, the emphasis is on placing these shapes in such a way that they can create interesting spaces instead of merely remaining shapes. The shape serving as the guiding theme in the new head office is the arch. Every building in the ensemble gets its own orientation by means of an all-determining arch shape. In this, every architectural element ‘sprouts’ from the concrete structure, which, as a subtle hint to the Gothic structure of the many surrounding churches, is always based on the arch (1). Because the shape of an arch ‘grows’ and is at no point the same, this also goes for the cross-sections and floor plans. This allows for the design of very specific floor plans that grow with the programme.

The footprint of the building has been kept as small as possible, so that pedestrians have clear passage. They can even use a large part of the first floor to cross the Nord-Süd-Fahrt. Public accessibility is also an important aspect in the rest of the ensemble. The third floor, for example, has a beer garden that is accessible for everyone via a majestically designed stairway and offers a unique view of the (flat) rooftops of Cologne. A TV-studio, a conference room and a concert space are also (semi-)publicly accessible and offer a view behind the scenes of this grand public Cologne institution.
2. unorthodox materials and oversized vents
Impression of the northern façade at the level of the episcopal residence.
With the bombing of Kassel in 1943, one of the few completely intact cityscapes of Europe was lost. In the 19th century, demolition did take place in this city, but not in the way Haussmann carried it out in Paris, replacing the structure of the medieval city by a baroque design with boulevards. Kassel’s luck was that the son of a Huguenot family that fled from France, architect Simon Louis du Ry, considered the possibility of levelling the city wall in the 18th century to be a reason for a possible, and comparably worthy, urban design of two consecutive squares that, together with the street running in between them, encompass about a quarter of the old city contour. The new design consisted of: a round plaza allowing for the connection of the old city and an expansion that was to be realised; a new street, both sides of which would be built on; and another large plaza in the shape of a large rectangle, which, on the short side, opens into the landscape. This plaza connects the formerly walled city with the Huguenot city lying outside of it: a rectangle divided into blocks, a small grid city. As the foundation, Le Ry’s urban design gave shape to the new city centre, as it was further developed in the 19th and the beginning of the 20th century. This city sprouted new streets, like offshoots in the landscape, an example of which is an expansion designed by Josef Stübben in the direction of Wilhelmshöhe. After the tabula rasa of 1943, the basic structure of the city was still there, in the form of the grand gestures of the baroque landscape architecture, the building plots and the course of the streets. However, the corresponding cityscape was gone, as was the largest part of the archives in which documents were kept on how it was designed. The rebuilt city of Kassel consists of a typical combination of two principles. On the one hand, a block perimeter development based on the old subdivision, including rules like a maximum height and the usage of a gabled roof. Often, the block was partially opened up and, when it was at all possible, it was transformed into row housing, still keeping the old streets as a basis. On the other hand, this echo from the past is being consistently contrasted with solitary modernist buildings, which are placed as monumental gestures in relation to the roads widened for car traffic. This is particularly the case for some large representative government buildings next to the motorway, overlooking the landscape in which the river Fulda flows. This city outline was designed by Wolfgang Bangert, who did research for the CIAM together with Walter Gropius before the war (they analysed how Berlin could have been modernised in 1932-33). A comparison of some of the road sections and maps shows more clearly how the modernist architecture from the period of reconstruction represents a link with the new road plan and how it relates to the different type of architecture next to it.

section 1: ständeplatz
Two office buildings make up an ensemble. In this location, they translate the bourgeois stateliness of the 19th century to the 21st century. One of the buildings is located at the end of Germany’s first pedestrian street, the Treppestraße. In this location, on top of the hill, the building appears larger than it is. With its ten floors, it is Kassel’s first high-rise building. The lower building on the opposite side of the street, however, also clearly marks the corner of the street leading to the station. In this traffic area, the two solitary buildings form a pair, in the classic way that characterises some of Mies van der Rohe’s designs: they are without a doubt modern, but also point to a timeless conception of basic rules in their structure and articulation. They are located in the busy traffic area and depict calmness and control over the area, which they define by being a deliberate counterweight to the open space. Now-
adays, pedestrians crossing the road form a natural part of this game of motion versus rest. As part of traffic planning, a pedestrian underpass could be found here until the 90s. The real estate market considers the removal of the underpass to be an improvement of the area's image.

section 2: lutherplatz

At a crossing further down the street, another two modernist buildings that shape the space are located, but here, the asymmetry of five roads (instead of the three roads at the Ständeplatz) leads to a completely different form of modernistic architecture. To give shape to the size of this large space, large disc-shaped buildings are located on two corners. One of them seems to want to block off the space from the traffic road that runs from outside of the city into the station area. When a driver turns into the street towards the station, the two buildings function as a crooked gate. For the sake of this gate effect, the building on the left sticks out of the block so far that a pillar on the sidewalk has to keep it in balance. While driving past, the building on the right, which previously functioned as a barrier, deviates to the right. The whole has the effect of an optical shift. It is a dynamic play for the driver. To emphasize this play, the horizontal articulation of both buildings dominates. In passing, the pedestrian is aware of the collage effect caused by the placement of the modernistic buildings against a completely different type of architecture, with traditional silhouettes with a gabled roof.

section 3: altmarkt

Before the introduction of Le Ry’s plan, this location was the only centre of urban life. The market took place here. In 1837, the old town hall that was located in this spot, was demolished and the market was partially relocated to the Königsplatz designed by Le Ry. Medieval architecture nevertheless dominated this place until 1943. A comparison of two sketches made from the same position show the Altmarkt before and after the war. Although the two sketches from this position have been made looking in two different directions, they clearly show a radically different reality. A modernist building on the second sketch shows a sort of optimism. It has a lively expression according to the typical style of the 60s, which also would not look out of place in a cartoon. On the opposite side of that building, there was a modernistic building with a very different character, compelling in its generic monotony, a character illustrating the authority of the police, which had its office in it. This building was demolished in 2006 and the section shows that in its place, another large building portraying the authority of a public service has been realised, the ‘Finanzzentrum des Landes Hessen’. The space still features an underpass for pedestrians from the period of reconstruction.

section 4: petrol station at weserstraße

Two hundred metres further on, and according to the same rules of the period of reconstruction, a residential area with a semi traditional contour was constructed next to the motorway, with a distinctly modernist petrol station on the other side. The petrol station from 1969 is now home to a snack bar. This is the location of the thesis project ‘Bauen im Bestand’. The project proposes to introduce the means of an underpass for bicyclists and pedestrians, which in other parts of the city is seen as part of the bad image that Bangert’s modernist approach saddled the city with, in this section. The author is aware of this. His intention is to bring about a radically different effect in the perception of the use of the same means.

jos bosman
The project proposes a transformation of the situation found to examine how the problematic aspects of Kassel’s reconstruction could be solved or even used. It examines transformation in three aspects: the planning, programmatic and architectural aspect. With regard to the planning aspect, it was examined how a free-standing building mass can give shape to a spatial transition. Programmatically, the project follows the historical use of the location and in this way tries to enhance its significance. The architectural intervention concerns the transformation of the existing situation and could thus serve as a metaphor for the whole project.

The location is at the Weserstraße, which connects to the ring road around the city centre at the Altmarkt. It lies on a narrow strip between the Weserstraße and the river Fulda, between a hospital that was transformed into an office building, the Karlshospital, and the warehouse of a former grain mill. The grain mill right behind it now serves as a small hydroelectric power plant and supplies power to 600 local households. Next to it lies the Finkenherd, an idyllic green island in the river Fulda. On the other side of the Weserstraße, residential buildings and a school complex can be found, in the form of individual strips perpendicular to the road. Opposite the petrol station, at right angles to the Weserstraße, the Zeughausstraße begins, a remnant from before the bombing. The Weserstraße is a significant barrier for pedestrians and bicyclists who want to cross from the Zeughausstraße to the banks of the river Fulda. The canopy of the former petrol station is a beacon in the city: because the small building lies in front of the warehouse’s and the Karlshospital’s building line and because it is visible from afar in the wide street profile, it takes a prominent position in the city’s image. It marks the turning point where the old Zeughausstraße meets the new Weserstraße and where there is a passageway to the green paradise of the Finkenherd.

Programmatically, the recognisability as a petrol station; the perfect location for that; the impending transition to electric cars and the close vicinity of the power plant come together in the proposal to transform the former petrol station into a charging station for electric cars. The fact that the process of generating sustainable energy can be observed at the spot is a perfect reason to include an educational function in the programme. Because the charging or changing of batteries takes time, the design will include a lunch café; a coffee bar and flexible workspaces.
In planning terms, the building volume is embedded in the city because of its Z-shape at the turning point mentioned above. It consists of two raised wings with one construction layer resting on columns and a middle part with two layers. Both wings are placed at right angles to the Weserstraße, one of them directly at the street and the other towards the river Fulda. The middle section lies parallel to the Weserstraße. The wing at the Weserstraße has the same function as the old canopy: that of beacon. The strong orientation perpendicular to the road enhances this. Because of the elevation, the wide street profile of the Weserstraße is also not interrupted at ground level.

The other elevated wing also has a strong orientation and serves as the marking point of the passageway to the river Fulda. The middle section anchors the building to the ground. The Z-shape of the building mass makes it clear that the two wings have different urban planning functions and links the design to the warehouse. The building mass could be seen as a continuation of the ‘New Monumentality’: the solitary position, the elevation and the strong horizontality are modernist style elements that carefully tune the design to the urban siting. A new bicycle tunnel directly underneath the building connects the Zeughausstraße with the bicycle path to the river Fulda and the Finkenherd. This adds a functional connection to the spatial effect of the building mass.

The architectural design concerns the transformation of the petrol station building. Given the small size, it mainly consists of reused façades that play a primary role in the new design. In addition to that, the layout of the existing building determines the place and shape of the new building’s middle section. The wings can be seen as extensions. The entrance is located underneath the wing at the Weserstraße. On the ground floor, the petrol shop can be found, with the stairs in the back and the battery changing station on the right of it. On the first floor, the lunch café is located in the wing at the Weserstraße. The flexible workplaces with the public education are located in the wing towards the river Fulda. At the very back, a coffee bar with a panoramic view over the water can be found. The wings’ façades are designed as infills between the floor and roof plates. These infills consist for the largest part of storey-high glass. With this, they also fulfil their role in an architectural way as modernist style elements. In the façades of the middle section, the transformation of the existing historical layers is used and worked out on an architectural level.

panoromic view of the new electric loading station
axonometric view of the former petrol station

1 bike tunnel
2 storage room
3 charging stations
4 battery exchange facility
5 tankshop
6 office
7 toilets
8 lunch café
9 foyer
10 meeting rooms
11 workstations
12 cafébar
The basis for this is part of the façade at the back of the old petrol station, where unfinished parts of the façade from different eras form an unintended, but beautiful collage. This wall is itself an aesthetic symbol of the value of historical traces and transformation. It provides the design strategy for the façades of the middle section: these too have been deliberately designed as a collage of old and new. In this way, these façades show the principle of the design: the historical layers serve as the basis of the design and are explicitly used in order to connect the design to the history of the location. This works both ways: history gives the design meaning and the location is developed a historically suitable way.

This thesis project serves as an example of using a solitary building mass, connecting it to the fabric of the city, and a way to use historical layeredness in order to enhance the character and the significance of the reconstructed city.
In contemporary urban planning and architecture, Potsdam seems to be unmanageable. The city centre is a renovated 18th century shopping street, the ‘Stadtschloss’ is being transformed back into the original situation without taking into account the current changes in the urban tissue and more than half of the residents live in GDR ‘Plattenbau’ on the outskirts of the city. The city is on its way to losing its identity that was once so strong and is changing into a generic medium-sized city in green surroundings.

Potsdam is considered to be a city on the tipping point between a non-generic and a generic development. It is a bricolage city made up of excelling or non-excelling niches that have existed side by side and alternated periodically. In this case, a niche is defined as a non-generic urban development as a result of a political and socio-economic situation. Some niches, however, have disappeared during the last century, creating space for generic urban phenomena that can be considered negative in Potsdam. If this trend continues, this new urban layer will dominate the specific character of Potsdam and the change will be a fact.

In the 18th century, the monarchy led to an escape from the generic and resulted in the residence city: a ceremonial city with a baroque urban design. This was strengthened by the garrison that took its residence in Potsdam. The two things mentioned above resulted in an economical niche that has its origins in the specific production for the ceremonial and garrison city. The development of the last 70 years and the disappearance of the monarchy and the garrison resulted in problems and shortcomings in the current Potsdam, leading to the city’s development towards the generic. The driving force behind this economical niche has disappeared and the only niche that is left is Potsdam as a science city. As a result of the peripheral nature of this niche, it does not contribute to the identity of Potsdam, but stands alone in the periphery.

Potsdam can be seen as a city in transition to its next era. It has not yet found a clear identity and is in search of a new positive impetus. The 20th century has had a disastrous effect on Potsdam. Its two most important niches disappeared: the residence city and the garrison city. The only niche left is science, although its relation to the city has always been limited because of its peripheral character. The buildings of the ceremonial niche have become a tourist attraction.

What remains of the historical niches is the architecture itself. It originated from the architecture of different historical niches and gives Potsdam a distinctive character with a clear architectural identity. The architectural quality the Altstadt used to have, has been raised to the ground by the Second World War bombing, but the rest of the architecturally pleasing buildings and districts are still there and give Potsdam a unique and distinctive character. The city has the potential to develop itself because of its great aesthetic and bricolage qualities. The future of urban development will tell whether or not these qualities will be lost and change into a generic urban development pattern.

Potsdam’s identity as a city is derived from the physical conditions, such as history, context and the current reality. According to Koolhaas (1994), it is unthinkable that modern architecture contributes to this. The population growth in Potsdam after 1945 and in the future implies an unsustainable process in which the historical context will become too small for the consumer demand. When the identity is so clearly linked to the historical context, this will result in future problems for the identity of Potsdam.

Koolhaas argues that the sphere of influence of a city’s character has significant effects on its periphery and that it is responsible for the identity. The stronger this identity, the greater the degree of identification by the surrounding entities. However, in ‘The generic city’ (1994), Koolhaas states that when the balance between the centre and the peripheral region is disturbed, the centre is weakened, stretching the distance between the centre and its surroundings to the breaking point. The problem of the centre is that it is per definition too small to meet its obligations. The concentric obsession of an all-determining centre leads to an expulsion from the centre to the periphery. This reasoning is very problematic for Potsdam. In how far can Potsdam keep its historical identity, when more than three quarters of its population live in the peripheral region?

The answer can be found in the idea of Potsdam as a collage city: a bricolage. The division into a historical centre and the peripheral region has already been made. A very relevant division, however, remains: the bricolage in different niches. Potsdam, as an excelling niche city, tries to escape the generic. The combination of these different elements - the niches - forms the city. Potsdam finds itself in an identity crisis, because it is on its way to losing its niches, the building blocks of the collage Potsdam.
Because of this, it might be best to approach the city as if it were a museum. A collection of ideas together forming an identity. These ideas do not have to be functional per definition, but they do need to be different in character.

Potsdam should be seen as a collage of niches, on which the city can build and on which its identity is based. O.M. Ungers elaborates on this theory in his ‘Cities within a City’, in which the city is seen as a city archipelago (Ungers, 1978). Such a view implies that urban planning no longer takes place on the level of the city as a whole, but on a the smaller scale of city districts. Within the urban tissue, these districts are selected on the basis of recognisable identities that distinguish them from each other. In addition to that, areas that have the potential for this are developed (further). In principle, this plan is completed on city level, to bring about a spreading of districts, but eventually, the actual planning and execution takes place on the district level, in the area that distinguishes it from the rest. In this way, the city escapes the standardisation of (housing) types.

The future bricolage Potsdam therefore does not consist of historically functional niches, but mainly of the architectural consequences of these niches. The science city is the only functional niche that is left. The Altstadt, Stadterweiterungen, Vorstädte, Siedlungen, Plattenbau and villas will be distinguished on the basis of housing typologies. The ceremonial niche is present in the remaining baroque city. It needs to be redefined now that the niche itself is gone. The task at hand is to strengthen these elements by proposing architectural interventions, so that the identity of Potsdam is kept intact and is strengthened where possible.

louis cobben

references

potsdam as a bricolage city
potsdam chance
a typological densification

louis cobben

This project is about a typological densification of an existing building type in the "Vorstadten" of Potsdam. It is about restoring the proportions between the historical context and the periphery by a densification of the former with the goal of strengthening the historical identity of Potsdam. It takes the two problems of Potsdam, the disproportion between the historical centre and the periphery and the housing shortage, as a chance to solve each other, leading to the project Potsdam Chance.

As opposed to the completed work or the immovable object, the concept of fabric implies the possibility of transformation. The typological and morphological development of the ‘Potsdamer Vorstadten’ has always corresponded with the socio-economic situation of Potsdam at the time. This means that the ‘Vorstadten’ could be adjusted at that time, which offers possibilities for the further development of the morphology and typology today: a transformation. In this further development, the identity of the ‘Vorstadten’ is strengthened in accordance with the theory of O.M. Ungers’ ‘cities within the city’. Every ‘Vorstadt’ has its own identity, morphology, open or closed building blocks and typology. This identity is strengthened in the design.

It was proven in the past that the ‘Vorstadten’, in line with M.R.G. Conzen’s ‘fringe belt’ theory, are capable of absorbing larger buildings. The theory of ‘fringe-belt’ development shows that there are many open spaces, mainly because of the influence of the royal court. These two findings both offer possibilities for development and densification. The consolidation of the three examined ‘Vorstadten’ takes place in different ways: intensification, succession and alienation. The identity of this consolidation is strengthened in the design, again in accordance with O.M. Ungers’ theory.
The ‘Vorstadten’ are currently subject to gentrification. The socially heterogeneous phase in which the suburbs now find themselves can be considered positive, but a negative trend in the form of social homogenisation of the district by the capital class has been started. It is impossible to steer the process of gentrification and this should not be desired. However, it is possible to incorporate Jane Jacobs’ four features for urban diversity in the new design.

The design focuses on one of these ‘Vorstadten’: the ‘Brandenburger Vorstadt’. The type of building that is present in this district achieved the highest density in the past, which offers the best possibilities for densification in the future when developing the existing type. The most common type in the ‘Brandenburger Vorstadt’ is the Mietwohnhaus. The ‘Mietwohnhaus’ type can be divided into three subtypes: the one with 5-axes, 7-axes and 9-axes. With axis we mean a façade axis. The number of façade axes determines the width of the lot. The depth of the lot varies. The appearance of the façade is mainly determined by a plastered façade to which the ornaments were added for the purpose of representation. The façade openings have ornaments and the ornaments bring about horizontal articulations on the façade. The façade is exemplary and the court consists entirely of plasterwork.

The building volume is determined by a front house and, possibly, a wing. A development like the one in Berlin, where back houses can be seen, did not yet take place in Potsdam. The historical floor plan only makes a distinction between a ‘zimmer’ and a ‘kammer’ in its layout: functional indifference. The investor let the occupant decide on the further layout. The only distinction there is, is the one between representative and private spaces. The house can be accessed via a porch at the back. The houses themselves consist of a public corridor from which the public spaces and the ‘Berliner Zimmer’ can be entered. From the ‘Berliner Zimmer’, the private corridor on which the private spaces are located, can be entered. The ‘Berliner Zimmer’ can be seen as the link between public and private spaces. Rules, based on five case studies, are drawn up with regard to the building volume, the façade and the floor plan from which eight rational, functional indifferent further developments of the type were carried out.

This is based on a rational further development with a maximum densification of the lot as the most important criterion. The rational developments serve as a tool for the three location-bound designs in the Brandenburger Vorstadt. The rational development shows that a typological development with maximum densification as a goal is possible. The principle of the public corridor, the ‘Berliner Zimmer’ and the private corridor works. Adding a back house to the house is not a problem. The maximum densification consists of up to twenty houses on the plot of the type with 9 axes. A densification of two and a half times the original layout.

Using the depth of the court and the height results in a factor five in densification. The functional indifferent spaces adapt the programme, that consists of houses, well. Adjusting the type to the locations is also not a problem. The ‘Berliner Zimmer’ takes in all deformations. The front house stays part of the dominant historical typology of the street, while the back part is heightened and joins the high-rise building ensemble, consisting of towers of the ‘Plattenbau’ typology - thirty and fifty metres in height - and the historical church towers of sixty metres and above. The densifying strategy works and shows that a large part of the future housing programme can be absorbed into the historical city before a switch must be made to the expansion of the periphery.

references
model of the building with five façade axes
section: inner block façade

street façade

plan of the first floor
In the late 1980s and early 90s, Eastern Europe’s Communist regimes unexpectedly collapsed. With the fall of the Iron Curtain, treaties were drawn up between the West and the East in which countries agreed to scale down military equipment and troops. A lot had to be changed in the Netherlands as well. A smaller army was politically desirable and obligatory military service was repealed. This strong reduction of the army’s size meant that many barracks became redundant. The leaving of the NAVO troops from the Tapijn Barracks in Maastricht in 2004 meant the end of the military use of the barracks in Maastricht, after a long military history. This historically valuable and highly potential area can now, after having been an enclave for almost ninety years, be opened up to the citizens of the city and become a part of Maastricht. The barracks have lost their intended inhabitants, but the buildings still occupy space and are part of the history of the city. What is a proper way to deal with this transformation?

The Tapijn Barracks in Maastricht offer a wide range of opportunities to the city and, with their ideal and romantic location, they are also the latest physical remnant of the city’s rich military history. The barracks are interesting because of their friendly and romantic character that seems to be disconnected from their potentially violent function. Most Dutch barracks are characterised by their link to their surroundings and these barracks are the most beautiful example of this. The barracks are carefully integrated in their surroundings and the design principle of a pavilion contributes to this, giving the ensemble a certain clearness and strictness - representing the military spirit. At the same time, however, the slightly turned and shifted position of the buildings gives the whole a playful and light character. This character varies slightly throughout the terrain and can - generally - be divided into the three main building campaigns.

Thanks to the different building campaigns, the Tapijn Barracks are a good representation of the values of military architecture in the period dating from the early 1900s until the 1970s. They perfectly illustrate the shift in conception with regard to military architecture from a static, extensive defence system, to a more dynamic accommodation for soldiers who can be deployed anywhere in the world. They
form the tangible continuity of barracks buildings, of which the pavilion structure is the most important characteristic. This structure is not only valuable historically, but also contains qualities that are still valued today. The rural appearance of the buildings fits the village-like character of both the military life of the soldiers accommodated and the composition of the buildings. The Tapijn Barracks are one of the last, integrant examples of the first generation pavilion structured barracks in the Netherlands.

The preliminary research concerned several collective inquiries. A group consisting of a total of ten students, was divided into four subgroups. Each subgroup conducted a different research in which military heritage was the binding factor. One solo researcher explored the relevant aesthetic characteristics of the Tapijn Barracks for the inhabitants of the nearby area. Another group examined in what way collective memory and historical heritage are relevant in today’s society, by examining the way people perceive the military enclave. A third group studied the relationship of barracks with the city and the landscape, by performing case studies of several barracks from different time periods in different parts of the Netherlands. The fourth group studied the way sculptors, photographers and other visual artists comment on objects and buildings that have lost their function. The combination of these different angles of the preliminary research, provided a strong and wide foundation for the secondary - individual - part of the research. Each student chose a building to elaborate on the design of that specific building and the terrain as a whole, leading to a multifarious view on dealing with military heritage.

wessel cramwinkel and kenny vonk

references
The vacant Tapijn Barracks are culturally and historically valuable as a whole, but the terrain does not form a homogenous whole. The middle part - the core of the military corps - has the least architectural and cultural values. Still, most of these buildings should not be demolished in future development plans, because of their function as part of the organisation of the ensemble and their urban qualities in relation to the other buildings. Their position allows for a more open and experimental approach for revitalisation. The design for the revitalisation of these buildings finds its origin in a research conducted prior to the design phase, which concerned contemporary visual artists dealing with loss of function and the transformation of object and space. This research showed that architecture, as a cultural discipline, can learn from contemporary visual art; not by copying its toolset, but by learning from the approach used by artists. They operate on a more personal level and ignore constraints, resulting in a conflicting and inconvenient situation triggering thought. Because architecture differs from art, however, it should create conditions for encounters and social interaction. An architect who discusses the role of function in architecture is Bernard Tschumi. In both his theoretical and architectural work, he studies the complex relation and confrontation of conflicting situations, dislocations and confrontations between architectural spaces, the programs and events taking place and the movement of the people involved. The confrontations, called ‘events’ by the French philosopher Michel Foucault, are the moments of raised consciousness, in which people experience the true nature of the objects and activities they encounter. The design of a dance academy in the buildings in the centre of the ensemble contemplates on the idea of creating ‘events’ with conflicting elements, functions and activities.

The basic principle in choosing the new function does not lie in its economic or socially desired value. In other words, no market research was executed. The idea behind opting for a dance academy was developed during the theoretical research. First, the question was whether to demolish the less valuable - or monumental - buildings, or to transform them. Tabula rasa versus the genius loci. The modernist movement would insist on the tabula rasa, a place freed from all its constraints. But that place would have no memory, no sense of the original habitual characteristics that are important to pass on to future generations. Keeping the buildings as they are, however, can quickly become an easy fill-in exercise, full of nostalgia and conservatism. This design stays away from the traditional and the modernist approach to reuse. It can be seen as a study on how far the tabula rasa can go, without losing the memory of the place. Instead, the new volumes that substitute old parts should reinforce the memory. A big contrast was needed to create a conflict as described above. This contrast was found in the poetic thought that a place that was founded for potentially violent purposes is now revitalized and a place for more civilized, cultural and playful activities. The conflict to be created can be most effective when the contrast is at its biggest. Furthermore, dance and choreography as a discipline resemble the Manhattan Transcripts, concerning movement, scripts, space and bodies.

The altering of the existing core buildings is a big operation: the three existing buildings and a new structure together form a new building. In this way, the existing buildings become interior elements in the building. This results in a differentiated and exiting interior, linked to the terrain as a whole. The new volume is not designed to fit its foundation - the core buildings - but some parts of the buildings have to be demolished to fit the dance academy. This not only creates space for the new building, but in some cases, it gives an insight into the construction and history of the buildings. Where new and old structures come together in conflicting ways, events can occur. The conflicts of both physical and bodily elements trigger movement through the building. In that way, the narrative of the military history of the place comes to life. Visitors and users of the buildings are offered room for interpretation: it is not a predetermined story or a mandatory route one has to walk. This design can appeal to everybody as well as nobody, in the same way art does.

A series of events calls for a fragmented, ad-hoc approach towards the buildings and the plan. But creating a building requires an organization, a structure. This structure is organized around the main performance hall. This space forms the heart of the building; it is the only space in the building where the original composition of the existing buildings can be perceived. Thanks to the pavilion style organization of the ensemble, interspaces like these emerge. The spatially valuable square that was formed as a result of this composition now serves as the main performance hall. The volume resembles a sculpture when seen from the outside; with its aberrant form, texture and colours, it is distinct from the surrounding elements. The round edges enhance this feeling, and also guide visitors along the volume. The most important factor that separates the form of the volume from its surroundings is the angle of placement. The volume is not lined out with the existing structure, but slightly rotated with an angle of six degrees. It seems as though it cuts through the three
visualisation of the spatial plan of the dance academy intruding the belly buildings
existing buildings, but in reality the volume stops before it can actually cut through the buildings. This is made clear by the glass edge around the place, where the volume almost touches the existing buildings. When inside, the core buildings can be perceived as sculptures intruding into the main performance hall; the corners of the three buildings act as scenery for performances. This gives the stage its character and links it to its location and history. Thanks to the rotation of the volume, the corners can be used in different ways, like the bar in the foyer which is located in a corner. The double skin around it contains the main circulation space of the dance academy, and also contains some functions on the ground level such as the toilets and the entrances.

The building represents not a single image; the new function acts as a frame, making the contrast between the dancers and the buildings an ‘event’. The combination of the existing architecture -structured, honest and functional- with the chaotic, treacherous and playful movement of bodies next to it and the additional architecture, gives meaning to all subjects. This happens fragmentarily throughout the whole ensemble; each fragment stands alone, but forms a part of a sequence of events. These events are the frames which ultimately form the narrative of the place that is created by its visitors. This narrative is thus not a predetermined story; it can be different every day, and for everybody. This makes the history and the future alive and dynamic.

references
the taste gap between architects and laymen

There are many indications that the architectural preferences of users and architects are growing apart. This difference in taste was described by British philosopher Alain de Botton, on the basis of a project in Pessac (The Architecture of Happiness, 2006). In 1923, industrialist Henry Frugès had Le Corbusier design houses to accommodate the families of factory workers. For this purpose, Le Corbusier designed sleek boxes with wide windows, flat roofs and bare walls, which were the epitome of modernism. He opposed sentimental traditionalists and restrained from every reference to the region or the outdoors. After moving in, people immediately began reconstructing the houses, complementing them with gabled roofs, windows with shutters, floral wallpapers and garden fences. According to de Botton, the factory workers did not desire a place in which they were reminded of modern industry, longing instead for their former home with their patch of land. This is merely an example of the difference in the tastes of architects and laymen. Later on, a lot of scientific evidence was provided, proving that laymen and architects do not always agree (Herschbergen, 1969; Groat, 1982; Nasar, 1988 and de Jong, 1994).

It is important that architects design buildings that are better tailored to the public taste. Architects need an instrument allowing them to listen to the public, without losing control over the design. A method based on scientific research is free from uncertainties like the architect’s assessment of what is considered aesthetically pleasing. For this, the architect not only needs to ask about the technical requirements, such as the amount of sunlight or the number of parking spaces, but also has to study the architectural taste of the public. This does not mean that a design should be based on the public taste only. Good architecture goes beyond beautiful and ugly. It concerns matters such as effectiveness, efficiency, the way in which it responds to its environment and, for example, interesting programming. In the designing process, an architect takes these matters into account, while users are only able to indicate whether they consider what they are being shown to be beautiful or ugly. It is therefore the architect’s task to develop an architectural framework on the one hand and to take into account the aesthetic wishes of the future residents on the other. For the latter aspect, research instruments of the Dutch Centre for Taste Research (CSO) have been applied to this architectural research.

instrument

In a CSO taste test, a panel is asked to taste a series of products and to fill in a questionnaire. It is impossible for a consumer to taste ‘absolutely’. Consumers can easily identify which of the five smoked sausages they like best, but they cannot create this sausage in advance, based on terms like sweet, sour and bitter. This is why taste research is always conducted using a comparative approach. This also goes for architecture. When comparing five houses, a
user can point out in which house he would prefer to live, but he cannot draw the ideal house without references. In this study, people are asked to judge projects by comparing them to multiple example projects. In the preliminary study, this method was used to gain insight into the local residents’ aesthetical assessment of the Tapijn Barracks. By means of emotional terms, an analysis was made of the associations people have with the Tapijn Barracks. The results give an impression of how the residents perceive the Tapijn Barracks.

conclusion of the preliminary study
The fact that the terms differ significantly shows that the respondents are able to attribute characteristics to the barracks independently of each other. There is thus a consensus on what is considered to be convivial, impressive and so on. It also shows that the terms are suitable for marking the differences between the various barracks. The Tapijn Barracks are considered to be the most appealing of this series of barracks. The barracks have an impressive and adventurous character, but also exude homeliness and cosiness. It does not matter whether people come from Ede or Maastricht. It may be that people from Maastricht are not attached to the Tapijn Barracks, because they are located in a private domain. The terrain of the barracks is cordoned off by fences and is therefore a blind spot for local residents.

The impressive and adventurous barracks have one thing in common: there is a strong sense of verticality and a clear focus on one spot. Apparently, these are the architectural features that evoke such feelings. The Tapijn Barracks in Maastricht and the Frederik Hendrik Barracks in Blerick are the most convivial and homely barracks. What is remarkable about this, is that the guard building in Maastricht and the barracks in Blerick are the two smallest barracks and that only the barracks in Blerick score low on impressiveness. It is noteworthy that the three barracks have a similar round shape around their entrance. It is possible that the entrance affects the conviviality of the barracks.

application
First, the main architectural structure was determined on the basis of factors laymen do not understand. These are matters such as the connection of the building with its surroundings, the historical analysis of Maastricht and the military heritage. Subsequently, research techniques were applied to include the aesthetic needs of users in the design process. The aim of the study is to select a design variant that will be appreciated most by laymen. One of the components of the design is the creation of public squares for residents. The squares in the images were rated higher as the visible outdoor space increased. A visible outside door, balcony and porch all added to the appeal of the square. The porch is most effective in this, followed by the balcony and finally the outside door. A façade without an outside door, but with a balcony (variant 2) is preferred to a façade with an outside door, but without a balcony (variant 3). Noteworthy is the levelling in variant 6. This seems to indicate that there is a limit to the number of outdoor spaces.

references
resultat: met 6 erg aantrekkelijk en 0 zeer onaantrekkelijk

variant 1, valuation: 2,8
variant 2, valuation: 4,1
variant 3, valuation: 3,1
variant 4, valuation: 4,4
variant 5, valuation: 5,2
variant 6, valuation: 5,6
the graduation studio

“Cultural Heritage and Sustainability: World Heritage cities as case study” is a graduate studio dedicated to reveal and discuss the impact of development-related changes in the protection of urban areas designated as World Heritage. It is integrated in an international research program, joining our department and the UNESCO World Heritage Centre (Paris). This studio has a focus on research, and links research to design. All students went on a three-month internship, joining a local government, and doing fieldwork in that specific city. This year’s group was the last of four graduation studios, setting the total to 22 students and nine case studies presented on protectedurbanplanet.net. The case studies of this year’s graduation studio were Amsterdam (NL), Edinburgh (UK), Queretaro (Mexico), Macao (China) and Valparaíso (Chile).

amsterdam as a case study

In 2010, the ‘17th century canal ring area of Amsterdam inside the Singelgracht’ was added to the UNESCO World Heritage List thus confirming its outstanding universal value (OUV). The local and national authorities now have the responsibility to manage and monitor this city of global cultural significance. Curious to understand how the protection of heritage and the urban development of a city can be better integrated, this research takes the Amsterdam canal ring area as a case study. It seeks to contribute to local management processes by identifying, locating and analyzing the characteristic elements, called attributes of Outstanding Universal Value (OUV), as well as, uncovering and analyzing the potential urban-development-related factors affecting those attributes. Revealing the real impact of developments on the valuable heritage assets can surely help steer future changes to have less or no negative impact.

the value of amsterdam

Due to the economic prosperity of the 17th century, Amsterdam needed to expand to accommodate the large growth of its population. The plan that shaped the urban expansions was solely designed to help the settlement exploit her ambitious plan for becoming an internationally acknowledged trade center. It included a strict set of rules that determined what functions could settle on which canals (Abrahamse, 2010). The Herengracht and the Keizersgracht were the exclusive domain of housing, whereas businesses, as well as houses, were allowed on the Prinsengracht and the radial streets (Hoffschulte, 2011). This resulted in a multi-functional urban environment that still exists today, albeit it has a different composition. The ‘mixed use of functions along the canals’ is recognized as culturally significant by national and international communities, when it was defined as one of the attributes of OUV (Kingdom of the Netherlands, 2009). It is still deemed important, as the latest Inner City Trend Report (Hoffschulte, 2011) states that the ratio between residents and employees is an “important measure for functional mix”. The report is optimistic about the current ratio, respectively 48% residents versus 52% employees, which is close to the ideal 50:50 ratio. Implying that the current situation is, according to their data, healthy in terms of liveliness and functional mix. However, this ‘ideal ratio’ does not exclude change when in comes to the buildings of the canal ring area.

functional mix versus mono functionality

In terms of sustainable urban development, it is assumed by the local partners in Amsterdam to be less invasive to match new functions to specific buildings with compatible typologies, instead of refurbishing buildings independently from the original function to adapt them to a random function. Moreover, recent research focusing on the effects of building consolidations in Amsterdam noted that although the functional integrity and the functional mix of the property as a whole remained stable; on the scale of the building there are trends towards mono-functionality (Claus and Swart, 2012). This concern is shared with the officials at the Central Borough of Amsterdam, though they lacked evidence to prove their suspicions. To contribute to this discussion, this research mapped and analyzed the attribute of ‘functional mix’, as well as, the potential threat of mono-functional developments for one building block inside Amsterdam’s World Heritage property; the building block surrounded by the main canals Herengracht (north) and Keizersgracht (south), and the radial streets Leidsestraat (east) and Nieuwe Spiegelstraat (west).
some results: evolution of housing over time span 1994-2002 f20 buildingblock
gray: building does not incorporate housing function
black: building incorporates housing function, no change over time span
red: housing function disappeared from building
gold: housing function appeared in building

some results
First, the functional mix of the block is mapped for the years 1959, 1969, 1979, 1994, 2002 and 2010. Then, by looking at the two most prominent functions, namely housing and offices, the functional mix is further analyzed both on the level of the building block and on the level of the individual streets. Numerically, it is determined what percentage of all housing/office area size is located in each street, as well as, what percentage of the area size of each street is occupied by the housing/office function. Looking at the functional mix over the years of the building block, it can be said that the Herengracht has had a strong emphasis on offices throughout the investigated time frame. The Keizersgracht and the Nieuwe Spiegelstraat show a strong increase of the housing function, and are in general more dynamic in terms of functional change than the Herengracht and the Leidsestraat. Furthermore, it can be concluded that the size of the individual offices and houses increased.

concluding remarks
In general, two distinctive trends in the building block became eminent: offices moved to the Herengracht, while housing became more prevalent in the block as a whole with a tendency to move to the Keizersgracht. Also, the functional units became larger, further evidencing mono-functional developments. The original buildings on the Herengracht are ‘double houses’, which are two to three times larger than the ‘city houses’ on the Keizersgracht. This may explain why companies tend to favor these buildings, while the original city house typology of the Keizersgracht remains better fitted for housing. This research also hints that the trend of mono-functionality is negatively impacting the typology of both types of buildings, considering they undergo (mostly internal) changes due to the growth of housing and office functions and their needs in amenities and facilities. This research proofs the suspected dynamics of functional developments in the canal district of Amsterdam. The investigated building
block is very dynamic in terms of functions, but such developments are not necessarily related to hotels, as feared by the local stakeholders (Kingdom of the Netherlands, 2009). It also shows that maintaining a perfect ratio sounds nice, in terms of managing the property, but when it’s only measured on the scale of the wider area, it can still have a large negative impact on the small scale.

Without the datasets that were used for this research – a hard-copy set of maps showing all functions per floor called Bouwblokdocumentatie – this research would not have been possible. Unfortunately, this monitoring practice and the consistent collection of data has been discontinued. The municipality has indicated there are no plans to reactivate it in the future. As this research evidences that the mono-functional developments are negatively influencing the integrity of the canal district of Amsterdam, and hints that this development affects other attributes such as typological attributes as well, we recommend that this practice should be reinstated, if possible in cooperation with academic institutions, so that changes can be closely monitored and the OUV of the canal-zone can be adequately monitored and protected.

note: This research was conducted in collaboration with Amsterdam’s local authorities, the Central Borough of Amsterdam, the Amsterdam World Heritage Bureau (BWE) and the Amsterdam Bureau of Monuments and Archeology (BMA)

references

dave van den berg and jolien bruin
Within the 17th century canal ring area of Amsterdam, one can find over 3500 buildings listed as cultural heritage. In order to remain lively, cities need to keep evolving and that often requires architectural and urban transformations. Many or most 17th century buildings have changed their original functions and are now transformed into hotels, apartments or offices (Berkers and Luiten, 2011). In the first part of the research, it already became clear such transformation has impact on the valuable characteristics of those buildings, which is not always positive. Local and national safeguarding institutions are active in Amsterdam since the beginning of the 20th century, still integrating cultural heritage management in urban planning remains difficult (Veldpaus et al. 2013). One important step on cultural heritage management is to identify and locate what exactly is significant in a building, so than one can better determine the impact on its cultural significance of subsequent transformation proposals. This research aimed at assisting this identification, by developing a methodology that enables to uncover the evolution in time on the location and integrity of the cultural significance of a building, taking a canal house, in Amsterdam as case study.

**what is the impact?**

Since the buildings were erected in the urban expansions of Amsterdam in 1613 (third large extension) and 1663 (fourth large extension), most buildings have seen changes multiple times. Due to its entrepreneurial spirit the canal ring area has managed to keep lively and attractive for over four centuries (Abrahamse, 2010). Thus, this ability to adapt is also recognized as being of cultural significance (UNESCO, 2010). Concerns now rise within the municipality on mono-functional trends as discussed before, affecting the buildings behind the façade.
impact of those developments on the buildings and their cultural significance can hardly be noticed from the outside, as the façades are hardly changing since monument law acts on them as a safeguarding measurement (Swart et al., 2012). Still, recent research has shown that the integrity of the canal ring area was affected (Swart et al., 2012; Van den Berg and Bruin, 2013), it seems that the impact of transformations on the cultural significance of the heritage assets cannot simply be determined by the tangible integrity of buildings, nor their external appearance.

what is of cultural significance?
Cultural significance can also be conveyed on more intangible grounds, such as the evolution or in the adaptive character of the heritage asset or urban settlement. This calls for a wider approach on prioritizing the present attributes and the conveyed values in a heritage asset. The complexity of applying hierarchy in heritage values does not expect to exclude subjectivity. Still, undeniably an important step to determine the impact of a transformation proposal is prioritization.

The cultural significance of Herengracht 448 was found conveyed in 87 valued attributes of cultural significance (Vlaardingerbroek, 2010). These attributes were grouped and reduced to three main categories: typology (tangible), elements (tangible) and routing (intangible).

impact on cultural significance
Cultural significance has proven to be conveyed in attributes of varied natures, tangibility and scale. Also, what is being defined as cultural significant strongly depends on the present definition and approach towards heritage, as well as, the relation to past values. Meaning that, even though the building changed often and to a large extend, the impact on the integrity of that building might not be negative, depending on what was and is being prioritized. Therefore, the question is: were the attributes valued at the time of change, being protected?

For Herengracht 448, this research focused on three attributes revealed from existing listed building descriptions and stakeholder consultations, that are considered to be the most significant: typology (tangible); elements (tan-
gible) and routing (intangible). The impact of functional change on these heritage assets was measured over the time frame 1911; 1991 and 2010. As such a method was developed to relate the impact to the significance, using existing data.

The methodology developed can no longer prevent the destruction of attributes of cultural significance which already took place, however it can help understand its impact, and as such improve the understanding of impacts of future developments. It argues the importance of performing cultural significance assessment as a starting point to instruct transformation proposals on what can or cannot be changed in the building, and even to use to sketch a scenario to reveal the impact of their proposed changes.

**References**


World Heritage Cities, like other cities, need to evolve to meet the needs of their current and future citizens. This requires both socio-economic and urban development. The challenge lies in finding a balance between this need for development and the need to safeguard the cultural significance of heritage. Over the past decades the definition of heritage management has been evolving from an object-based approach towards a more holistic approach that includes notions such as the intangible, setting and context, and urban- and sustainable development (Veldpaus et al., 2013). These notions are accompanied by a greater consideration for the social and economic function of (historic) cities; this approach is known as the landscape-based approach. The recent UNESCO (2011) Recommendation on the Historic Urban Landscape (HUL) provides guidance on such a landscape-based approach at an international level, yet, it is up to the national and local governments to adapt, disseminate, facilitate and monitor its implementation, which is not always a straightforward task. This research intends to assist on such an implementation, by looking at Amsterdam as a case study and taking the HUL as a starting point to better understand the way Amsterdam is mapping its resources. This in relation to the result of the first part, revealing a main source of data mapping is being discontinued. Colleague student Rianne Bennink, who had Edinburgh as a case study, conducted a similar research there. In addition, this research is part of a PhD research on the applications of this HUL recommendation, and therefore, the methods proposed by this research are adopted here.

The comprehensive approach of the HUL consists of six steps (A-F); this research focused on the first step, ‘mapping the cities natural, cultural and human resources’. To understand how to adapt the general guidelines of the HUL for local use and vice versa, an Assessment Framework for current policy has been developed (Veldpaus and Pereira Roders, 2013). As such, the aim of this research is bi-fold. First, it aims to test a part of the HUL Assessment Framework. Second, this research aims to reveal to what degree World Heritage City Amsterdam, already complies with the recommendations by HUL in terms of mapping resources.

This research analyzes a heritage policy document (City of Amsterdam, 2013), an urban planning document (City of Amsterdam, 2012) and a document that is used as a setup for the Periodic Reporting to UNESCO (Central Borough of Amsterdam, 2013). The documents are assessed by finding any reference to the documenting of resources, and categorizing these references into the parameters of the HUL Assessment Framework. The Framework distinguishes between eleven tangible and ten intangible parameters, which range from “established practice” (such as mapping ‘period/style’ and mapping ‘buildings’) to more recent notions such as mapping ‘layers in the urban settlement’ and ‘evolution’. Recent research (Van den Berg and Bruin, 2013) identifying Amsterdam’s attributes of cultural significance, has shown that these attributes populate all parameters of the HUL Assessment Framework, thus corroborating the relevance of these parameters and strengthening the hypothesis that in order to protect Amsterdam’s cultural significance, all parameters should be represented in the local urban and heritage management documents. The framework checks if this is the case. Each parameter is evaluated using a scale, showing the ‘range of application’ of the HUL, varying from the lowest ‘o’ to the highest ‘5’.

This research revealed that Amsterdam maps both tangible and intangible resources. However, this is done without distinguishing between resources of cultural significance and factors that affect the property. The tangible resources are predominantly mapped on the level of the object, which is more established practice, while the intangible resources are exclusively oriented towards functionality and society. This could indicate gaps in the local policy; however, more research is needed before this conclusion can be drawn. First of all, not the full range of documents was researched, and also the assessment framework turned out to be difficult in use while assessing one of the six steps separately.

In addition, the research showed only some resources are mapped regularly e.g. the zoning plan has a required update every ten years. Many resources are actually gathered reactively on a need-base. This means that when problematic developments are suspected, an investigation is ordered if the financial resources can be made available. Local stakeholders also mentioned that they do not have the resources to compare any of those data to subsequent years.
Finally the research also shows that data collection in Amsterdam takes place on the level of the individual building, and on the level of the larger urban district (statistics). However, what happens on the level of the street, the ensemble, and building blocks, remains unclear. This is also a critique to the framework, as this matter of scale levels is not included. Interestingly enough, the data to carry out this type of research on all levels of scale appears to be available; therefore there is reason to believe that there is a lack of (time for doing) comparative analysis, rather than a lack of data in the monitoring of Amsterdam’s attributes of cultural significance. Future research could explore the possibilities for large-scale data analysis, perhaps by connecting to current research projects such as Open Source City and Amsterdam Open Data.

references
The Portuguese word ‘Ilha’ means island. An ‘Ilha’ in Porto, Portugal, is a typology of low cost housing which spread within the city in the 19th century, as a result of the industrial development and population growth. They received this name, ‘Ilha’, due to their character of isolation from the urban space in which they were located. The working class dwellings were established within backyards of middle class houses, and were surrounded by walls from all directions, connected to the street through a narrow corridor and an almost unnoticeable entrance. The Ilhas represented the main housing typology in the city at the beginning of the 20th century.

The extremely small houses (around 4x4 m) along narrow corridors rapidly became a major public health issue since they lacked quality and comfort. And, despite all public trials of destroying them and relocating the inhabitants through the 20th century, they still do. The typology survived through time and still exists, providing living conditions that are in many cases rather similar to the ones of the past. More than 1,000 Ilhas still exist within the city of Porto, sheltering more than 13,000 people. The largest existing cluster of Ilhas in Porto can be found along São Victor Street, which was chosen as the project study area. In this cluster, located near the centre of Porto, around 700 people live in approximately 29 Ilhas.

It is still the objective of the municipality to tear down all Ilhas of Porto, and they have been erroneously demolishing them through the past years. There are reasons to believe that they should be preserved. The most heard sentences in São Victor Street are: “I will die here” and “I would never leave this place”. The Ilhas are an example of people’s attachment to the living space, so strong that it overlooks the low living quality standards and results in satisfaction and permanency. This is the greatest advantage of this housing typology, and the main reason to keep them.

Nevertheless, the residents still live in extremely small dwellings with poor living conditions, in many cases without a private toilet, and they lack financial sources to improve this situation. Next to this, the area has a very negative image within the city, as a result of the historical reputation of the Ilhas as unhealthy places, creating a barrier between the inner and outer scales of the urban block.

The problem is quite complex. How to keep the community alive? How to improve the degraded dwellings without financial sources? How to decrease the negative image within the city and increase the relationship with the outside space? And above all, how to do it all without governmental support? The existing conflicts were classified into social, economical, scale and physical gaps, which are nothing more than a translation of the conflicts that form the complete problem. Therefore the main question is: “Which innovative solutions can minimize the threats on the positive aspects of the Ilhas and how can they be implemented in order to fill up the social, economical, scale and physical gaps?”

Because there is no support from the authorities, the objective of the research is to develop improvement scenarios for the Ilhas and their surrounding urban space that can be achieved with the efforts of the population itself. The main concept of the proposals is the ‘urbanism of self-improvement’, that binds all objectives in a spatial improvement methodology based on volunteer and community work. The concept is based on a necessary reevaluation of the relationship between market, government and civil society. In the ‘self-improvement’ concept, the civil society is perceived as an essential stakeholder and main engine of the urban transformation. The whole process of the transformation is carefully built up by subsequent scenarios, with for each step key-moments for the reevaluation of choices and decision making.

The proposals are based on successful innovative solutions listed in a toolbox of successful examples of intervention made with none or little governmental support, and are developed in the form of guidelines. They propose improvement in the large scale, increasing the relationship with outside the study area and diminishing the negative image within the city. In the inner-block...
Urban design and planning

Ilhas in 1940 and in 2012

Ilha in detail
scale, the community activities are incentivized through implementation of shared facilities in abandoned spaces. And at last, the inner space of the *Ilha* is improved through a group construction approach. The development of the defined guidelines is a rather uncertain process. Therefore, the proposals are presented in a ‘view’ which is only an illustration of what the future results could look like, but without the assumption that the space would have that physical appearance.

The main strength of the project result is the thought that urban changes can happen in different ways than the usual. This new approach of urbanism includes strong public participation and a whole new position of the planner within the process. This approach is not based on any general theoretical framework, but on a pragmatic and problem-oriented working method. In this project, the urban environment is not considered in its general form, but the social and spatial dimension of the ‘*Ilhas*’, as an ‘assemblage’ of the city, determines the focus of the research. Therefore, the working methodology of analysis and the application of self-improvement methods from the Toolbox can surely be applied in other spaces.

The project does not aim to spread a large scale urban revolution where only the people take care of their own space - because the Government is still a very important actor in the urban sphere and they should be involved - but it shows that it is not necessary to wait for the Government take the action on urban problems as if it is the very only solution.

Perhaps this change of mind is the positive legacy left by a time of crisis: more social awareness, innovation within the working method, and design-thinking in a process oriented way could be the rise of the public-oriented design and the rebirth of urban designing and planning.

![Image](https://example.com/image.jpg)

**the view: some examples of the proposed interventions**
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beauty and thinking about making

In the Museum of Science in London stands a beautiful piece of furniture called ‘a philosophical table’. Philosophical tables date from the time that science called itself natural philosophy. A sort of compact and portable laboratory set up, it was an expensive plaything for wealthy people, who would use it to recreate the scientific experiments of their time in the comfort of their drawing room. Such tables were beautifully crafted pieces of furniture with the purpose to serve as the focus for thought and speculation.

The aim of the graduation studio ‘The Naked Architect’ is to use this idea of the Philosophical Table on one hand in its proper historical sense, as a laboratory table upon which to conduct experiments; and on the other hand to perform experiments in space and spatial configuration.

Thought becomes possible by using examples to allow thought to find its way from a question to an answer and from there to another question. Thought demands objects to think with and think about, just as much as our bodies need useful things like tables to survive their environment in comfort.

So a philosophical table, within the confines of this project, is at least two things: it is the designed and realized product of an intellectual struggle with a specific concept, and it is the focus and object of discussion. A normal table is a thing we use to decorate our home, sit at, eat at, work at and have conversations around; a philosophical table as interpreted in this exercise, focuses on being both the product and the subject of discussion. So these tables are the product of philosophical discussion and themselves objects to further philosophical discussion, mostly about the nature of making. Each student took a specific concept such as Kunstform und Kernform; hylomorphism; mass; tectonics; ornament and structure; ambiguity and spatial hierarchy; the body and perception; the notion of craftsmanship or Tao and evolution. All of them questioned these concepts through a process of design, making and reflection. As such these tables are contributions to the debate about the nature of design research and, in their way, contributions to philosophy. The interesting aspect of the process of the graduation studio is the complexity of results and the wide range of topics each student developed.

The starting point of Beauty and Making represents a field to explore through different perspectives, which are the specific concepts visualized by the tables. Each of them, designed and built in 1:1 scale, is an individual and unique aspect and interpretation of the “thinking about the making”, as Alison and Peter Smithson called it. The concept was defined in the way to work simultaneously on theory and practice. From a theoretical statement, the exercise was carried out in order to apply that theory to a practical field, such as materiality, structure, ornament etc…

Used as guidelines and results of the Studio, two projects will be explained more thoroughly. The first one deals with duality of Structure and Form. According to Karl Bötticher the core-form (Kernform) is the mechanical, necessary, structurally functioning scheme of forces; while the art-form (Kunstform) is its clarifying counterpart, its symbolic expression. These concepts are strictly related to each other and their dialectical relationship explicates the synthesis between the ontological status of the structure, the way it works as a set of material forces, and the representational role of ornament, that veils and speaks at the same time. The joint is where core-form and the art-form
interact and interlock. The joint, the juncture, shows the way structural requirements and design merge, or at least take account of each other.

The table focuses on the idea of mass and the technique of pouring. Pouring material and thereby creating what appears to be a homogenous mass, puts the field of tension between the core-form and the art-form in a clear but problematic perspective. In the making process, the mould takes on the role as the art-form, it shows the negative of the form of the final product. At the same time, the poured material in its entirety constitutes the core-form; the structural play of forces. It has no specific or articulated joints; the material acts at the molecular level throughout the massive volume, which thereby becomes a manifold unity of microscopic and invisible joints. Plaster of Paris and water react and create the structure and the form of the object in one go. Structure and form merge into a single unity, but here and there we soon see zones of stress forming. Although the structure is not made explicit in specific and visible joints and connections, they still exist and play their role, revealing themselves at the surface where that surface cracks and chips. The load-bearing parts of the table, its ‘legs’ form a continuity with other, structurally burdensome elements, which embody a “useless” load. But both affect the diagram of forces at work within the table. Can one simply identify the one as core-form and the other as art-form? Not really. In this instance core-form and art-form converge.

The second project takes its inspiration from philosophy of Taoism, which is based on the central idea that Tao does as nature does. Taoist philosophy proposes that the universe works harmoniously. One must place one’s will in harmony with the way of nature. The founder of Philo-
sophical Taoism Lao-tzu, a philosopher of ancient China, modelled the pattern in which natural things develop. So how does nature work? Living nature works according to the pattern of natural selection. Variations are produced, some are selected for use. That which is selected tends to survive and must by definition be fit for the environment in which it survives, otherwise it wouldn’t survive. There is no design involved just an offering of possibilities, some of which work well and other which do not, and die out.

The table explores this Taoist/Darwinian notion of natural selection. The design started without a preconceived form, except the generic idea of becoming a table as well as a particular way of folding a piece of paper into what might, at a stretch of the imagination, be called ‘a pair of trousers’ or a double cone. The design had to take full account of the natural proportions of the material, otherwise it would simply collapse. Research into the material revealed its wonderful tensile proportions as well as its high coefficient for friction. And as paper is vulnerable to shear force, nothing that would induce it to tear could be employed. Following a multitude of experiments with all sorts of variations, the solution that best fulfilled the requirement of a table slowly emerged from the limitations that were imposed. The hand-folded ‘trousers’ had to fit snugly so that they would interlock well and simultaneously provide the required frictional resistance to prevent them falling apart. The forces had to be efficiently transferred from one element to the other and be dispersed to the ground. Gradually the relatively complex form emerged, with legs like that of a ballerina, not because they look good, but because they work well structurally.

jacob voorthuis

wenlei ma
mass as an architectural concept

elisabetta bono

The concept
The idea of mass as an architectural built form, but also as a way to perceive space has been explored in theory and practice. Mass as an architectural concept entails Structure and Form, or, as Karl Böttcher calls them, Kernform and Kunstform. Core-form and art-form generate solid, but also void forms, one being essential understanding the other one and vice versa.

We would not understand a window without a frame or a wall, just like we would not perceive a courtyard building without standing in the void inside. If the solid functions as a structure, the void can be considered an art form, or, in other words, the clarifying characteristic that reveals the mechanical component.

This way of thinking can be applied on different scales as well: on an architectural, a technological and even an urban level, with the urban pattern showing the same rules. Streets, inner yards, gardens and galleries are negative shapes of the visible formwork that is the city. And it is fascinating trying to imagine this inverted version of the city. What would change? The perception of spaces? Or maybe just the elements that affect the experience of the space?

The goal is then to find a way to model the relationship between what is built, the solid, and what is left empty, the void, by using mass and its features as a tool. Obviously, it is not just a matter of materials and building techniques, but also concerns the way mass behaves in space and how it expresses its features, such as stability and majesty in relation to its surroundings.

A stereotomic (massive) volume reacts to light, shadows, orientation, spatial organisation, circulation and even programmes. Moreover, mass allows for the shaping of the architecture of the new building, following the location’s characteristics and its morphology. Multiple layers from different historical periods function as a network of contributions aimed at modelling the image of an understandable piece of urban context.

The building / the courtyard/ the cultural centre
Keeping in mind the guidelines provided by the preliminary analysis on the location, the project represents a new interpretation of the traditional typology of a courtyard, which is the most used and widespread in the project spot. The building is part of a defined urban context, characterised by a high density pattern, with an average of 75% built and 15% void.

As a dynamic mass, it puts itself forward as a new landmark in the city centre of Pavia; it creates social spaces and useful activities, underlining its identity and thus becoming a recognisable object. The strong link with the urban pattern at the same time enhances the role of the building as an exception. The architecture in fact uses some traditional typological elements, but it inverts other features. For instance, an entrance is usually a passage in a wall, obtained through an opening that runs through a part of the building and ends in a private yard. Following the inversion trick, entrances will be voids defined by masses. The goal is to provide the same spatial references as the typology at issue does, but through new inputs.
The architecture explores massiveness by using sculptural volumes and thick walls, resulting in an irregular rhythm of the composition. The initial impression of a homogeneous uniform block of concrete instead reveals a variation in materiality and texture. Smooth polished surfaces merge with free disposition of independent volumes containing secondary activities. Pedestrian circulation is not meant to take place in a rigid direction, but along a flexible and subjective path.

The rough façade of the second level on the other hand, emphasises the monolithic character of the auditorium volume, the core part of the building, which is more enclosed and reachable through one entrance.

The spatial experience involves different kinds of space: covered; semi-covered; uncovered and open; semi-open and closed. The connection of these spaces results in semi-spaces, the spaces in between that give a special complexity to the design. They indicate a change, a transition, in the same way the portico does in the courtyard typology, by linking building (solid/closed) and yard (void/open).

In the project, galleries and passages around massive volumes articulate intermediate spaces, which always change from one point to another one. Walking from the main entrance, the width of the gallery expands towards the courtyard, while tilted walls hide or reveals parts of the building. The cantilevers of the first floor volume provide covered spots and create gaps between the existing buildings in the plot and the new architecture. They express tension between new materiality and something placed there years ago.

Furthermore, spaces in between serve as spots that provide references of the surroundings, offering a view of the building and the surrounding city.

In conclusion, using mass as a means to shape architecture it is a matter of perception and experience of space, but also a topic for study with regard to how it behaves and how it expresses itself through structure and form.

In the building in the city. entrances are void enclosed by the mass of the building itself. the two floors present different textures of the concrete: polished for the ground floor and rough for the first floor.
longitudinal section of the whole building. the slope in both levels leads to the focus of the cultural centre: the courtyard and the stage of the auditorium

view on the courtyard meant as meeting point in the building, but also as social space for the city
This design is a reflective experiment on the research question 'how to start the design process by thinking about material'. In this project, reed, which is commonly seen in traditional thatched roofs in the Netherlands, was chosen as the starting point.

The research should be seen in the context of the routine usage of the 'form-to-material' pattern of design. The consideration of material is generally left to the end and is sometimes a rather hasty and random process. The fact that material is merely seen as texture reflects the current trend of people caring more about 'how it looks' than 'what it is': they pay more attention to abstract information than physical substance. Correspondingly, a large number of buildings are designed to be merely beautiful, as a public advertisement or worse: cultural fast food.

If we look back to the time before industrialization and modernism, architectural work was more concrete and practical. The majority of architectural designs were created according to the principle of 'material-to-form', the opposite of the form-to-material pattern. This project aims to interpret this notion in a contemporary context and attempts to identify and visualize the pure beauty of materials that has been lost. The idea is to design a house completely covered with reeds, as an extension of the landscape of fields. In the past, Dutch farmers used wheat straw from their own field to thatch the roof. Buildings dressed in certain materials united man and the environment in harmony. In the late 20th century, reeds gradually replaced wheat straw. Reed is similar to wheat straw and the material precisely represents qualities consistent with fields where crops grow extensively. On the other hand, the building is expected to form an environment in which users can closely interact with the material. To be consistent with the landscape and to make installation easy, the shape of the house is extremely pure and simple: a cube as elegant as the flat field it stands in. The form of a courtyard is the result of inverting the conventional pitched roof to a degree that depends on the drainage requirements of reeds. The 300 square metre house is designed for a family of four. Around an 8 by 6 meter courtyard, rooms are arranged according to different light conditions. Instead of using partition walls, the main space is defined by the up-and-down ceiling. The flowing circulation provides different heights of views, offering a panorama of the surrounding fields.

The façades make full use of the advantages of thatching techniques, by means of which nearly any imaginable pattern is possible. Inspired by the landscape of the open field and the paintings of Vincent van Gogh, a series of broken lines are created around the openings. The hand-made embossed patterns represent unique, imprecise and rough qualities, just like the emphatic strokes used in van Gogh’s oil paintings.

The inner courtyard and the study penetrate each other. Nature is framed within the square courtyard. Such a quiet atmosphere allows people to sensitively perceive the sound of rain, the flow of clouds and the rhythm of snow. One side of the roof is lowered to the ground level, so that the owners can sit on, lean against or lie on the grass-like material and interact intimately with the architecture, using all their senses. In conclusion, the design illustrates how material helps decide and inspire design. Materials can also be used to extend nature into architecture, where beauty is expressed through the use of details and a rich physical experience, in a moment when you see, hear, smell and touch a material with great attention to detail, patience and due respect. In other words, materials are able to ‘express’ and architecture should not only be functional in a practical sense but also functional in the sense of being comfortable, enjoyable, a place of emotive sensitivity.

The discussion regarding materials is not just intended to overturn the notion of form-to-material design. Instead, it aims to provide an alternative, a new way of thinking. There is no right or wrong in starting a design process on the basis of material or form. Only when diversity of thinking is guaranteed, creative ideas that offer the best chances of achieving beauty can be formed.
In his manifesto ‘Complexity and Contradiction in Architecture’ (published in 1966; the book is seen as one of the starting points of postmodernism), American architect Robert Venturi argues that every architectural task is complex, as the architect always has to try to unite Vitruvius’ three pillars in a design: utility, stability of structure and aesthetics. Venturi speaks out against modernists; they try to solve or simplify this complexity, which could lead to superficial and even boring architecture. Yet, according to Venturi, architecture in which complexity has its place and is not nullified is interesting and offers additional qualities: “I am for richness of meaning rather than clarity of meaning; for the implicit function as well as the explicit function. […] A valid architecture evokes many levels of meaning and combinations of focus; its space and its elements become readable and workable in several ways at once.”

It is therefore important for the perception of the user to provide insight into the complexities of architecture. This creates a vivid perception, allowing the user to discover more and more new things by looking at the design for a longer period of time. However, complexities and contradictions cannot serve as an excuse for incompetent designers.

Complexity needs to be dealt with in an intelligent and thoughtful manner. It is therefore important that despite the contradictions or difficulties in the design, the aim is always to achieve one whole: “But architecture of complexity and contradiction has a special obligation toward the whole: its truth must be in its totality or its implications of totality. It must embody the difficult unity of inclusion rather than the easy unity of exclusion. More is not less.”

The manifesto does not have a clear structure. Venturi makes his position clear by means of numerous examples, drawing deeply on a spectrum of references from, inter alia, the Renaissance and the Baroque. To make the book more comprehensible and to get a better grip on the matter, the graduation studio wrote a new version of the book. This ‘catalogue’ consists of the following components: (1) the studio’s interpretation of the theory, (2) an addition to the number of cases, meticulously analysed on the basis of Venturi’s conceptual framework and (3) a comparison of the cases in order to best determine the span of the concepts.

The reinterpretation of the theory involved the development of a clearly hierarchical structure, divided into
attitudes, approaches, principles and means. These are the guiding terms of the research. There are two distinct attitudes in architecture: ‘either-or architecture’ and ‘both-and architecture’. The latter is the attitude Venturi prefers: both-and architecture. Within the field of both-and architecture, two approaches can be identified that concern the sequentiality of the design: using order as a basis and accommodating contradiction, or using loose parts (dis-order) as a basis and later bounding them into one whole. Within the contradiction adapted approach*, the principles of adapted contradiction and juxtaposed contradiction are applied. These principles are in fact a collection of means to identify the complexity in a design. Within the ‘difficult whole approach’, the principles of equal combination; hierarchical combination; dominant binder and inflection can be found. In addition to the principles and their means, there are a number of overarching means, such as associative and double-functioning elements, and the poche space, which may apply to both approaches.

After an examination of the theory, it was questioned and tested in 20 cases selected from a time period of 400 years. The incorporation of these cases serves several purposes: they are a test of the theory and they show how the principles and means described can be combined in a design. They also lay bare the shortcomings and family equations in the theory. The latter are questioned by means of cross comparisons. Striking features and blind spots in the theory are exposed here.

The complete tactics of theoretical redefinition, the analysis of cases and the theoretical expansion of the theory after the addition of the cases lead to important overarching conclusions. It was found, for example, that the proposed distinction between two design tactics does not work in practice. The approaches of the difficult whole and the contradiction accommodated were often combined in the design. Another conclusion is that the framework used remains subject to subjective judgements. Although work in this field is not yet conclusive and might require further studies, the framework provided in many respects offers a way to question complexity within a design.

yanne janssen and erik hoogendam

references
a baroque bricolage
a reinterpretation of the baroque as a plea for localised ‘complex’ architecture

ryanne janssen
Venturi’s ideas are an interesting, but also unusual basis for a present-day graduation project, given the fact that this theory was presented to the public (of architects) in 1966. Because of this, it could nowadays be considered outdated. Nevertheless, a number of timeless themes are addressed in Venturi’s ‘Complexity and Contradiction’ that welcome further study. In his manifesto, Venturi repeatedly discusses architecture from the past and emphasises the positive value of its use. He calls these elements ‘vestigial elements’. Despite the large value Venturi places on these elements, he only examines this category on the basis of a few examples. However, he does not identify different sorts of vestigial elements, nor does he describe how these can be applied within the field of architecture. By examining this and making it more visible, this project can be a valuable addition to Venturi’s theory and the design practice in general.
The study of the vestigial element consisted of a more or less identical structure to the preliminary research: a literature study, cases and eventually some cross comparisons to determine the span of the different concepts. Using these research methods, the following research question was answered:

How can vestigial elements be used in the field of architecture and does this concern an order or sequence?

Eventually, it was shown that there are four categories of vestigial elements. The first category was taken from Venturi’s work: the spolium element. Spolia are conventional building elements used for a second or third time. This means that they were part of another building before. This makes their application both ambiguous and striking; a very clear link with the past is made and both the architect and the client are greatly aware of this.

The concept of the second category comes from the cases of the preliminary research. During the study of the Neue Staatsgalerie by James Stirling, it turned out that he gives architecture from the past an ironic touch. To this end, he replicates, inter alia, a ruin and large classical columns. In this case, one could argue that spolia elements are being copied, prompting the name of the second category: spolia 2.0. Spolia 2.0 mainly concerns copying elements or groups of elements within a larger whole for the purpose of adding an ironic touch or simply because no authentic/genuine historical material exists.

There is also a superlative of spolia 2.0, that is the copying of an entire building or coming up with a very similar variation on it. This is called a sign in this study. It concerns very similar, sometimes even commonplace variations of vestigial elements on a full building level.

The fourth and last category is the archetype, which also came up a few times in the cases of the preliminary study. The archetype, just like the sign, occurs on building level, but differs from it, because the archetype is in most cases subject to more abstractions and is open to linguistic innovations.

Cross comparisons show that a sequence can be associated with the categories, depending on the theme within which they are applied. In this way, spolia are rather literal in their application, but not the least complex. The archetype is the most fruitful for design and abstraction. Some categories also turn out to be strongly linked and are well fit for combined use; for example, the archetype in combination with the spolium 2.0 element.

The research, along with a studio excursion to Rome to study Venturi’s examples in real life, resulted in principles for the design of a new Royal Netherlands Institute in Rome (KNIR). This assignment involved different complexities: (1) functional complexity (is it a building for living or studying - will it be a house or a library?); (2) linguistic complexity (how to design a Dutch bearer of culture in an Italian city?) and (3) architectural complexity - the combination of Vitruvian aspects and the propagation of Venturi’s ideas.

For the design, an (existing) archetypical baroque floor plan was used as a spolium element and served as the basis of the final result. The Baroque was chosen as an overarching theme, because this style period thrived in the city of Rome and in this way, the new building will embrace the identity of the place. This style also has a strong link to Venturi’s concept of inflection, which concerns the intrinsic relationship between different architectural elements within a larger whole. This theme is thus a combination of the linguistic and the architectural complexity.

By means of vestigial elements, references are made to different (baroque) buildings in Rome, such as the colonnade of Borromini’s Palazzo Spada, the Pantheon and the San Carlo alle Quattro Fontane, but also to more general archetypes like a rotunda with a dome; this also reflects the linguistic and architectural complexity.

All of this was carried out within the concept of ‘the bastion’, with wander spaces, bookcase doors, secret rooms and a large massivity, which provided a solution for the functional complexity. The different themes were incorporated into the building from large to small and are further accentuated by subtle details and poche spaces. This gives the building many different layers of meaning and allows various combinations to draw attention. In this design, the programme is secondary to the sign that constitutes the building. For this purpose, Adolf Loos and his Chicago Tribune Tower, a case that was part of the theoretical research, are called upon:

“I have used space wastefully”, Loos admitted, to achieve the most impressive effect. “The creation of a monument occurs at the expense of space.”

This building is not a conventional beauty, but he who makes the effort to get to know her will perhaps be fascinated by her complex richness and the many confessions she carries in her.
ground floor plan
gothic complexity
reconstruction of the nave of the utrecht dom church according to
the architecture of complexity and contradiction

erik hoogendam

An architecture of complexity and contradiction requires showing conflicts, such as the difference between new and old. In addition to that, conflicts serve as guidelines within the design process: although they are often negated or simplified within the field of modernist architecture, they can lead to an enrichment of the design of complex and contradictory architecture.

The selected task of this project, the reconstruction of the nave of Utrecht’s Dom Church, requires a reflection on how the connection to the existing building should take place. How do new and old relate? Will a distinction be made visible? Does the design bring about a conflict? Because the connection to the existing situation is a very relevant issue for this task, there is a possible approach: contradiction adapted. This term, from the work of Venturi, refers to the build-up and, subsequently, the break-down of order. In the design of the nave of the Dom Church, contradiction adapted was considered as a means of design. This approach resulted in a design in which the nave is connected to the choir of the church, while external architectural and programmatic influences are also accommodated. The aim was to develop an contradiction adapted that reflects ambiguity: even though the new construction is similar to the existing structure, the differences show that it is a new addition. The cases of the study The Architecture of Complexity and Contradiction show that contradiction adapted was often hidden behind the outer façades of the buildings. The issue that was faced during the exploratory design process was therefore: how can accommodated contradiction be expressed in the façade and in which way is this an analogy with the current situation? The task chosen is a means to test whether this would be possible.

In this case, accommodated contradiction results in the combination of two systems. The first system is derived from the former: the nave that was destroyed by a storm. This situation was rationalised into a grid of 6,300 mm x 6,300 mm, providing a structure that is connected to the current Dom Church.

The second system contradicts this. This system takes it shape from a centrally oriented floor plan with diagonally placed furnishings, based on De Keyser’s Noorderkerk in Amsterdam. The accommodation of this system, resulting
in manipulation to allow merging, causes the design to differ from the existing situation. The result is a construction with a second church hall, which will serve as a space for studying, reflection, the proclamation of the Word and additional parts of the programme.

Although contradiction adapted is the primary means of design applied, other means are also used. Inflection, another concept of Venturi’s theory, implies continuity between the different parts of the building. Analogy, an attitude within the field of tension between mimesis and contrast, serves to visually link the façades to the existing church. If the design looks both new and old, it adds its own meaning to the chosen abstraction.

The goal was to come up with a design like Döllgast created for the Alte Pinakothek in Munich, or like Chipperfield did for the Neues Museum in Berlin. Both of these designs have a structure that is abstracted on the basis of texture. Achieving this required an assessment as to which of the components of the typology, construction and decoration could be used and/or abstracted.

The design was created on the basis of a few principles: the building envelope, derived from the grid of the destroyed church and the projection line and gutter heights, provides the contours and brings order. The rhythm of the existing Dom Church is also maintained. The pilasters, columns and flying buttresses are abstracted. Finally, the pointed arches, coming from the existing gothic church, determine the shape. Their verticality, suggestion of movement and adaptability within a complex design make them the bases of the new system: ‘Gothic Complexity’. This theme serves as additional repertoire for Venturi’s theory.

The result is a design that has become its own system, by means of a complex floor plan, composite columns, arches and ‘ogival domes’. All of this partially takes place behind the analogue façade: although the shape of the building has been affected and, so to speak, fans out, the complexity remains hidden behind the façade’s elements. Analogy plays a dominant role as a third system, partly restraining the complexity. This method could be interesting for other historical projects that involve expansion, as an alternative to the frequently applied contrast.
Keeping in mind the architecture of complexity and contradiction, new possibilities arise in the design process. The acceptance of conflicts makes it possible to allow them in the design, instead of masking or ignoring them. Because of this, complexity itself needs to be restrained and designed. Although this does not facilitate the design process, it does result in a rich architecture that harmonises strained relations. Moreover, the analogue façade connects the construction to the existing Dom Church in a natural way.

References
joy in vacancy

For years now, the Dutch media has been paying great attention to unoccupied office buildings. Research has shown that almost 27% of these buildings are unoccupied at the moment (van der Boon, 2013). The prospects of improvement are also not good. A third of these properties will, in all likelihood, not find a user. Structural vacancy has become a reality. To take a position on this problem as an architect, some basic knowledge is required with regard to the background of the problem, office buildings and typologies, (programmatic) trends and transformation types. The report ‘Leuker dan Leegstand’ gives architects an introduction to these topics.

In the transformation of an office, sensory perception plays an important role. The perception of old buildings usually does not match the perception needed for a new function. To fully incorporate sensory perception in the transformation process, a design tool was developed that is presented in the ‘Leuker dan Leegstand’ report, together with an introduction to sensory design.

A study into the background of the vacancy issue shows that municipalities play an important role in the vacancy problem. In the Netherlands, the issue has been studied in five Dutch cities with different characters. The issue and the municipal policy were taken as the bases to paint a picture of the vacancies. This study shows that the vacancy problem in the cities does not depend on the size of the city, but is mainly a result of municipal policies. In cases where municipalities put emphasis on large office locations in the past, the problems are relatively significant. Larger municipalities have more policy documents relating to the problem, whereas smaller municipalities sometimes do not even acknowledge the problem. Offices have a specific structure. The study examined the origins of office buildings and divided them into categories, so that in future research, it can be quickly determined what type of building the concerned office building is. The different types of offices were divided according to place, space and usage. Some examples of these office types are: cubicles; group offices; open plan offices; the so-called convent office; etc.

Trends are related to changes in society. These changes affect the built environment. The trends discussed are general trends stemming from demographic, economic, socio-cultural, spatial and administrative trends. In addition to these, programmatic trends are described, such as: urban farming, a growing creative industry, the vital care for the elderly, student housing and flexible workplaces. These trends are transformed into a programme that can serve as a reference for the new utilisation of an unoccupied office building.

In order to give unoccupied offices a new function, they will have to be transformed. Multiple strategies exist for bringing about a successful transformation. These approaches vary considerably and one is not per se better than the other. The strategies may have different perspectives. From an architectural perspective, for example, transformation can be addressed on the basis of eight rhetorical figures or on the basis of a study into perception value and conservation. From the constructional perspective, the transformation principles have been divided into three principles: old carries new, new carries old or new is constructed next to old.

In addition to all these aspects directly related to the new utilisation of an unoccupied office building, emphasis is put on the sensory perception of a space. This approach has been chosen, because it is an often forgotten aspect. Many architectural designers focus mainly on the visual joy in vacancy.
perception of a space. The sensory perception of a space or building is however determined by the perceptions of all senses: sight; hearing; smell; and touch.

Eleven case studies were conducted with regard to relevant buildings and for five of these, a sensory analysis was carried out. These buildings were considered relevant when they responded specifically to a current trend or had undergone a transformation, or when the new utilisation of an office building was concerned. Furthermore, the case studies were chosen in such a way that the broadest possible range was created that can serve as a reference, motivation or an inspiration for individual students.

After this, an extensive analytical model was set up for every sense on the basis of a survey. This survey consists of many terms that are antonyms. Together, the terms express a perception value for the perception of a particular sense in a chosen space. By combining the analyses of the different senses, a perception profile for one space is created. This perception profile is depicted in the form of sliders. On both sides of the sliders are contrasting concepts. Every sense has its own colour in the slider and the perception can be read from the place of the colour in the slider. The complete profile forms the ‘DNA’ of the space. An example of a perception profile can be seen in the above illustration.

Later, this analysis was reversed and it was tested if it could also be used as a design tool. This was tested during a workshop for 100 bachelor students. First, the desired perception per sense was determined for a space with a predetermined function. Subsequently, the design was analysed from the perspective of each sense. This resulted in a successful day. Students indicated that especially materialisation and interior decorating were looked at in a different way in relation to architectural design. The research served as a basis for initiating projects in which vacancy problems were dealt with in a clever way. To clarify this, two projects will be considered in more detail.

The first project, conceived by Sjoerd Raaijmakers, approaches the vacancy problem from the problem itself and tries to find a generic solution for it. Current social developments such as the changing nature of work, sustainability and communal living form the basis for a search for the architect’s role in transforming unoccupied office buildings. It turns out that the architect needs to design a system in which the community itself is part of the transformation process. This system is called Interplay.

The second project, conceived by Maaike Krijnen, deals with the problem in a specific location, a business park on the edge of the city centre of Breda. In this project, sensory design is the most important theme and it is discussed in more detail by choosing to design for the target group of the visually impaired. Contemporary architecture revolves around the visual aspect and by not making this the most important thing and by designing on the basis of perception profiles, an attempt was made to stimulate the other senses in the same way. This resulted in a perception route, allowing people with visual impairments, but also the ‘sighted people’, to go on holiday in the city.

Sjoerd Raaijmakers and Maaike Krijnen

References
This project aims to find a role for architects with regard to the vacancy problems. This role needs to be based on current social developments. A study was carried out into three current themes: changes in the nature of work; sustainability and communal living and working. After this, the conclusions drawn from these studies regarding the role of the architect were bundled and translated spatially. This design is a generic system that can be applied to an office building and has the name ‘Samen Spel’. On the basis of an example in Amsterdam Nieuw-West, it is shown how the transformation process of an unoccupied office building into a future-proof building for a living and working community can be carried out according to this system.

changes in the nature of work
The demand for offices has fallen sharply in recent years, partly due to the changes in the nature of work. Because of recent developments in terms of communication technologies and the free exchange of information, people are less bound to an office environment. As a result, the number of self-employed entrepreneurs and homeworkers is on the increase. More and more work is being done at home. The modernist ideal of separating living and working is on its way out. Self-employed entrepreneurs and homeworkers allow working hours and spare time to merge and draw up their own daily schedule. The type of business itself is a solitary one, but freelancers compensate for this by meeting in collective buildings for freelancers. Because of this, the benefits of working at home are lost. A small-scale solution for this is the development of living and working buildings for freelancers.

sustainability
Sustainability is the second theme that relates to the role of the architect in ‘interplay’. The longing of society for a smaller-scale structure shines a different light on these issues. The English conservative philosopher Roger Scruton states in his book ‘Green Philosophy’ that rooting an individual in the local community brings with it a sense of responsibility for his immediate surroundings. The architect can play a role in binding a community to its surroundings, making it love its home. He (the architect) needs to design a solution in which the community itself becomes part of the transformation process. By putting an effort into the place they live in together, people are bound to the place and each other. Ikea has been using this
The design of the game elements is based on the ease of assembling and on attaching the user to his element.

strategy for years. It does this, however, to bind customers to the company.

a community
The last theme focuses on the role of the architect in designing a properly functioning community. For this, a monastic community, the Sint Willibrordsabdij in Doetinchem, and a modern community, community De Papenhuist in Den Bosch, have been examined on the aspects of closeness and regulation. The closeness of a community turns out to be of great importance. An architect should help to establish a community in which lines of communication between the members are short. In this way, problems can be resolved earlier. It is also important that the community itself is involved in drafting the rules that contribute to its functioning. In order for people to be bound to these rules, the rules need to belong to the community. The architect therefore designs a framework that allows the community to set its own rules regarding the use of the building.

a system
The conclusions drawn from the different studies are eventually merged into a system: a generic system allowing for
The communal transformation of unoccupied office buildings. The role of the architect lies in designing this system. This system should bring self-employed entrepreneurs and homeworkers together, accommodate the work they want to carry out in the building and must separate living and working. In addition, it should transform an office space into an environment to which users want to bind themselves. The community therefore has to become part of the system and has to be able to adapt it. The architect may design it, but the residents need to be involved in the implementation and regulation of the system. The design is after all intended to contribute to a close community.

‘Samen Spel’ uses a game approach to identify the roles of the architect and the community in the transformation process. It consists of four basic components: game elements, the game board, the game rules and the game tactics. The game elements in ‘Samen Spel’ represent the generic spatial modules that users themselves can place in the building. The community itself can also construct these elements. It could be a wall or a module with, for example, a bedroom. The community, however, cannot place these elements everywhere in the building.

The architect can impose his expertise by means of the game board. This consists of the changes made to the office that are specific to that office and for which expertise is required that the community does not have. The specific design of the game board allows for a generic solution in combination with the game elements to be built by the community. The game elements should be fixed to the grid of the game board in order to realise a physical separation between private and public spaces. In such a way, the architect can influence the layout of the spaces.

This he can also do by means of the game rules. These are written rules that determine how the game elements should be placed on the game board. By laying down as few rules as possible, the community is given more space for the formulation of its own rules regarding the placement of elements. The ways in which the elements are actually placed and will be altered in the future are the game tactics the residents apply. They can continue to make adjustments to the building in case of, for example, changes in family compositions. Hence, a future-proof usage of the building is ensured.
At first sight, it seems as though everything is experienced through the eyes, but when you close them, you will be aware that there are more senses. In determining the new function of an unoccupied office building and substation, sensory perception has been given an important role with the selection of a specific target group, that of the visually impaired.

The project location can be found at the Tramsingel in Breda. There, a business park is located between the railway tracks and the river Mark. In 2012, many offices in this location were unoccupied and a homeless shelter caused a lot of problems, even though the location is ideal, because the inner city and the central station are within walking distance of it. After first choosing an office building at Tramsingel 22, the area of the plan was extended to include the substation at Etnastraat 5. As opposed to the office building, it stands free in its surroundings. It also dates from a different period.

The office building at Tramsingel 22 was built in 1988. For a long time, it was home to a housing cooperation, but for some years now, the largest part of it has been unoccupied and it is deteriorating quickly. Because of the clear structure, the building offers the perfect opportunity for conversion into a hotel, which can be accessed through a circular hall in the design. The building provides an excellent opportunity to create rooms, because of its clear structure. This opportunity was seized by converting it into a hotel, which can be accessed through a circular hall.

The substation was built in 1955 and is located at Etnastraat 5. The building has many characteristic features, such as the engraved coat of arms of the city of Breda in the emergency lighting. In 2013, 75 % of the building will be unoccupied due to a complete renewal of the installations. This raises possibilities for smartening up this building with its glazed tiles.

Each blind or visually impaired person is a unique individual. They all have different eye diseases or conditions, which makes it impossible to design a perfect building for visually impaired people. There are, however, many practical applications that make daily life easier. The three focal points in this are: touch, contrast and accessibility. By means of touch, a direct link with the materialisation is provided. As regards the acoustics in the building, the materials chosen play an important role. By contrasting different sounds, visitors can better orientate themselves. In addition, the difference in acoustics explains a lot about the function of a space. It is therefore expedient to tile the bathroom and the restroom and to lay carpet in the rest of the hotel room.

Each function includes activities. At the hotel, for example, the following activities take place: reception, moving around, sleeping, washing, eating, having drinks and informing. The way in which a space will be perceived has been described per activity according to perception profiles. In addition to that, a list was made with structural elements that can be divided into areas of different sizes. These different areas are: intimate (0 - 0.45 m), personal...
(0.45 - 1.2 m), socially sensitive (1.2 - 3.0 m), public (3.0 - 7.0 m) and remote (7.0 m and more). From this, together with the perception profile, a conclusion follows in the form of a sketch with a keyword. This led to the architectural starting point on which the design was based.

the perception route
This design process resulted in the creation of a perception route along which different functions are located, such as the hotel, the perception garden, the hamam, the kwatta bar, the orchard and the dock. This route flows through the surroundings with its green nature and is therefore in line with the vision of Breda 2030. The vision states that Breda’s lobe structure, with its green branches, should be extended further into the city centre. De Mark is one of these green branches and with the orchard and the perception garden, it is provided with greenery that is not only intended for recreational purposes, but also has a function. The orchard, for example, will produce fruit that can be used in the kwatta bar. In the design, the route through all the surroundings is the primary route. The secondary route runs through the hotel, up to the roof, where a rooftop terrace with a bar is located. The tertiary route consists of the corridors on which the rooms are located. In the hamam, the spiral runs downward and literally and figuratively turns around the belly stone, on which the ritual takes place.

audible crossroads
It should be clear where a decision to change direction needs to be taken. By marking these places, they will stand out. The idea was to make them audible and to guide people through the surroundings by means of sound. A xylophone was used for setting reference sounds. The instrument has wooden or metallic bars that can be struck with mallets and because of the variation in the length of the bars, the tones differ. At a crossroads, the floorboard will be struck with a cane or stepped upon. The lasts planks of the floorboard before a crossroads will have a sound box underneath them and will be separated from the structure by letting them rest on ropes. Doing this allows the planks to resonate and, partly because of the sound box, results in a very different sound than that of the rest of the floorboard route. Because not all people with a visual handicap use a cane, a stream of water flows underneath the floorboards, which falls at a crossroads as a result of the difference in height. In the middle of the crossroads, it can be heard exactly on which side the water falls and thus where the route can be continued. The stream is connected to the greywater systems of the hotel and the hamam, but the underground fountains have their own pump at each crossroads to let the water fall in one particular rhythm. Underneath the crossroads near crowded places, such as on the streetside in front of the hamam, the pressure on the stream or the difference in height could be increased to amplify the sound. At half a metre into the route chosen, an engraving can be found on the railing with information on the things to do in that direction, in the same way the numbers of the platforms are nowadays engraved into the railings at train stations.
route of experience
In the mid-1970s, interest in industrial archaeology in the Netherlands grew. An example of this are the dozens of remaining abandoned brickyards in the country. As a result of the mechanisation of the production process and the growing competition that came with it, hundreds of clay brickyards in the Netherlands found themselves forced to close.

Partly due to the location of the remaining factories, in the floodplains of the rivers, it was often not economically interesting to demolish the building. The buildings were not in anyone’s way and thus remained vacant or were temporarily used for storage. Following the high water of 1993 and 1995, it became likely that these cultural and historical relics would disappear after all. The key planning decision (PKB) Room for the River was made to protect the Netherlands against a recurrence of such a situation. One of the problems identified by the PKB are the flood-free areas that used to serve as clay brickyards.

Reallocation projects are very different to new construction. In a reallocation project, old and new are brought together. The way in which this is done is based on the design approach, which is project dependent and determines the quality of the new design. At present, Heuff is no longer a complete brickyard ensemble. The identity of the factory, however, is ensured by the preservation of the kiln and the chimney. Because of its incompleteness, it is not suited for the likely new function of a museum. However, a function that responds to the identity of the brickyard is conceivable. A work and design atmosphere within the same theme of ceramics could react to this well with regard to its organisation and functioning. This way, a direct relation with the environment and the history is maintained.

### cultural heritage

After the closure of the brickyard Heuff in Vuren, it not only lost a large part of the buildings, but also its function. Because of this, necessary maintenance to the remaining complex became unprofitable during these 21 years and if there is no intervention in the future, deterioration will occur. Because time not always allows us to appreciate what will be appreciated in the future, it could be important to preserve the brick kiln. The cultural and historical analysis shows that Heuff plays a significant role in the description of the history of the Dutch brickworks. Many books were based on documents coming from Heuff’s archives. Now that developments are taking place towards the restructuring of the flood plains, it is all the more important for designers to respond to this.

### urban design

The landscape characteristics created by the brickworks needs some explanation. A location with several traces, from boreholes and clay pits to brick remnants in the near
surroundings is an incomplete image when the core is missing. The existing complex is merely part of a former complete ensemble, but it still tells the story of the location. With respect to the location, the building and the function, a reallocation would be a logical consequence. A unique view, offered from the kiln, over the river Waal and the landscape is an inspiring element in this.

**building technique**

In concrete terms, the Heuff building is in an exceptional structural state. Many projects in the inventory are subject to damage by moisture and natural vegetation. In this stage, neither of the two factors have caused any structural damage to the building that is worth mentioning. In the building, many shapes, components and materials can be found that can be reused, reprocessed or recycled. The wide range of possibilities in using the materials in such a way that they, at the same time, reflect the past, present and future, is a challenge in the design process. When looking at the dimensions and the layout of the building, the question is whether or not the kiln can be considered a building. Perhaps the structure could be best described as a brick machine. The repetition of the oven chambers with a width of three metres and an average depth of thirteen metres will influence the design approach. To what extent will technical building adjustments need to be made for creating a balance between functionality and the preservation of the identity?

**reallocation**

The starting point of the reallocation is giving Heuff back its place in the existing structure, a new identity not merely as a cultural monument or ruins, but as a functioning building that fits in with the modern day existence. It cannot be ignored that the brick industry was here for three centuries and a certain recognisability that has affinity with this ceramic industry needs to be reflected in the design and its function. The aim is to develop a common space that is open to the public and attracts people from the area with its appearance. To establish a centre, a creative breeding ground, where people from the region can make use of work spaces and studios. A location in which cooperation takes place between the ceramic industry, resulting in innovation in the field of qualitatively and aesthetically outstanding products. Giving the public insight into the innovations and possibilities of this century old and, at the same time, ultramodern material. In short, a location in which things are organised for the different regional segments.

By turning the former factory into a ceramics work centre and exhibition space for the newest technologies in the field of ceramics and architecture, the complex will develop with the times and could become valuable again.
design
To accommodate the functions of the requirements programme and in order to protect the kiln body against the elements, adding a new roof is necessary. Therefore, after the reallocation, Heuff will have two floors. It is desired to keep the work space and exhibition spaces separate. To make a distinction between exhibition and work spaces at Heuff, the choice was made to make a cut-out in the kiln body. By making this cut-out, a central work space is created, with the possibility of closed spaces on both sides, where the different sub-functions can be accommodated. With this intervention, it becomes possible to accommodate all work-related functions on the ground floor. On the outside, this intervention will not disturb the identity. The top floor will serve as an exhibition space. A void in the size of the cut-out makes the working process of the ceramic artist visible for the visitor at Heuff. The entire imaging of the process strengthens the eventual feeling for the ceramic product.

In the design, the addition of the ceramic roof is central. In its design, the architectural qualities of the former roof were used, that characterised Heuff from its early years until 1940. These characterising features, i.e. a double width and the symmetrical daylights, are included in the new design. To avoid repetition in various reallocation projects, the exact or partial reconstruction of the existing structure, an attempt is made to use a new approach through a free-form shell structure. Designing a radical shape with a material that does not seem to be suitable for that purpose: the site-specific bricks. This way, also thanks to the design of the ceramic work centre, the possibilities of this material are shown.

conclusion
Because of its anisotropic and liquid composition, brick is a very challenging choice with regard to architectural engineering, construction and execution. To be able to take on this challenge, a study was launched into the technical and physical building structure of the roof package along with the concerned structural behaviour that was analysed by means of a computer-based finite elements analysis. The complexity and the intensiveness of labour, which drive up the costs, are the main reasons behind the decrease in the realisation of complex structures in developed countries like the Netherlands. Semi-prefabrication of brick elements can save time at the building site. As opposed to the traditional formwork systems, in which every part needs to be custom made, the application of a pneumatic formwork in combination with the prefabricated elements was made possible and used for Heuff. This will not only reduce the execution time, but also save on materials. Combining all of this resulted in an ideal combination of cultural heritage, innovation and the functional use of space in a unique location in the floodplains.
Many people have an idyllic idea of the countryside, with farms spread over the landscape and agricultural activities alternating with nature. The countryside is described as being ‘beautiful’, ‘green’, ‘quiet’, ‘spacious’ and ‘free’. (The Netherlands Institute for Social Research, 2008)

Reality turns out to be more unruly; times have changed, even in the countryside. Farming businesses expand by establishing mega stables out of necessity. Other farms lose their agricultural function and become vacant or are made into dwellings. Unoccupied farms deteriorate and have a negative effect on the image and the quality of life in the countryside.

Monumental farms, with many authentic details, are able to preserve the memory of the agricultural past. But many non-monumental farms exist that are the example of the countryside dynamics. They have been renovated over and over again, the agricultural past slowly disappearing from them. These buildings, however, do have great potential; it is these buildings in which the current zeitgeist is reflected. These buildings are ideal for making a next step in the development and preparing the area for the future without losing the link with the now and the location.

The Hulsthoeve is one of these non-monumental buildings in the Brabant countryside. The building was constructed between 1868 and 1878 and has gone through many developments: changes related to a changing agricultural use, but also the transformation into a house. Especially after the latter, not much was left of the former farm. The entire existing Hulsthoeve has since been used as a residence and thus reflects the development that can now be seen in the countryside in its appearance. The building still refers to the long-fronted farmhouse, but it can be seen in all details that the building no longer has an agricultural function.

The Hulsthoeve is located in the Green Forest, a national landscape in the tri-city area of Tilburg, Den Bosch and Eindhoven. National landscapes are unique, characteristic landscapes designated by the Dutch State, in its policy document on spaces, to continue to develop socio-economically, while preserving or strengthening the core qualities (CBS, PBL, Wageningen UR, 2013). The regional council has elaborated on this in a development vision for the Green Forest, aimed at cooperation between the Green Forest and the three cities mentioned above. The task of the region lies in an increased showcasing and liveability of the qualities. The qualities of the city and the countryside can complement each other in a valuable way through cooperation.

The Hulsthoeve will be made into a holiday home with a congress/workshop space. These functions are in agreement with the development vision of the Green Forest and make the area more liveable. The congress/workshop space focusses on departments and teams of businesses from the cities looking for an external location for a brainstorming session or teambuilding activities. The reallocated building offers facilities for organising a presentation or meeting, but also features a large multifunctional space for, for example, yoga lessons or workshops. The activities at the Hulsthoeve can be alternated with activities at and around the information point that will be established in the old barn on the plot of the Hulsthoeve. It is possible to spend the night in sustainable hikers cabins in the associated fields.
Buildings without a monument status lack a valuation, making it unclear which parts need to be preserved during a reallocation. Research into the context, the history and the current state of the Hulsthoeve shows that especially the view from the street side is valuable in relation to the surroundings; the preservation of the view ensures that the new design maintains a link with the location. The research also shows that the characteristics of the current spaces do not match the qualities needed for the new functions and that the detailing and physical properties of the envelope are not in agreement with the current building regulations. This means that radical changes are necessary to guarantee a new future for the building.

The most original part of the Hulsthoeve will be turned into a vacation home, because the closed character offers the privacy desired for a residential function. This also counts when it concerns a temporary residence, as is the case with vacation homes. The space on the plot behind the house is a nice private outdoor space. A new volume is designed for the other half of the plot. The space is placed against the rear boundary of the plot and thus offers a view of the landscape and the river, ‘de Dommel’. A free space is created in the front of the plot, which is ideal for parking cars, making the new function better accessible.

The vacation home is housed in an indoor space behind the existing, closed view. At the back of the plot, there is a grand view of the landscape. A gradation is applied in the new design, allowing the user to decide, according to the weather conditions and own preference, to what extent he or she wants to be inside or outside. The part that is preserved will be connected to the new congress/workshop space by means of a covered outdoor space. Underneath this outdoor space, the walls of two old spaces, from which the roof is interrupted, are still present. The old indoor spaces are still enclosed by the original walls, but both the old roof and the new roof have been removed in some places to make these spaces into sheltered outdoor spaces. The garden is an enclosed outdoor area, because it is separated from the Dommeldal by an old garden wall. Yet, in several places, you can look over the wall to see the landscape of the Dommeldal. There, the Brabant landscape can be experienced in its purest form.

Where valuable, parts of the existing building have been preserved. They have been incorporated into the new design in a subtle way. New parts are built with materials from demolition projects. The new Hulsthoeve will be the showpiece of client A. van Liempd Sloopbedrijven and its subsidiary 2Life-Art. They want to demonstrate that demolition materials can be the raw materials for new buildings. In addition to the perception of the place, the reallocated Hulsthoeve will therefore also be a perception of the materials and details. How can more justice be done to the place and the existing building than by making it liveable in so many different ways and for a wide public in the future?
The vacancy rate is a current issue in the whole country, but there are many different farm typologies. Although the reallocation of every typology results in a number of specific challenges, the method developed for the valuation of the Hulsthoeve can serve as a case study for the valuation of other, non-monumental farms in the countryside.

references
In the search for more sustainable housing, passive houses play an important role. By means of thick insulation, airtight construction and a good solar orientation, the heating demand is reduced in winter. This strategy, however, is close to reaching its limits for two reasons. First, the effects of more insulation or a better airtightness are becoming smaller: in an uninsulated home, the heat demand can be halved by ten centimetres of insulation material, but in a home that is already insulated, ten extra centimetres only make a difference of a few percent at most. In addition to that, this way of building increasingly leads to overheating during summer. To take a real step forward in terms of energy saving, a radically different strategy to passive building has been examined: an adaptive façade. This is a façade that responds to changes in weather or the behaviour of occupants by opening or closing, by becoming thicker or thinner or by letting more or less heat through. The façade acts as an animal that starts exuviating, sweating or shivering in response to its surroundings.

The adaptivity is based on three physical properties: insulation value, solar gain and thermal mass. With regard to all three, it was examined when, why and how they should change. Research shows that the thermal mass does play a crucial role, but that it does not have to be adaptive. Solar gain and insulation do have to be adaptive and for insulation a distinction was made between the insulation of the windows and the insulation of the rest of the façade.

This idea was translated into a new prefab façade system, based on the Trombe wall. A Trombe wall is a heavy, thick and dark wall with a glass external layer, to catch solar heat. Because of its large mass, the collected heat gradually penetrates into the space behind it. There is no insulation in the wall, otherwise the heat would never be able to penetrate it. In the Netherlands however, a normal Trombe wall does not work well. This is because when the sun does not shine, the façade loses a lot of heat, due to not being insulated. Because of this, the adaptive façade is composed of Trombe elements with shutters. These shutters are placed in front of the façade when the sun does not shine, in order to keep out the cold.

The functioning of this Trombe wall has to do with the thermal mass of the wall. Because of this, the solar heat can directly penetrate the windows when the sun is shining and contribute to the indoor climate, while the sun shining on the façade is collected and will start to penetrate into the space a few hours later. In this way, the solar heat can be used for heating the house until about six hours after sundown. And especially in the hours after sundown (the evening), the heater in the house is turned on. The deceleration of this effect does not depend on the solar
strength, but can be determined by the right combination of the insulation value and the thermal mass of the wall. Because of this, it is possible to tailor the design to the expected usage by choosing the right wall thickness.

In addition to that, another change was made to the standard Trombe wall. In the new design, the space between the glass layer and the wall can be ventilated. In the summer, the wall can absorb heat from the space during the day. At night, the wall cools down from both sides: on the inside with the windows open and on the outside by opening the shutters and ventilating. This makes summer night ventilation extra effective.

The second element of the new façade system, the shutters, ensure extra insulation during the winter when it is dark outside, in addition to that they also function as sunblinds in the summer. Furthermore, the shutters, thanks to their reflecting surface, can ensure that light penetrates deeper into the space. To achieve this, they are folded up underneath the window. In short, the shutters provide both adaptive insulation and adaptive solar gain.

The moving shutters give the façade a dynamic look and thus make the house that has them more attractive. In addition to that, the added value of the shutters is in an increased sense of security, greater comfort and more privacy. This ensures that the wall does not only serves as a physical building feature, but also becomes a desirable object, also for those who do not have sustainability at the top of their list of priorities.

The façade elements are made of sustainable natural materials, such as wood and clay, combined with high-tech materials, such as biodegradable plastic composites, resol foam and phase change materials. The purpose of this façade is to save energy, which should lead to a more sustainable world. With this as a higher purpose, it is unthinkable to not take the environment into account in the choice of materials and details. As many materials as possible have the highest classification of the NIBE (the Dutch Institute for Building Biology and Ecology, which conducts research on sustainability in the built environment) and the façade has been designed in such a way that it can be dismantled to separate materials.

The effects of this façade on the indoor climate have been tested by means of simulations on a design for an annex to a house in Amsterdam made by the architecture agency Upfrnt. The design met the requirements of a passive house and had blinds to minimise overheating. In the simulations, the design as it was originally drawn was compared to the same building, but with the adaptive façade on the south and east side of the building. Thanks
to the adaptive façade, the heat demand of this house was reduced by as much as 40%. The comfort, measured as the percentage of people being dissatisfied (ppd, predicted percentage dissatisfied), significantly improved, because it was hardly ever too hot in summer.

To always place the shutters in the most comfortable and energy efficient position, an automatic control system with sensors was designed. The users can also, at any time, turn off the automatic setting and decide what happens. In combination with an understandable interface, this helps with regard to the acceptance of adaptive façades in houses. This shows that the idea has a potential in making energy-neutral building possible in a sustainable, comfortable and user-friendly way.

the principle on a sunny winter day
a. the sunbeam is collected between the glass and the wall
b. the wall slowly heats up
c. with a delay of about three hours, the heat penetrates into the space
d. the shutters are closed in the evening, but the warmth of the sun is still in the wall
e. after a couple of hours, the wall starts to cool down from the outside
North in the wind

jáchym van erning

At the moment, many buildings in the Netherlands are unoccupied, particularly office buildings. Solutions for this problem are being sought and a significant part of the work of the next generation of engineers and architects will consist of redevelopment projects. The Overhoeks Tower, directly opposite Amsterdam Central Station, is one of these unoccupied office buildings. Because of its massive concrete structure, the building deserves a new function. A new interior and a new façade ensure that the building again meets the high standards of today, while the iconic crown will get an extravagant replacement. The Overhoeks Tower is the former headquarters of Shell in Amsterdam. The tower stands on the very edge of the “Noord” district, right next to the ferry to the central station. The tower had been unoccupied since 2009, before it was sold in the summer of 2012 for use for a new purpose. The adjacent tourist attraction EYE draws flows of tourists to Noord. The Tolhuistuin, on the other side, is also well visited. A large flow of commuters in the direction of the city centre can be seen passing the tower. The Overhoeks Tower stands at the crossing of these routes.

Encounter

The design is focussed on combining these flows of people and will connect the different groups by allowing encounters to take place. Amsterdam Noord could become a greater attraction for tourists. In addition to that, residents of the city need to have a place in which to show themselves. In the latter case, the focus will be on artists, because this district has a serious lack of studios and exhibition spaces.

To put these groups in touch with each other, there will be a number of studios in the tower. Here, artists can rent their own or a shared space for a short or long period of time. To offer artists a direct possibility to exhibit their work, every studio will be connected to an exhibition space. The exhibition spaces form a route through the tower, from the ground floor up, that is accessible to visitors. When artists are open to it, they can open up the doors of the studio and give visitors a “glimpse behind the scenes”. Perhaps the latter can even contribute to the work to be done in the studio.

In order to better understand the way in which the Noord district functions and to experience its independent and quirky environment, one would have to be able to stay there for a longer period of time. For this reason, a hostel was added to the programme, which will be included in the mix of artists and tourists. This way, the artist cannot only invite exhibition visitors into his studio, but also open his space to the hotel guests. He can, for example, organise workshops and master classes, creating a free and open atmosphere.

In the hostel, the emphasis is also on encounters. Not just between guests and artists, but also between guests. The communal living room and kitchen are the most important spaces, because here, contacts can be made in a relaxed and informal way. Most activities take place here. Privacy is limited to the sleeping areas and sanitary facilities.

Wind

Another aspect of the modern building task is the responsible use of energy. New buildings are sometimes “energy-neutral” or generate energy. These new buildings offer plenty of space for this, while in redevelopment tasks, it is often more difficult to fit in. For the Overhoeks Tower, it was decided to increase visitors’ awareness of energy, in combination with the exhibition route through the tower. The impact of wind on a building is shown to the visitors. The power, dynamics and volatility of wind energy are made visible, tangible and audible. Although it is not continuous, the route will gradually lead upwards through the tower. With the increasing height, the intensity of the wind outside also increases. By using different interventions at different heights, the experience will be enhanced and the amount of wind will increase. Eventually, this crystallisation of wind energy results in a climax in the spot where it can be best experienced: on top of the tower, with your nose in the wind. Here, a space will be created that will be entirely defined by wind: the Wind-active Space.

Although the presence of wind is made visible on every floor, the attention is always first on the exhibited works of art. Only at the top, in the Wind-active Space, the wind demands full attention.

Wind-active space

The replacement of the crown on the Overhoeks Tower can be extravagant. When standing below, you will be excited by the odd shape and see that something is going on. But only on entering the pavilion, you get a close eye on what it is that is going on. Or do you?

The lift takes you up to the highest level of the tower. The last part to the pavilion requires taking the stairs. You feel the air getting fresher and you can already hear the wind blow. Beams creak, squeak, grind. You imagine yourself to be in a traditional windmill. At the top, you suddenly find yourself in a new exhibition space. You see part of the roof and the reason it squeaks and creaks: beams attached to a large hinge. But why do they move? Are they moving? The
part you can see is so small that you cannot really be sure. Maybe you’re daydreaming.

The second space, however, confirms your suspicions. This space is perpendicular to the last and the moving beams reveal a bit more of their full length. But now, the width of the space is limited and you can only see a couple of beams at the same time. How exactly this movement works is not entirely clear. And how do they move?

After this space, the curtain is finally pulled back and the pavilion shows its true form. Truss after truss after truss together span a space. Right? Are they trusses? They move... all of them. And meanwhile you can hear the wind. You almost forgot that you are standing in a space 75 metres above Amsterdam! Where is the view anyway...
The fabric between the trusses does provide daylight, but obscures the view.

Going onwards through this space, the view is finally there. The trusses will also move less as you approach the glass door. Is it a relief? Then why do you keep looking back...?

Outside, you will be granted a view of Amsterdam and you can sit down to have a cold glass of wine. Leaning backwards, you now become aware of a moving colossus above your head, coming closer quickly, it’s going to crash! And it takes off again. A flapping wing, and another one there. That’s how they do it. Quite the power, this wind. Better to continue this short walk up to see how this looks from the top.

Like Theo Jansen’s “strandbeesten” (beach animals), the pavilion crawls over the top of the tower. In an elementary way and with simple means, it is made clear what kind of power wind is. The flapping, striking motion of the wing shows, in a surprisingly simple way, how volatile the wind is and how strong and wild or how soft and hesitant it can be.

The beast on the tower, although it has a smaller habitat than Jansen’s animals, has such a large size, that it can be seen from the inside. Its ribs are the walls and ceilings of the pavilion. When the wind blows, the pavilion turns like a slow weather vane, the wings on top catching the wind energy. With this energy, the ribs are put in motion, up and down, up and down. Hypnotising. The harder the wind blows, the more overwhelming is the effect of the movement.

structural design
The Wind-active Space is an exotic structure that requires special attention. Many of the mechanisms needed to store the energy and to put the ribs in motion require specialist knowledge. The design of the installation is a specialised skill. To stay within the domain of the structural designer, the research and design was limited to the elements that are actually building components and not part of the installation.

First, it was checked whether the existing structure has enough capacity to carry the extra weight. Subsequently, the force distribution in the ribs of the Wind-active Space was mapped out and it was determined which dimensions are part of the design. By means of simplified calculations, it was shown that the required dimensions, sections and construction parts have sufficient capacity to make the building do what it does.

starting points
The intended use, the desired effect and the architectural image result in a large number of requirements. The pavilion should be a replacement of the old crown. This means that the shape of the pavilion need be a reference to this, when seen from street level or from a distance. Therefore, it, just like in the old situation, is kept separate from the roof of the tower, save for a core. The previous crown was merely a canopy, with little thickness. In the new situation, different spaces are placed in it, increasing the thickness of the whole. To keep the desired image, the volume does not end in a straight or round way, but always in sharp diagonals. This allows for some blurring of the actual height.

The moving parts are the elements that matter in this pavilion. The latticework of beams will portray the wind by means of undulation. This is best expressed when the latticework has a uniform shape, with matching beams and an equal distance between them. The latticework is, preferably, detached from other (structural) elements and has such slenderness, that it is still perceived to be latticework.

The perception of the movement that will run through this latticework is most evident when as many beams as possible are visible at the same time. For this, the biggest possible spaces are desired.

principle of the construction
On top of the tower, a new core will be constructed. The old core will be partially demolished and the square shape will be continued in a round one. This new round core will be the axis around which the pavilion can rotate. Only one floor is needed, which protrudes on all sides. The core is the only fulcrum. In addition to this, the desire for spaces that are as open as possible means that the aim is not to place any structural elements on the floor. Because of this, the structure is placed entirely on the underside of the floor. At the edges of the floor, the structure can of course be renewed.

At the top of the core, hinged trusses are constructed and powered. The trusses span between the end of the core and the extremity of the floor.
moving structural components

The roof and the façade of the Wind-active Space consist of a latticework of moving beams. This section is repeated, constantly changing in size and orientation, and, in this way, forms a space. The roof beam is moved up and down by the tensile bar, which is connected to a crankshaft. Between the beams, a sailcloth hangs, which has to have some play to be able to absorb the different movements of the adjacent beams.

The mechanical scheme of this structure is virtually identical to the schematic section. It is immediately apparent that the long roof beam is the supporting element, supported at its pivot point and by the diagonal draw bar at two thirds of the length. Thanks to the crankshaft, the roof beam makes a fluent up and down movement. Because of this movement, no abrupt loads are generated. Three static positions can be identified, from which the mechanism should be monitored:

1. roof beam with its tip at the maximum height
2. roof beam with its tip at the minimum height
3. horizontal roof beam

Checks are carried out at the place where the longest roof beam can be found. The difference in height between the tips of the roof beam, between the highest and lowest positions, is 1.5 metres. This distance was decided upon to make sure that the space underneath remains usable for people, without any danger, and that the effect is not so extreme that it becomes unpleasant.

The beams are made of wood and have a reasonable size. In a first design, the section is estimated to be 400x100 mm, homogeneous laminated wood, strength class GL32h. The cloth is a waterproof, but light transmitting tarpaulin. The tensile strength of the tarpaulin is not decisive. The hinged portals are evenly radially distributed starting from the core. The constant spacing ensures that the structure can be easily looked over, avoiding the blurring of the experience of the movement. The total volume consists of 60 of these trusses. The trusses are therefore rotated 360 / 60 = 6 degrees relative to each other. Not all parts move and not all parts are full trusses. In total, there are 35 moving trusses around the exhibition space and the restaurant.

In the design of the trusses, snow and wind have been taken into account on the basis of the longest truss in the three static positions. The external and internal wind pressure, both pressure and suction, have been introduced in all possible combinations. The envelope shown shows the most extreme occurring forces. It immediately becomes clear that pressure also occurs in the tensile bar, because the wind pushes the roof beam upwards. Tensile and compressive stresses also occur in the part of the roof beam that lies between the pivot point and the diagonal draw bar. In addition, large bending moments occur in the roof beam, at the spot where the hinge is connected to the tensile bar. This situation turns out to be the least favourable: external wind suction, positive internal wind pressure. This would be the case when the wind blows at right angles to the terrace with open terrace doors. This will result in overpressure inside and suction outside at the back of this truss. Since this situation is also very decisive compared to snow, the roof beam will be dimensioned according to it. After a new calculation, a section of 650x210 mm is set. In this case, the beam can withstand a maximum acting moment of 295
kNm with a simultaneous pressure force of 303 kN. The load is less on every other beam and smaller sectional dimensions suffice. Since the length of the roof beam is gradually shortened, a series of sections of a decreasing size is an option. If the beams are shortened at constant beam height, the changing relationship between the beams will eventually distort the image.

**effects on floor construction**

The truss bears most of the load via the roof beam and the tensile bar. The façade beam and the lower beam have been loosely suspended from the roof beam and therefore only transfer a fraction of the load to the floor latticework. Examining the reactive forces shows that there are four occurring forces, thanks to the different wind loads. They are all about 30 kN. The small force already gives it away, and a new check shows that the floor latticework can easily absorb this load.

**drive rod**

The next thing to be considered is the bar that was described as the tensile bar above. The analysis of the wind load showed that this was not a correct description, since pressure can also occur with certain wind loads. From now on, it will be called the drive rod, because this bar makes the truss move up and down. The trusses previously described define the space and need to show the undulation. The drive rod is present in a more subtle way. It is visible when one looks closely, but becomes nearly invisible in the overall picture. This is why the bars are not made of wood, but of steel. In the bar, pressure or tension of only 279 and 314 kN, respectively, occurs, but the buckling load in case of the normal pressure force is of course decisive. The bar is pivotally connected at both ends and therefore, the Euler buckling load may be used. From this follows a \( I = 2000.0 \times 10^4 \text{ mm}^4 \) with a selected profile of 160x160x10 mm. Here too, as for the profiles of the floor lattices, a square profile was chosen to make the connections easier and to limit the surface area exposed to corrosion.

It could also be noted that the bar does not necessarily have to be attached at the top and outer side, when the bar does not merely serve as a tensile bar. The reason for choosing to do so anyway is the desire to keep the inside space as free as possible from obstacles hindering the experience of the wind movement. Since this bar needs to make the truss move up and down, this movement will result in the occurrence of greater forces. Newton’s second law describes force as the product of mass times acceleration: \( F = m \times a \).

It immediately becomes clear that the force that will be exerted on the drive rod for the purpose of the undulation depends on the speed with at this takes place. The undulation cannot be transmitted through the pavilion too quickly: it needs to become a stimulating, but also pleasant space. This means once every ten seconds. The acceleration of the crankshaft will therefore, also given the limited distance it covers, be far below 1.0 m/s² and will more likely be about 0.01 m/s². Because the mass is equal to the largest occurring tensile force (in case of unfavourable wind) divided by the gravitational constant, it will never be more than 32 000 kg. The force needed to move the roof beam will be in the range of a few kilonewtons, which seems reasonable.
From the 1970s, many studies have been conducted on folded plate structures. These systems are based on the principle of increasing the structural height by introducing folds on a flat surface. The increased structural height in its turn results in an increased bending stiffness of the system. In current day construction, many different applications of this principle are known, just like variations of the system, like the Origami structures.

A new structural system can be developed when instead of folding over a straight line (as is the case for traditional folded plate structures), a curved folding line is introduced. Because of the curve in the fold line, curvatures in the (previously flat) elements are created.

The principle of ‘curved folding’ has, until now, only been the subject of study in design studies of artists, industrial designers and, to a lesser extent, architects. Practical applications of this folding principle can be found in the packing industry and the automobile industry, where curved fold lines in the coachwork allow for the achievement of the desired aesthetics and the introduction of curvatures and extra stiffness in the exterior of the vehicle. These studies and applications show the geometric potential and elegance of the principle of curved folding. This thesis, however, focusses on the investigation of the structural properties of the system and the possibilities for implementation on a building scale.

Two structural principles for curved folded plate structures can be distinguished: folded plate structures and shell structures. As mentioned above, folded plate structures get the desired stiffness by increasing the structural height by applying folds in straight (plate) elements. The stiffness of shell structures is achieved through the introduction of curvatures in the thin-walled shells, which also results in an increased structural height. It is therefore reasonable to assume that these two structural principles can be combined and will possibly reinforce each other with regard to the structural behaviour of curved folded plate structures.

A material that is well suited for this application is plywood. These timber plates are characterized by good strength and stiffness properties obtained by laminating thin layers of timber, leading to an almost homogeneous and orthotropic behaviour of the material. Besides that, timber has a good machinability and is a lightweight and also sustainable solution.

To understand the geometry that arises when a fold is made along a curved line, research was carried out to determine the influence of different parameters on the geometry of the most simple curved folded element: the basic element. This research was divided into a geometrical analysis based on a rigid bar model, which mimics the geometry of a basic folded element, and a mathematical approach.

For the geometrical research into the basic curved folded element, three main parameters can be distinguished: the shell shape factor ‘a’, which indicates the degree of curvature of the shells in the folded state (assuming the curve has a parabolic path), the fold shape factor ‘b’, which indicates the degree of curvature of the fold line in the unfolded state (assuming the curve has a parabolic path) and the angle between the two plates in the folded state (fig. 2). These three parameters affect each other directly. This means that when, for example, the curvature of the fold line (with fold shape factor ‘b’) and the angle between the two plates (angle) are known, it will be possible to determine the curve of the plates (with shell form factor ‘a’).

The rigid bar model consists of sixteen rigid bars that are jointed together in nine nodes (fig. 3). The connection in nodes 4-5-6 approximates the curved fold line. By rotating the bar model around the ‘fold line’ until the desired angle is reached, a mechanism is created in which the nodes approximate the corner and centre points of the curved folded plates in the folded state. The results obtained by the rigid bar model show that the curvature introduced in the plates due to the folding process is equal for both plates.

The mathematical analysis continues with the assumption that the curvatures of both plates in the basic curved folded element are identical. Based on this knowledge, mathematical definitions can be defined for the two shells. The definition of the fold line makes it possible to determine the intersection of the two shells, allowing for the calculation of the angle between the two plates, meeting the conditions set by the fold line. Both methods lead to similar results (with a difference smaller than 2%), leading to the conclusion that the approximation method with the rigid bar model is a good method to approximate the geometry of a basic curved
folded element. In addition, it follows from the research into the geometry of the basic curved folded element that a larger curvature of the fold introduces larger curvatures in the plates for equal angles of . This effect increases as the value for angle between the plates decreases.

structural analysis of the basic element
For the structural analysis of the basic element, the curved folded principle was translated into a possible structure for a building. This was done on the basis of structures consisting of connected basic elements, resulting in a structure of singly curved shells that are repeated from convex to concave. A coupling of six plates in total can be schematised like a structure. From this design, two extreme situations for the basic curved fold can be extracted: the 'wall-element' (vertically placed) and the 'roof element' (horizontally placed).

The structure is modelled as independent plates that are connected in the fold line by hinges. The influences which the adjacent elements in the structure exert on the single basic element were not taken into account. These influences depend to a great extent on the geometry of the desired structure, making them too variable to be properly estimated. Because these influences were not taken into account, a safe approximation of the element's capacity was obtained.

Numerical research into the structural properties of the basic curved folded element has assessed the influence of the three main parameters for different boundary conditions. The force-displacement relations, internal forces and deformations and fold curve forces are (among others) investigated at a constant load. In addition, the stability of the element in a displacement control calculation and the influence of different (realistic) load cases have been analyzed.

The results show a difference in performance for the wall and the roof element. In general, it can be concluded that a decrease in angle leads to a better performance of both basic elements. An increased curvature of the fold line (and thus an increased curvature of the plates) also leads to a better performance of the elements. The same element obtains, however, a much higher stiffness when used as a wall element than when used as a roof element. This is primarily because the roof element is deformed under a vertical load, in a 'less folded' shape, further decreasing the performance of the element. On the basis of the structural research into the curved folded basic element, a number of critical points can be distinguished with regard to curved folded systems.

1. Elements with a large angle between the plates
2. (Almost) horizontally placed (roof) elements
3. Elements with a large plate length

In the design of a curved folded plate structure, it is therefore necessary to pay attention to these points and to prevent that these critical points converge.

geometrical analysis of the curved folded system
A multiplication of the basic curved fold results in a curved folded system. The geometry of such systems depends on a large number of parameters. The main parameters of a curved folded basic element have been expanded with three parameters: the number of folds in the structure 'n', the length of the plates 'l' and the span of the structure 'L'. Just like the curvature of the plates ('a'), the curvature of the fold line ('b') and the angle between the plates ('ɑ'), also the angle between the plates ('ω'), the length of the plates ('l') and the span of the structure ('L') affect each other directly (fig. 4).

By subsequently connecting these systems, a smooth sinusoid path of the fold line is created. Extreme values
for all parameters eventually lead to a geometric error. This is the result of fold lines joining, which is impossible in practice. Transformations of the basic curved folded system lead to different base geometries. One of the examples of this is the creation of a wedge-shaped element in order to introduce the curvature in the floor plan. Combinations of these base geometries eventually result in freeform models.

structural analysis of the curved folded system
By means of numerical research, the effects of the two main parameters, that is angles $\alpha$ and shell shape factors 'a', on the structural properties are mapped for a system with 8 curved folds. The magnitude of the angles is expressed as the relation between angle $\alpha_1$ and angle $\alpha_2$. Again, the load-displacement behaviour under a constant load and the influence of the main parameters on the effect of realistic load cases on the structure is examined. These analyses make it possible to derive optima for the vertical and lateral stability, taking into account both the strength and stiffness requirements of the studied system. From this, it can be concluded that an increase in the curvature of the plates (shell shape factor ‘a’) results in an increase of the strength and stiffness of the system, even though this effect gradually decreases with regard to the lateral strength and stiffness. It is also apparent that the effects of the relation between the angles on the vertical stability are reversed compared to the lateral stiffness and stability. Since this study is based on timber plate material with a minimal weight, an optimum can be determined for a curved folded system with eight curved folds at $\alpha_1/\alpha_2=0.9$ and a shell shape factor ‘a’ of 0.5.

conclusions and recommendations
This research shows that the concept of curved folds can be applied to buildings. It shows many different variations in geometry and it has been translated into a structural system. From this, it can be concluded that the application of the concept of curved folds in the design of structures is feasible, taking into account the issues mentioned above. The concept is able to create many interesting geometries, while structural efficiency is achieved. Despite this, this thesis has only shown a small fraction of the possibilities of curved folded structures. A broadening of the conducted parameter study will provide more insight into the effects of the other parameters on the structural behaviour of the system. In addition, further numerical and experimental research is needed to enable a practical application of a curved folded structure in the future.

references
technology for innovating building practice
The last decades society has seen a paradigm shift in the way we deal with the environment due to the introduction of several international covenants and agreements. Where the Kyoto protocol already focused on the decoupling of (economic) growth and carbon, the recently adopted roadmap to a resource efficient Europe aims at decoupling growth from resource use (European commission, 2011). A novel method for reducing the amount of material used for structural components in a building is the use of structural optimization in the design process. Weight reductions of structural members cascade through the structural system, decreasing design loads on other structural members. However, current production methods and processes are not adequately equipped for producing elements whose shape is derived from a structural optimization analysis. The shape of structural elements, as we know it today, is mainly characterized by flat, rectangular uniform sections. This is not based on optimal structural efficiency, but mainly on the economic efficiency of rectangular, flat formwork that is commercially available (Cauberg et al. 2008). The best results thus far have been achieved with fabric formworks. These mechanically pre-stressed membranes transfer loads solely by linear tension, reducing the volume of the necessary formwork up to 1/300. Subsequently, transportation, storage, landfill and thus embodied energy is also reduced. However, the method can be complicated since often a large quantity of additional falsework is needed. Due to its nature to conform to funicular shapes, a production method based on inflatable membranes which can be partly or fully rigidized is believed to be a promising solution. In that case the formwork of the three-dimensional structure consists entirely of inflatables and is therefore completely based on form-active principles.

**rigidized inflatable structures**

**an innovative production method for structurally optimized elements**

joost van de koppel
stan van dijk

**structural optimization**

Structural optimization in an architectural context was first introduced by Lucien Schmidt in 1960 by applying an optimization process thus far only used in the automobile and aeronautical industry. Three types of optimization can be recognized; i) size, ii) shape and iii) topology (Rozvany, 2001). Topology optimization by means of empirical case studies was performed on section active structure systems to determine their general morphological features. The relation between structure and form, i.e. the structural morphology, of these optimized elements is very strong. The resulting topology and morphology of an optimization routine is determined by the force distribution through the design space and the different constraints and performance requirements that act on that specific design space. Since the morphology of an optimized one-bay beam can be recognized in every optimized section active structure system, and most of the general morphological features are reflected in an optimized beam, it served as a case for the proposed production method. This topologically optimized three dimensional beam was shape optimized using the ParaGen method (von Buelow, 2012). This method enables designers to explore parametric geometry based on performance aspects. A population of 1276 different solutions was created algorithmically, based on a highest specific stiffness fitness function. Ultimately, using FEM analysis, the most promising solution was size optimized resulting in the definitive case.

**fabric formwork**

The proposed production method uses an inner inflatable, or secondary mould, which serves as falsework and is either temporary or semi-permanent. Five inflatable
application of structural elements in a built structure

concrete scale model
structure typologies can be distinguished which can be used as falsework. These typologies, together with the optimized section active structure systems, were analysed according to four morphological indicators (Herzog, 1976). Hereby, the typologies and optimized elements could be assessed according to the same criteria, leading to the most promising combinations. For the optimized beam structure, the most suitable inflatable typology is the straight high pressure system. In all the cases, the falsework should be fabricated using PVC coated polyester mainly due to its high availability and low cost. On the outer surface of the falsework, tubes which can be partly or fully rigidized are inflated and represent the optimized structural element. Due to its superior properties, polymer composites were regarded as the most promising material for the rigidization of a membrane. Several different rigidizable materials for terrestrial and space applications exist. These materials can be classified as materials which are initially flexible to facilitate inflation, and can become rigid when exposed to an external influence (Cadogan et al. 2001). Based on ten criteria relevant to this research, and meetings with experts from the space industry, it can be concluded that no rigidizable material used for space applications is currently suited for a transfer to the construction industry. However, their main advantages, i.e. rigidization on command and rapid deployability, can be utilized when combining their structure with commercial manufacturing methods such as resin transfer moulding or vacuum infusion.

prototypes
In order to test the influence of the straight member computer models derived using the ParaGen method versus their curved member counterparts, twelve scale models were fabricated of four different geometries. The geometries represent either models with a high or low specific stiffness, low deflection or highest stiffness. Results of the five-point bending test of these models confirmed that the geometry chosen as the case for the production method possesses the highest stiffness. It also showed that certain geometries are disadvantageous with respect to curved members. These results combined with a full structural analysis were used to demonstrate the proposed production method in a full size prototype. The prototype was fabricated of braided glass fibre tubes which were inflated around an inflated PVC coated polyester tube. The glass fibre was finally impregnated with a polyester resin using hand lay-up, leaving the final rigidized optimized structure.

conclusion
With the fabrication of the prototype the proposed production method was demonstrated in full size. The method is a synthesis between the optimization of structural elements, and the optimization of fabric formwork. The main advantages are its extremely low self weight and rapid deployability, which can be increased when a rigidization method use in space can be utilized. The system can either be kept inflated or can be rigidized to make the...
structure independent of air pressure, increasing the possible applications of the method. Rigidized inflatables can for example be used for emergency relief, temporary structures, military applications, or for the reinforcement of existing structures. The secondary mould can be removed to leave a rigid structural element, but research still has to be done into the combination of a rigid optimized outer structure and inflated inner tube. In this case, the entire structure will act as a tensairity. Following the principle of combined action, the strength will be larger than the sum of the individual parts, rendering an extremely light weight, rapid deployable, high strength element.

references
Vernacular architecture is a category of architecture based on culture, climate and locally available construction materials. These mostly low-tech structures, have proven to be energy efficient and altogether sustainable. This style of architecture can be found all over the world, also in artic regions. In artic regions the materials ice and snow are abundant and inexpensive to manufacture. This gives it a high potential in construction, especially considering that transportation of other building materials to remote artic areas is very expensive. However, there are some limitations with using snow and ice; ice and snow are relatively weak and extremely brittle compared to conventional construction materials. Thereby ice usually shows a significant creep deformation over time. During WWII the principle of reinforced ice is developed. Reinforcement of ice can improve both mechanical and thermal properties. Adding a second material will not only change material properties but also change the building method.

The knowledge on both is rather limited, which hampered its application. Until now only small-scale laboratory experiments are done with reinforced ice. The goal of this master thesis is the development of a building method for the application of reinforced ice to stimulate the accessibility and broaden the applicability of large-scale reinforced ice constructions.

research method
The thesis is based on literature and experimental research. The literature research consists of three datasets. Dataset one material, is about research to plain ice and ice composites. Engineering requirements like structural, mechanical, thermal and optical properties are investigated. The second dataset is about the building method. Every different type of building methods are studied and analysed. The last dataset is about reinforced shotcrete. Through history reinforced shotcrete is studied in more detail compared to reinforced ice. Knowledge can be gained for the development of a building method with reinforced ice. The conclusions of these datasets form the preconditions for the cyclical process; an alternation of (re)design and experiments. It starts by verifying single variables out of literature and throughout this process the experiments grow in complexity to verify the design.
results

Ice can be reinforced by particles, fibres or structural materials. Until now ice reinforcement is rarely applied. Methods which do use reinforcement make use of macroscopic, prepositioned reinforcement. A homogenous distributed microscopic fibre reinforcement turns out to be the most effective for making large shell structures of ice. Natural cellulose reinforcement materials are preferred because of their low costs and availability in artic regions. Experiments at -20°C in a cold storage have shown that adding 10% of sawdust is the most effective cellulose reinforcement. This is done by bending and compressive tests.

As a base material the combination of water and snow, which forms a slush, is the most suitable. The snow has several functions: it lowers the temperature of the water which speeds up the freezing time and thereby increases the maximum layer thickness per spray session. Snow also serves as a natural emulsifier; by thickening the mixture of water, snow and wood fibre, the fibre reinforcement will be more homogenous distributed. The function of the water is to partially melt the snow to a more denser snow-ice.

The method of spraying / blowing is the most favourable technique to apply both base and reinforcement material. By using a pump, hose, nozzle and compressed air, the mixture can be sprayed onto a mould. By using an inflatable mould, shell structures of different forms can be made easily.

conclusions

During this research the building method of spraying a slush of water, snow and cellulose fibres was designed and tested. Pumping a slush causes problems. Any kind of narrowing in the hose or pressure applied on the slush, changes it into solid ice. In a revision of the design, the application of snow should be done separate from the water and fibres. Or the snow should be replaced by a non-compressible emulsifier. Further research is needed to test this revised method.
field experiment

During this research also the preparations for the first large scale reinforced ice field experiment were started, called the pykretedome project. The knowledge of this thesis will be put into practice by this record attempt to make world’s largest ice dome during the winter of 2013/2014.

The dome will be built by using an inflatable membrane bag. The bag is made of two flat circular foils with their edges welded together. The ideal dome shape will be determined by the rope cover that will be placed on top of the membrane. In this way the membrane bag doesn’t require a 3D cutting patron. By spraying thin layers of snow, water and wood fibre the mixture will freeze onto the membrane. When a dense and homogenous reinforced shell of about 1/100 of the total span is reached, the membrane bag can be deflated. In this way large spans of more than 30 meters could be possible with a relatively easy and fast construction method. The membrane bag and rope cover can be reused immediately after the shell is completed to build multiple domes in one winter season.
In the field of structural engineering, the material and cost efficiency of structural systems is currently receiving an increasing degree of attention. The focus is on reducing the ecological footprint and meeting the generally limited budget for a structural system. In order to achieve this, computational design- and calculation-methods are being developed that allow for complex parametric and iterative optimization possibilities. In this context, the lightweight structural systems called gridshells are increasingly applied.

Gridshells are a grid of beams in the shape of a free-formed, doubly-curved structural system. The form-active, fluent geometrical configuration of the gridshell significantly increases the load resistance of the system. Through their organic and form-active configuration, gridshells combine expressive architectural freedom with the ability to span large distances, making efficient use of materials.

By considering the gridshell's complex geometry and reactions to loading, its application and optimization in the current field of structural engineering can be placed in context. This context can be explained through a quote from E. Brown, who defined structural engineering as:

“The art of molding materials we do not really understand into shapes we cannot really analyze, so as to withstand forces we cannot really assess in such a way that the public does not really suspect” (Brown, 1967).

In this context, the efficiency optimization of the gridshell aims to simultaneously minimize costs and the use of materials and increase architectural freedom. This increased efficiency can be achieved through increased understanding of the gridshell's structural behavior. Pursuing this aim, the geometrical configuration of the gridshell is redefined to increase the efficiency towards a greater load resistance. Throughout the research, the most prominent methods used are: the Dynamic Relaxation method (Lewis, 2003), the Direct Stiffness method (Timoshenko and Goodier, 1951) and the Iterative Stiffness method.

**form-finding**

Because the complex configuration of a free-form gridshell is not directly definable, a form-finding approximation technique has been developed. Implementing the complex geometry of the gridshell and the close relation between its form and load, the gridshell is discretized into beams and nodes. This discretization of the system allows for the approximation of any complex geometrical form through iterative approximation. Because it also allows for a wide range of grid-configurations – such as triangular, square, hexagonal, or a combination of shapes – the freedom in architectural design is further increased. For the form-finding method, the Dynamic Relaxation method is applied.

The Dynamic Relaxation method can be defined as a numerical, discrete element method. The method is based on the Law of Conservation of Energy and Newton's Second Law. Through the combination of these laws, a relation between acceleration and force or energy is defined. Applying this method, an equilibrium of out-of-balance energy – and thus stability – of the system is aimed for. This aim is achieved by allowing translational and rotational deformation and displacement of the beams and nodes in the system. This approximation of an equilibrium by means of displacement forms the basis of both form-finding and optimization:

- form-finding: approximation of equilibrium between kinetic (displacement velocity) and potential energy (internal energy)
- optimization: minimization of the (internal-) potential energy or strain-energy

Converting the grid of beams into a flexible net of springs of a certain stiffness and equilibrium length, this net can be draped or projected over a geometrical form. Subsequently allowing the displacement of the nodes over the defined surface will lead to the springs in the system trying to attain their equilibrium length. By making all springs equally stiff, an evenly spaced grid can be designed, approximating a wide range of complex free-form shapes. Based on iterative approximation, the form-finding method provides a very flexible method of design. In addition, a fast definition of the system in any free-formed shape allows for various concept-studies of form or grid configurations.

**iterative stiffness method**

Allowing the validation of the structural design of gridshells, the described form-finding method is extended. In order to achieve this extension, an equally accessible and fast method of validation is developed. Defined in this paper as the Iterative Stiffness method, the functionality of the Dynamic Relaxation (form-finding) method is extended to include rotational stiffness.
this extension, the beam-stiffness matrices from the Direct Stiffness method are implemented. Through this combination of methods, element-forces in both statically indeterminable and determinable systems can be approached. The derived method can therefore be applied to structural systems ranging from relatively simple portals or trusses to complex geodesic domes and free-form gridshells. Furthermore, following iterative approximation, the Iterative Stiffness method implements geometrically non-linear and dynamic behavior. Through this implementation, the Iterative Stiffness method can be applied to a wide range of structural systems, significantly widening its scope.

**Optimization Efficiency**

By allowing the structural response under loading to be fed back into the Iterative Stiffness method, the efficiency of the gridshell can be iteratively optimized. A stepwise minimization of the strain energy in the gridshell is achieved through the deformation of its form and grid configuration. By approaching the most efficient configuration of the system through form-finding, pressure arches are formed. These arches convert bending moments to normal forces, decreasing the strain energy and with it the amount of material in the system.

For the definition of the optimization approach, two optimization methods are considered:

- Discrete thickness optimization: local mass redistribution through redistribution of material towards areas of high strain
- Reversibility method: global mass redistribution through reversal of the hanging structural configuration optimized towards self-weight resistance (as applied by A. Gaudi in his design of the Sagrada Familia (Crippa, 2010))

Through the combination of these methods, the gridshell’s geometric form configuration is iteratively deformed. A simultaneous redistribution of the grid configuration further increases structural efficiency. Because of the iterative approach of efficiency, the derived optimization technique shows clear similarities with the iterative form-finding technique previously described.

Deformation of the structural system towards a minimum of strain energy occurs both locally and globally. Although local deformation influences global deformation, and vice versa, their deformation directions towards strain energy minimization may differ. By increasing the accuracy of the optimization approximation, local and global deformation – and thus minimization of strain energy – are separated. Guide-curves are implemented to control deformation, guiding successive nodes into smooth curves from support to support (1). By establishing a fluent configuration of the gridshell, irregularities in grid configuration, and thus the flow of energy through the system, are avoided. Additional optimization control is achieved by setting a maximum displacement-distance for the grid from its initial form, i.e. guide-form control. By setting this deviation as a global or local variable, the deformation of the system can be influenced. Supporting both architectural and structural design, optimization deformation can be guided towards certain areas or shapes. Through this control, an optimized approximation of the initial architectural configuration of the gridshell is achieved.

Although guide-form control provides control over the optimized structural configuration, it also significantly restricts the approximation of efficiency. This restriction is depicted in which the optimized configuration of a gridshell restricted by guide-form and –curves respectively can be seen (2,3). The comparison of these configurations clearly shows the higher adaption and higher attained efficiency of the system controlled only by guide-curves. The possible restriction of the achieved efficiency must be taken into account in the final optimization of the gridshell (4). For increasing the efficiency of the gridshell, different load types and directions may be considered. Efficiency of the gridshell under varying loading direction is therefore approached through the scaled combination of the optima under separate directions. This scaling is performed by ratio of their influence on the strain energy. Through this combination, further insight into the gridshell’s reactions to loading is achieved.

Initially aiming towards maximum efficiency, the apparent significant deviation from the initially designed form – when controlled only by guide-curves – is provisionally
accepted. A subsequent optimization of the gridshell shows a significant increase of its overall structural efficiency. Examining the structural response of the gridshell during optimization leads to an increased understanding of its behavior under loading that can be used in guide-form controlled optimization.

applications
Combining structural validation with design freedom and control over the optimization of the gridshell, the Iterative Stiffness method may serve both architect and structural designer in the initial design and variant study of a gridshell. The method is defined as a parametric tool in Grasshopper – a generative modeling tool for Rhinoceros 3D – and combines 3D modeling and structural validation. Through this combination, complex geometrical configurations can be quickly assessed and/or altered. The method therefore allows fast variant studies of different form and grid configurations.

certainty
The application of the Iterative Stiffness method during the structural design of a gridshell significantly increases the achievable efficiency and saves materials and costs. The method is parametric and allows for quick and well-founded variant studies of geometry and composition for a wide range of structural systems. Combining esthetics with structural functionality, the derived method serves both architect and structural designer. Through this combination, the efficiency of the design and structural validation stages can also be increased, further saving development costs of the gridshell. Furthermore, through the accessibility of the optimization method, the complexity of gridshell design, calculation and optimization is reduced, stimulating the increased use of the gridshell in the field of structural design.

discussion
Because it allows for the highest degree of geometrical deviation from its initial configuration – and thus the highest increase in the structural efficiency of the gridshell – the use of the guide-curve controlled optimization approach, prior to the guide-form controlled approach and final optimization, is recommended. Although deviation from the architectural design of the gridshell is usually likely to be restricted, following this recommendation, a significant increase in insight into the structural behavior under loading can be obtained. Through this insight, the structural efficiency can be increased at an early stage of the gridshell’s design by combining the design and structural validation stages of the systems.

references
imposed deformations in steel fibre-reinforced concrete
the effects of cracking as a result of imposed deformations on
the load bearing capacity and stiffness of storey floors made of steel
fibre-reinforced concrete

jeroen hendriks

Steel fibre-reinforced concrete (SFRC) is an alternative
to reinforced concrete. Steel fibre-reinforced concrete
is a composite material consisting of a concrete matrix
containing randomly distributed steel fibres. It is made by
adding about 0.3 to 2 volume percentages to the concrete
mixture.

If steel fibres are added to normal strength concrete (up
to C60/65), it hardly effects the initial compression and
tensile strength of the plain concrete. The major advantage
of steel fibre reinforced concrete expresses itself when
the first cracks occur. In contrast to plain concrete is SFRC
capable to withstand a proportion or (when a high dosage
of steel fibre is applied) an even higher tensile stress.
This post cracking behaviour results in an ductile failure
behaviour and a large deformation capacity. The latter is
particularly beneficial for static indeterminate structures.

Steel fibre-reinforced concrete is currently mainly used
as industrial flooring, because of the good properties
with regard to liquid density. More and more research is
being done to explore the possibilities of steel fibre-
reinforced concrete as a (partial) replacement of traditional
reinforcement, which would lead to savings on labour
costs for, for example, braiding.

knowledge gaps
In 2011, a pilot project on steel fibre-reinforced concrete
was realised by a number of companies and the TU/e. The
pilot project consisted of casting and then testing of SFRC
casco bays, balconies attached to the casco and finally the
testing of a steel fibre reinforced concrete foundation slab
on punching shear. The results of this pilot project show
that there is a future for steel fibre-reinforced concrete in
cantilevered structures without traditional reinforcement.
Following these good results, the Dutch Civil Engineering Centre for Execution of Research and Regulation (CUR) decided to set up a committee: the Pre-adviscommissie Staalvezelbeton (Pre-advisory Committee for Steel Fibre-Reinforced concrete). This committee drew up a report (Preadvies Commissie Staalvezelbeton, 2012) to map the available knowledge and the knowledge gaps. This report concluded that there are many methods available to calculate the stress distribution in an structure and the capacity of the cross-section. Unknown is the effect of imposed deformations, the adverse influence of aggressive environments and the structural behaviour under fire conditions.

**numerical model**

If a crack occurs in a structure, the stiffness of the zone near de crack will decrease significantly compared to the uncracked sections of the structure. Because of this large difference in stiffness, the majority of the deformation will be concentrated in the local zone around the crack. Various models have are available to describe the local behaviour of a crack in plain concrete (but also in steel fibre-reinforced concrete). The two most frequently used models are Hillerborg’s Fictitious Crack Model (FCM) (Hillerborg, 1976) and Hordijk’s Multi-Layer Model (MLM) (Hordijk, 1991).

The Multi-Layer Model is the most suitable for this application because of its flexibility in changing properties per layer and it is easy to model in a spreadsheet program. The Multi-Layer Model was developed by Hordijk (1991) to examine the behaviour of plain concrete under a cyclic load. This model was also used by Kooiman (2000) to model steel fibre-reinforced concrete. The model is based on three basic principles:

- First the beam is divided into halves, which are connected by springs. The effective height of the cross section is divided into n number of layers and each springs represents the behaviour of a small layer.
- A linear strain/ displacement distribution is assumed over de height of the beam. By using the stress – deformation relationship of the springs, the deformation in each layer can be converted to a stress. When adding stresses of each layer the internal axial force can be computed. The internal bending moment can be found by multiplying the force in each layer with the corresponding lever arm.
- The third principle is an incremental procedure. In small steps the deformation at the bottom of the beam (CMOD) is increased and for each step equilibrium can be found by iteratively searching for an corresponding deformation at the top. The corresponding internal moment and deformation can be plotted of this step. By repeating the incremental steps, the load –CMOD diagram can be simulated.

The schematization is applied to a influence zone of which a length is assumed with a length equal to half of the height of the effective cross section. Using the stress - deformation relationship of the springs, the deformation of each layer can be translated into an corresponding stress. Kooiman (2000) used only one spring to model the behaviour steel fibre-reinforced concrete. In this thesis research, it was chosen to separate the behaviour of plain concrete and steel fibres, by treating them as two parallel springs. The main reason for this modification is the higher level of flexibility of changing only the behaviour of the fibres without effecting the plain concrete.

The plain concrete in compression was schematised by means of an elastic-plastic behaviour and the behaviour in tensile was schematised by means of a linear tensile branch and a softening branch. The steel fibres become active when the maximum tensile stress in the plain concrete is reached. The stress – deformation relationship of the steel fibres is derived from the results pull-out tests found in literature.
The effect on material level has been experimentally studied by performing wedge splitting tests. Notched specimens are subjected to bending by driving a wedge into the notch, until the desired crack width is achieved. Then the specimens are unloaded and half are subjected to compression and the other half of the specimens are load again with a bending moment.

The results of the crack specimens loaded in compression show a first part with a relative low stiffness. In this first part the steel fibres will take care of the compression stress. When deformation has reached a certain value, a tipping point is visible in the graph. From this point on, the plain concrete will take over the compression force from the steel fibres. The stiffness of this second part is almost equal to the young's modulus of the uncracked concrete in compression. The deformation at which this tipping point occurs is less than the initial crack width. The cracked surfaces don not fit neatly together anymore and the concrete takes over the compression from the steel fibres sooner.

As similar first path with low stiffness becomes visible when a cracked specimen is loaded in bending again. Furthermore the stiffness of this first part decreases when the initial crack width increases. The strength after completion of this first path, is equal to the uncracked tensile stress. So no reduction occurs in both compression and tension for a cracked section at the material level.

The wedge split tests that were carried out have been modelled numerically by means of the Multi-Layer Model mentioned above. Through inverse modelling, the input parameters were determined in such a way that the simulations best approximate the experimental values. In order to calculate the effects of an increasing initial crack, a factor $\alpha$ and $\beta$ were introduced, representing the decrease in stiffness of the run-up path in tension and compression, respectively. The factors are a linear function with the initial crack width as the only variable.

To examine the behaviour on the structural level, a combination of an tensile and bending test is conducted. First, the specimens were subjected to a centric tensile force and when the desired crack width was achieved, the tensile force was released and a 4-point bending test was carried out on the cracked cross-section. The development of the crack width over the height was measured by means of four measurement brackets. In order to predict where the crack would appear, dog bone shaped test pieces were made, which were then incised in the middle.

To be able to load the specimen like a beam, the specimen is connected to a steel frame on both sides, using glued steel plates. This steel frame creates a beam with a length of about 2.5 m on which the bending test can be performed. If a crack appears in the construction as a result of a prevented deformation, a certain 'residual tensile force' will be present in this crack. The magnitude of this residual stress depends on the stiffness of the crack; the stiffness of the uncracked floor parts and the stiffness of the structure to which the floor is connected. To examine the effects of the different stress levels, an initial crack width of 0.3 mm was used in the tensile and bending tests and the following percentages of the maximum tensile force were applied during the bending tests: 25% (about 12 kN); 45% (about 20 kN) and 75% (about 36 kN).

The fact that a percentage of the maximum tensile force needs to be maintained during the bending of the test piece requires that the tensile force be applied ‘in’ the beam, instead of from the ‘outside’ on the beam. As a result of the bending, the beam will rotate around the cracked cross-section. The line of action of the normal force, however, needs to be in the heart of the beam during the bending as well. If this is not the case, the eccentricity between the line of action of the normal force and the centre line of the beam will result in an extra bending moment in the cross-section. In order prevent this eccentricity, the hydraulic cylinders that provide the normal force are connected to the steel beam. This way, the cylinders rotate with the frame and the position of the line of action will remain level with the centre line of the beam.
Finally, a connection need to be made between the horizontal cylinder of the one frame and the support beam of the other frame. This connection must be able to initiate the normal force centrically, in the best possible way, but also must be able to rotate when a bending moment is present. To make this possible, the choice was made to attach a spherical bearing to the horizontal support beam. In this way, some imperfections of the test piece and/or the frame will be corrected and the whole structure can rotate while a force is present. The position of the spherical bearing’s pivot point was chosen in such a way that it is flush with the rotation point of the test piece (the incised cross-section).

During the 4-point bending test, the bottom hydraulic cylinders serve as supports and force is initiated by the upper two cylinders. The cylinders are operated by hydraulic hand pumps. The two horizontal cylinders, the bottom two vertical cylinders and the upper two vertical cylinders are connected in such a way that there is an equal oil pressure (and thus an equal force) in every pair.

results and conclusions
The results of both the experimental research and the numerical simulation are shown on page 144. On the primary vertical axis, the vertical deflection in the middle was plotted against the initial crack width. The orange line and points represent the deflection for a load of 4.0 kN of the numerical simulations and the experiments, respectively. From the results, it can be concluded that the vertical deflection of a structure without an initial crack is a little less than 1.0 mm and that this deflection increases to almost 4.0 mm in case of a 1.0 mm crack. Also noteworthy is that the results of the experiments are well approximated by the numerical model.

The green line and points represent the deformation under failure load. At this load, a greater increase in deflection can be seen, that is 1.5 mm without a crack up to 8.0 mm with an initial crack of 1.0 mm in the experiments. The numerical model shows an increase of 4.0 mm to 9.5 mm. It is also striking that under the failure load, the deformations of the experiments and the numerical model do not match as well as they do under a load of 4.0 kN. As mentioned above, this is probably due to the variation in the material properties of the test pieces.

On the secondary vertical axis, the maximum point load of the 4-point bending test is plotted. The failure load predicted by the numerical model decreases from 6.5 kN to 5.0 kN with a crack width of 1.0 mm. The results of the experiments vary, but also show a decrease of 6.0 kN to 5.0 kN. It can be concluded that the maximum load decreases by about 20% with an initial crack of 1.0 mm.

Material tests show that in both pressure and tensile, the same strength is achieved in a cracked cross-section as in the uncracked situation. Only the stiffness needed to achieve the maximum stress decreases as the initial crack increases. However, the failure load decreases
when a complete structure is considered, like in tensile and bending tests. The fact that although the strength on the material level does not decrease, the strength on the structural level does decrease, can be explained on the basis of the stress distribution in the cross-section with an increasing initial crack. Because of the weak run-up path of the steel fibres subjected to pressure or tensile stress in a crack cross-section, a relatively large part of the height around the neutral line is required before the maximum stress is obtained in the cross-section. Because the stiffness of this run-up path decreases as the initial crack width increases, the height needed before the full capacity of the steel fibres in tensile is reached and before the concrete takes on the compressive stress, increases.

This results in a lower compression and tension force in the cross-section and the shift of the neutral line. The combination of these two phenomena ensure that a lower internal moment, decreased by 10% and 20%, can be absorbed by the cross-section. In addition, a larger deformation over the height of the cross-section is needed to use the full capacity, resulting in a larger curvature. The decrease in moment capacity and the increase in curvature lead to a lower effective stiffness, respectively factor 2.5 (with an initial crack width of 0.5mm) and 4 (with an initial crack width of 1.0mm) and thus a greater deflection of the structure.

The results of the tensile and bending tests in which tensile force was present during the bending test show that the behaviour of a crack cross-section subjected to a combination of bending and normal force lies between elastic and plastic. With a normal force of 75%, the cracked steel fibre-reinforced concrete cross-section is still able to absorb 50% of the capacity it has when no normal force is present. Furthermore, a linear relation can be seen for normal forces between 0% and 75%. No single theory is available yet that properly distributes the normal force and bending across the cracked cross-section. It turns out to be impossible to maintain a stable crack width during tests with a normal force that is higher than 75% of the maximum tensile force. The crack steadily grows and it is not possible to carry out a bending test. Furthermore, it can be concluded that the proposed model, which is based on a linear decrease of both the strength and the stiffness, well approximates the results of the experimental research.

references
Computational analysis of climate change adaptation measures at the building and street scale focused on vegetative measures: case study for the city of Arnhem

Bart Merema

Scientific research shows that our climate is changing significantly (Wilby, 2007; Sanders and Phillipson, 2009). The average global temperature is expected to increase between 1.5° C and 4.5° C in 2100 compared to the last century (KNMI, 2006). Furthermore, there is an increased probability of very hot summers, which results in a greater risk of associated negative impacts. Cities are more vulnerable to this change in climate due to the high presence of low albedo surfaces and the lack of vegetation. As a result, increased heat stress can be experienced on hot and sunny days. During the 2003 heat wave in the Netherlands, heat stress caused approximately between 1400-2200 deaths (Garssen et al. 2005). To decrease heat stress, adaptive measures can be implemented: for example high albedo surfaces, water facilities and vegetative measures. Climate Proof Cities (CPC) is an extensive TNO-led research program in which Eindhoven University of Technology is a main participant. This program focuses on adaptive measures to reduce the vulnerability of the urban environment. One of the cities studied in the CPC program is Arnhem and in particular the J.P. van Muijlwijkstraat. The goal of the present study was a computational analysis of the effect of vegetative measures. More specifically, the intention was to explore the cooling effect of implementing vegetation in a complex urban environment. The computational analysis is based on Computational Fluid Dynamics (CFD) and is performed for the J.P. van Muijlwijkstraat (1).

Basic Effects of Vegetation

Vegetation has effects on both air flow and on air temperature. The mean air flow is affected by the form, drag and friction of the vegetation resulting in a lower wind velocity inside and behind the vegetation volume. Furthermore, momentum is extracted from the mean flow resulting in an additional loss of kinetic energy and conversion to turbulent kinetic energy. The cooling effect of vegetation is constituted by evaporation and transpiration. Evaporation is the transformation of liquid water to water vapour from wetted surfaces (leaves and stem parts) and transpiration refers to the transport through the leaf stomata. These two processes combined result in direct cooling and humidification of the air inside the vegetation volume and the near vicinity. In addition, vegetation (trees) also provides shading. For computational modeling of the air flow and cooling effect, sink and source terms were implemented in the governing equations, and this implementation was validated based on previously published experimental data.

Vegetative Measures

Examples of vegetation are green roofs, green façades and trees in the street. In previous research by Wong et al. (2003), the thermal benefits of rooftop gardens on the environment were studied. It was shown that the maximum temperature difference between a green roof and a situation without vegetation was at maximum 4.2° C. However, the cooling was limited by distance. In research by Alexandri and Jones (2008) a building street canyon was modeled with various configurations of vegetation. It was observed that the temperature decrease was quite significant for both surface and air temperatures, both inside the canyon and at roof level. Colder climates however, like the Dutch climate, benefit less of vegetation. In this moderate climate the average daytime decrease was between 1.7 - 2.1° C. Furthermore, the research showed that green walls have a stronger effect than green roofs when applied inside the canyon. In research by Dimoudi (2003) a 0.8° C reduction in ambient air temperature was found for a 10% increase in the ratio of green to built area.

Sink and Source Terms

To determine the influence of vegetation on air flow and heat transport in the present study, sink and source terms were implemented in the Reynolds-averaged Navier-Stokes equations supplemented with the realizable k-ε model (Shih et al. 1995): the momentum (ui), turbulent kinetic energy (k) and turbulent dissipation rate (ε) equations. The sink and source terms were based on literature information (Bruse and Fleer, 1998; Katul et al. 2004; Melesse Endalew et al. 2010). They were written in C++ source code and compiled as user defined functions into the CFD code. Evaporative cooling involves extensive equations with several unknown parameters, therefore either several assumptions needed to be made, or a simplified approach needed to be followed. In this study, a simplified approach was followed in which a fixed value for cooling was imposed (W/m²) for the vegetation volume, based on experimental data from the literature in combination with the leaf area density (LAD) given in m²/m³.

Validation Studies for Vegetation Air Flow and Determination of Cooling Power

Two validation studies were conducted. The first study dealt with a spruce canopy in which the vertical velocity and shear stress profiles were measured by Amiro (1989), and which were fairly accurately reproduced by the CFD model. The second study was used to determine the
cooling power of vegetation and was based on the study of Shashua-Bar et al. (2009). The cooling potential was found to have a value of 500 W/m³ for a LAD of 2.0 m²/m³ (i.e. 250 W/m³ for LAD = 1 m²/m³). As a consequence for the Arnhem case study for vegetation this fixed value was used for the trees, green roofs and façades to describe the cooling rate caused by transpiration.

**case study city of Arnhem: computational geometry and grid**

The street under study is the J.P. van Muijlwijkstraat in Arnhem (1,2). This street is chosen because of the geometry of the surrounding building rows (i.e. rather simple building blocks) and the location near the city centre where high temperatures can be experienced. The street contains a high share of stone materials such as asphalt and concrete that can absorb and store a large amount of heat. The length of the street is approximately 400 m and it is roughly west-east oriented. The street and its vicinity were modelled based on the actual geometry. A high-quality and high-resolution structured grid was made consisting of about 35 million hexahedral cells. For grid generation, the best practice guidelines by Franke et al. (2007), Tominaga et al. (2008), and van Hooff and Blocken (2010) were used. In the investigated area, the J.P. van Muijlwijkstraat and the nearest vicinity, a higher density of computational cells was applied compared to the rest of the domain. In this area the quality of the grid is of particular importance for an accurate prediction of the wind flow and heat transfer. The dimension of the complete computational domain was 1200 m x 950 m x 500 m (L x W x H) with a blockage ratio of 2.4 %. For the vegetation volumes special fluid zones were implemented which were needed to assign sink and source terms to these volumes.

**boundary conditions**

Boundary conditions were applied for a realistic worst-case scenario in terms of heat stress in the city. Data concerning solar radiation, air temperature, wind velocity and wind direction on a very warm day during a heat wave in the Netherlands (16 July 2003) were employed for the steady-state simulation. It should be noted that it was not the intention of the study to reproduce the inherently transient weather conditions on this day, but rather to evaluate the effects of vegetation under realistic steady-state boundary conditions. The weather data were derived from the meteorological station Deelen which is located five km north of Arnhem. Appropriate profiles of mean velocity (5.1 m/s at 10 m height), turbulent kinetic energy and turbulence dissipation rate were applied at the inlet of the computational domain, for east wind direction.

1. view of j.p. van muijlwijkstraat, arnhem
(aerodynamic roughness length of 0.5 m), along with corresponding parameters for roughness in the wall functions (Blocken et al. 2007). The inlet air temperature was 34.5°C. Mixed convection inside the domain was modelled with the Boussinesq approximation.

scenarios
In total, five scenarios were simulated to study the cooling effect of vegetation. Results of air temperature inside the street canyon were obtained at pedestrian level. In addition, selected vertical cross sections of locations in the street canyon were made to indicate the air temperature differences for the different scenarios compared to the current situation. The five scenarios were:
- current situation with small trees (crown starts at 4 m height up to 9 m height, LAD: 0.55 m²/m³)
- no vegetation
- scenario with a row of large trees in the street (crown starts at 4 m height with a height of 6 m, LAD: 0.55 m²/m³)
- scenario with green façades (LAD: 3.00 m²/m³)
- scenario with green roofs (LAD: 3.00 m²/m³)

results
The scenario with no vegetation results in the highest temperatures. Further, it is found that green roofs only provide a small amount of cooling within the street. Green façades can deliver cooling with a maximum of 0.8°C, where the average cooling is low. The highest amount of cooling is provided by the “new trees” scenario: on average 0.5°C and a maximum cooling of 1.6°C compared to the current situation.

To show the effect of vegetation on air temperature the results for vertical cross section nr. 3 are shown for the most promising scenario, which is the “new trees” scenario. Figure 4 shows the temperature difference in this scenario compared to the current situation. The location of the tree volume is indicated by the dashed rectangle. Note that cooling is experienced across the entire width of the street canyon. The lowest temperatures are found inside the tree volume with a maximum air temperature difference of 1.6°C cooler compared to the current situation. In the lower part of the street canyon at pedestrian level the air temperature is decreased by at least 0.6°C. On average the air temperature decrease inside the whole street canyon is 0.5°C compared to the current situation.

discussion and conclusion
The additional trees provided the largest cooling effect inside the street canyon. A single tree row provided cooling inside the street canyon with maximum and average air temperature decreases of 1.6°C and 0.5°C compared
to the current situation. The maximum cooling of 1.6°C is comparable with values of 1.7 - 2.1°C for cooling found in a study by Alexandri and Jones (2008). For façade greening and green roofs less cooling was found and only close to and within the vegetation volume. Furthermore, green roofs are not effective in cooling down the air temperatures at pedestrian level since most of their cooling effect is restricted to the roof level. Finally, already in the current situation some cooling is found for the trees present in the street and in front of the street. The air temperature decrease found for the current situation is on average 0.2°C and at maximum 0.5°C. The results are supported by those of previous studies: measurements by Shashua Bar et al. (2011) also indicated that trees are the most effective measure for cooling a courtyard. Furthermore, Srivanit and Hokao (2013) showed that for trees in an outdoor space more cooling at pedestrian level was found compared to green roofs, especially on summer days.

**recommendation**

The most effective adaptive vegetative measure which can be taken is implementing trees inside the street canyon. The case study showed that implementing a single tree row already decreased temperatures inside the whole street canyon. Other adaptive measures like façade greening and roof greening are substantially less effective measures. The cooling effect found with these measures was low and hardly noticeable inside the street canyon. Furthermore, for green roofs the cooling was only found near roof level and not inside the street canyon. This study has also some limitations, as it was only performed for a specific urban geometry and the vegetative measures were only applied in a single street. Further research should focus on evaluating the cooling potential in different urban geometries and for situations where vegetative measures are applied to a larger area within the city.

**references**


Numerical analysis of wind energy potential in the urban environment of Eindhoven

Argyrios Papadopoulos

Carbon dioxide emissions and global warming have become a major hazard to the public health and environment. A crucial factor in reducing carbon dioxide emissions is energy saving. Use of renewable energy sources is vital in the built environment, which accounts for one third of global energy demand. There has never been a better time to benefit from application of renewable energy systems. However, not all renewable energy sources are equally environmentally friendly. Wind energy achieves the lowest greenhouse gas impacts, along with the lowest air pollution impacts compared to other sources (van Bussel, 2011).

The Netherlands is a small densely populated industrial country with dense agriculture. Space is limited, which can be a disadvantage. Therefore, in-situ (urban) wind generated electricity is a promising solution to reduce grid energy reliance, where it is mostly needed. In order to achieve this, research on energy potential of various urban environments is required, which is the primary goal of this research.

On small scale, the characteristics of wind vary greatly and show only a few similarities to wind characteristics of large horizontal axis wind turbines in wind farms. Strong three-dimensional effects and flow separation on top and edges of a building characterise the wind flow over urban areas. The wind velocity varies significantly on the top of buildings compared to an open field. Wind power application in the urban environment demands a cautious micro-siting assessment, in order to prove a feasible solution (Mertens, 2003).

Wind resource assessment through simple national wind and regional maps of wind potential cannot provide quantitative data in dense urban environments for specific buildings. Moreover, wind resource evaluation by performing measurements is rather costly, time consuming and it can provide an analysis on the wind resource assessment only for a limited number of locations in the urban environment. Use of CFD in analysis of wind resource assessment proves to be a vastly valuable tool in a complex and large urban wind environment, such as the Eindhoven city center in this study.

The topic of this thesis is numerical analysis of the wind flow in order to determine wind energy harvesting potential in the urban environment of Eindhoven.

Simulations are performed to determine the effect of urban environment on wind flow with CFD. The numerical results are combined with meteorological data, statistically analysed, in order to determine the wind resource potential in Eindhoven city center.

Methodology

The study was conducted in several stages as follows: initial, core and concluding phases.

The initial phase involved literature study, focusing on wind energy systems, wind performance in the built environment, CFD practice guidelines and software manuals. One of the most valuable topics reviewed was the use of CFD to assess wind energy potential.

The core phase included the pre-processing, including familiarization with the software, in order to reach the milestone of generating a model of the city center of Eindhoven. This model was used at the process stage, in order to run CFD simulations, and later on, at the post-processing stage, to obtain and analyse data of the simulations.

The concluding phase of the project involved calculation of the wind energy potential using a combination of CFD results with meteorological data, determination of wind amplification factors, wind power and wind energy for the examined wind system configurations and eventually discussion on the results, recommendations for further research and concluding stages.

CFD Modelling

The city center of Eindhoven is chosen for the numerical analysis of wind flow in an urban environment, covering an area of about 5.1 km². The city is located in the North-Brabant province, in the south of the Netherlands, forming the fifth largest city of the Netherlands and the largest one in Brabant. It is characterized by a mixture of low-rise and a few high-rise buildings, commercial and residential, with open spaces such as squares, roads and parks. A visualization of the constructed model of the city center of Eindhoven is shown in figure 1.

The 3D steady Reynolds-Averaged Navier-Stokes (RANS) approach in combination with the realizable $k$-$\varepsilon$ turbulence model approach (Shih et al. 1995) is used in this study,
because they are considered to provide good agreement with full-scale measurements in urban environments and show good performance for wind flow around buildings (van Hooff and Blocken, 2010; Franke et al. 2004). The k-ε model adds the turbulent kinetic energy k and the turbulence dissipation rate ε equations to the RANS approach. The RANS approach is the most validated in CFD for urban aerodynamics and implementing the RANS approach reduces the computational time required for simulations, compared to Large Eddy Simulation (Tominaga et al. 2008; Franke et al. 2004). The complete list of the boundary conditions, computational settings and parameters is found in the master thesis (Papadopoulos, 2013).

The Ventec roof’s pre-constructed geometry is implemented in the generated Eindhoven city center model. The buildings selected for the assessment of the Ventec roof are the Admirant, Regent, Kennedy tower, Rabobank, Stadhuis and Vertigo TU/e.

A comparison analysis is performed on a wind turbine installation on the center of the rooftop of the high-rise buildings, with and without the Ventec roof system. It was decided not to adjust overhangs to the buildings and to allow one meter spacing between the building rooftop sides and the Ventec roof for fitting purposes, concerning the complexity of the model. Figure 2 depicts how the Ventec roof is adjusted at the building rooftop of the Kennedy tower.

For this study, it is decided to assess a specific VAWT (Vertical Axis Wind Turbine). This way, the boundary conditions for the comparison of the two cases are matching for both cases. For this purpose an H-Darrieus installation with a rated power of 1.7 kW is chosen, by taking into account dimensional constraints of the Ventec roof.

**wind resource estimation**

The main objective of this research was to estimate the wind energy potential in the city center of Eindhoven. This estimation is visualized in the form of wind resource maps. In order to achieve this, data from the CFD simulations are combined with meteorological data. Therefore, in this study three cases of wind energy potential are examined, based on calculated results for wind amplification factors:

- at 10 m and 20 m height above ground level
- at 4 m and 11 m height above rooftops of buildings exceeding 9 m height
- a comparative study at the high-rise buildings, where the Ventec roof is used

Height at 10 m above the ground is considered for the case that a micro wind turbine would be placed on top of a streetlight. Similarly to the MIT case study (Kalmikov et al. 2010), the performance of a freestanding wind turbine when placed at 20 m above the ground is assessed. The case at 4 m above the rooftop of a building is taken into account in order to place a turbine high enough to avoid low wind velocities and high turbulence close to the recirculation region. The reference velocity is taken at the center of height of the assessed turbine, which is 2 m; therefore, the top of the turbine is at 5 m above the rooftop (Mertens, 2003). It is noted that the mast height of a roof mounted wind turbines can vary, depending on each building. It is stated that a height of 11 m above the rooftop of a building is considered for checking how the influence of a building affects the wind flow above rooftops of buildings.
CFD simulations are combined with meteorological data, obtained by NPR 6097. A wind amplification factor is used to combine wind velocity amplification CFD results at the location of interest with meteorological data. This way the power density and energy potential are determined. The most significant milestone of this process was to generate wind resource maps showing the power density and energy potential above building rooftops of variable heights of buildings, combining results from different wind directions into one map. In order to achieve this, data points of where a turbine could be placed are taken at an equal distance of 10 m. The effect on the wind flow that each turbine would have on another, if a wind farm was allocated on the top of a building or above ground level is taken into consideration.

The following wind amplification factor has been determined.

\[ y = \frac{U_{\text{turb}(z)}}{U_{\text{inlet}(60m)}} \]

Equation 1

Here, \( U_{\text{turb}(z)} \) is wind velocity occurring at a certain height above the rooftop of a building or ground level and \( U_{\text{inlet}(60m)} \) is reference velocity at the inlet profile of the simulations at 60 m height.

Figure 3 presents how meteorological data are transformed into terrain related contribution and design related contribution to determine local urban wind statistics. The design related contribution is obtained by the CFD calculation, while the terrain related contribution in this study is obtained by NPR 6097.

The calculation algorithm used for generation of the wind resource maps is summarized in the following steps:

1. Wind velocity meteorological statistics are obtained for the three wind directions simulated.
2. Weibull parameters are determined.
3. Local wind velocity probability distribution is calculated for each data point.
4. Local power density is estimated for each data point.
5. Local energy estimation for a specific VAWT turbine is estimated for each data point.

Conclusions

For the determination of the wind energy potential in the urban environment of Eindhoven, the following conclusions are stated.

A limited wind resource is available at locations above the ground level in the urban environment of Eindhoven. The average wind power is 13 W/m² and 25 W/m² in the cases of 10 m and 20 m respectively, above the ground level. In addition to that, wind resource is limited above low-rise buildings. Buildings have a significant effect on the wind flow in the urban environment. The denser the urban geometry, the higher the reduction of wind velocity. High-rise buildings have an increased effect on the wind flow, reducing wind velocity at surrounding buildings located in their wake region.

There is an increased wind resource potential at specific building rooftops above 30 m. For these buildings, the wind power resource varies between 38 W/m² and 170 W/ m². The yearly energy potential, for the specific H-Darrieus wind turbine assessed, varies between 0.1 MWh to 0.8
MWh per year. The maximum output of the results is shown in the cases of the two tallest buildings in the urban environment of Eindhoven city center, the Admirant (105 m) and the Regent (96 m) buildings. For the case of 4 m above rooftop, the wind resource is depending on the position on building rooftops, while for the case of 11 m above the resource, the wind power resource is less direction dependent, with a 55% increase in resource potential compared to the 4 m case.

Wind resource potential is not only dependent on the height of the buildings, but is dependent on the location of the buildings and the surrounding buildings. Only with CFD, this dependency can be made clear for a large urban environment. There are cases, such as the Pullman hotel (36 m) and the high-rise buildings at Fellenoord-Eindje (30 m), which have a larger resource potential than buildings of 45 m height (Green tower).

Use of the Ventec roof on the top of high-rise buildings has a significant positive influence on the wind resource potential, increasing the power density up to 170% and the yearly energy potential up to 240%. The percentage change of wind resource is the highest for the case of the Rabobank building and the lowest for the Admirant building. However, even for the lowest percentage change, the increase of potential is 136% compared to the case at the same height above a flat roof.

**references**
The Netherlands has one of the world’s most crowded railway networks where many small platforms are located at the routes between the large stations. The intercity passenger trains only stop at the larger stations and are allowed to travel along the smaller stations with a maximum velocity of 140 km/h. Prorail, the company responsible for the maintenance of the railroads in the Netherlands, has the ambition for the near future to create a connection with six passenger trains instead of four passenger trains per hour between the larger cities, in order to cope with the increasing number of passengers. Beside these trains, different freight trains are forced to travel along the tracks in the period between two passenger trains. This makes the railway network even more crowded. A suggestion by Prorail to lead all trains into the right direction is to increase the maximum allowed running speed for freight trains from 80 to 100 km/h.

The movement of a train causes deformation of the surrounding air, creating aerodynamic effects. A compression wave is generated ahead of the train and an expansion wave is generated behind the train. Both waves can result in wind nuisance at a station platform when a train passes with high speed. The waves can easily be cleared by the surrounding air when a train moves through open air. However, when a train passes a tunnel, the waves are forced to flow into a certain direction.

Designing underground railroad stations becomes more and more popular from both a logistic and an aesthetic point of view. It provides new land on a central location, noise is being reduced and the separation of the city due to the railroad disappears. However, Gilbert et al. (2012) show that the wind velocities inside a tunnel, caused by the passage of a train, last for a longer period due to the so called ‘piston effect’. Experiments have been performed with a 1/25 scale model of a German ICE-2 train running along a track and wind velocities were measured during the period the train passes. Measurements have been performed at three positions besides the track in open air (1) and inside a tunnel (2). As seen in the results, the most critical wind velocities caused by the passage of a train are likely to be felt at a platform inside a tunnel, and the earlier mentioned waves can clearly be subdivided (2).

**validation study**

Computational Fluid Dynamics (CFD) is used in this study to analyze wind effects on pedestrian platforms caused by trains passing through a tunnel. CFD encompasses the generation of numerical solutions for flow problems. An advantage of CFD simulations is that they generate whole flow-field data of for instance wind velocities. However, verification and validation of the simulations are required in order to obtain accurate and reliable results. Therefore, in the present study, grid-sensitivity analyses are made and the results from the wind tunnel experiments performed by Gilbert et al. (2012) are used for CFD validation. Gilbert et al. (2012) describe and analyse train-induced air movements in a confined space. A scale model of a German ICE-2 train is travelling with a speed of 32 m/s through a tunnel, where wind velocities are measured at different positions inside the tunnel. The measured wind velocities at the first PRB (Cobra Probe head, black line in figure 2) have been used for comparison with the CFD results.
CFD calculation settings

CFD simulations based on the unsteady 3D Reynolds-averaged Navier-Stokes (RANS) equations supplemented have been performed with the realizable $k$-$\varepsilon$ model. The available best practice guidelines (Franke et al. 2007; Tominaga et al. 2008; Blocken and Gualtieri, 2012) have been used to reduce the errors and uncertainties during the CFD simulations. The guidelines are based on cross-comparison between CFD predictions and measurements. In addition to these guidelines, use is made of the sliding mesh method, in order to create relative movement between the tunnel and the train. For this method the domain has to be divided into two subdomains: a stationary domain, including the tunnel; and a moving domain, including the train.

The fairly complex round faces of the German ICE-2 train make it difficult to create a high-quality mesh of this moving domain. First, faces have been created, covering the volume of the train as precisely as possible. Afterwards, a meshed volume is created around the faces. Due to the complex geometry of the train it was not possible to use only hexahedral cells. Tetrahedral and prismatic cells have been used for the volumes with deviating geometries.

The complete list of calculation settings that have been used to give the best representation of the measured peak gusts in the experimental study is found in the master thesis (Straathof, 2013).

some specific observations
An advantage of CFD simulations is that whole flow-field data of for instance wind velocities can be generated, besides the wind velocity at one certain position. Two notable observations that could not be seen in the experiments are analyzed in this section.

Theory states that the expansion and compression waves increase in velocity as a train moves through a tunnel. The results of the CFD simulation are in line with the theory. The highest wind velocities inside the tunnel do not occur at the measurement spot, but at the entrance of the tunnel just after the nose of the train has passed. The compressed air ahead of the train gets partially cleared by the open air in front of the tunnel. This results in a wind flow through the tunnel in the direction of the opening with peak velocities higher than 35% of the speed of the train.

case study

Two situations that are likely to occur at a Dutch platform have been examined in the case study: one including a Dutch intercity train and one including a freight train. Both trains are travelling through a tunnel including a platform with their maximum allowed speed on the Dutch railroads, which is 140 km/h for the intercity train and 100 km/h for the freight train.

CFD calculation settings

A model of a fictive underground railroad platform has been created with use of the guidelines by Prorail (Prorail OVS00067, 2012). The guidelines are intended for platforms next to tracks where trains are allowed to travel with a maximum speed of 140 km/h. The width of the platform is determined by the width of each of its four zones: a safety zone; a walking zone; a waiting zone and a circulation zone. Each zone has its own minimum dimensions and all together the total width of the platform has to be at least 3.4 m.

The risk of wind danger caused by a passing train is not yet explicitly taken into account in these design guidelines. As an example: according to the guidelines by Prorail (Prorail OVS00067, 2012), people are allowed to walk at 0.8 m
away from the platform edge during the period a train passes with a speed of 140 km/h. For the case study the cross-sectional area of the tunnel has been copied from the tunnels that are currently under construction at Delft railway station.

Based on the simulated wind velocities at different spots on the platform it is assessed whether the wind climate on these locations is comfortable, uncomfortable or even dangerous. Summarized, the simplified criteria that have been taken into account are:

- 0 - 5 m/s = wind comfort
- 5 - 12 m/s = wind discomfort
- > 12 m/s = wind danger

results

When exploring the results it can be stated that no wind danger occurs during the period the freight train passes. Wind danger is seen just after the intercity train has passed the positions where the wind velocities are simulated. This is a result of an oscillation in the expansion wave behind the intercity train. This oscillation can best be seen when taking a closer look at the vortex development behind both trains. The development of the vortices behind both trains is shown by pathlines colored by the velocity magnitude at three different positions: ‘open field’, ‘tunnel’ and ‘platform’. The vortices behind the intercity train can be seen in the upper part of figure 3, whereas the vortices behind the freight train are seen below this figure. A horizontal cross section with pathlines colored by velocity magnitude is shown at a moment before the trains run into the tunnel. The two trains show completely different vortical structures, as drawn by the black lines in figure 3. Two standing vortices are generated behind the freight train with air flowing towards the rear of the train at the inner side of the vortices. The velocity magnitude of the vortices behind the freight train is higher in comparison to the vortices behind the intercity train, despite the lower moving velocity. Two helical shaped vortices are generated behind the intercity train and there is no clearly visible recirculation zone behind this train, resulting in a lower speed of the wind inside the vortices. This can be explained by the fact that the intercity train is more aerodynamically shaped in comparison to the containers of the freight train.

Figure 4 shows the vortices as the trains run through the tunnel before reaching the platform. It can clearly be seen that the velocity magnitude increases, especially for the intercity train, which is a result of the occurring piston effect.

Figure 5 shows the vortices as the trains reach the platform. It is seen that the velocity magnitude of the vortices is slightly reduced, though it is higher than in the open air. This can be explained by the increase in the cross-sectional area of the tunnel. The blockage ratio for both trains is lower at the platform in comparison to the blockage ratio inside the tunnel.

In figure 5 a horizontal/lateral deflection is seen in the expansion wave (dashed black arrows in figure 5) and, since this wave is stretched out due to the narrow tunnel, it causes high wind velocities at the platform. This deflection is caused by the air zone at the platform, where the static pressure is lower than behind the train. The expansion wave gets more or less sucked towards the platform. The vortices behind the freight train are much more attached to the rear of the train. Therefore, these vortices are less sensitive to the pressure differences aside from the train caused by the air zone at the platform. Consequently, no wave towards the platform is generated in this case.
conclusions
The present computational study based on CFD and validated with wind tunnel measurements has investigated the wind effects on railway platforms of trains passing through railway tunnels. Not everything has been investigated into detail and some assumptions have been made due to time constraints. Nevertheless, based on the results derived from the two cases, two general conclusions can be made:

- An intercity train, as is modeled in this study, generates two helical vortices in the expansion zone behind the train, which exhibit a lateral deflection as soon as the train reaches the platform. This deflection is caused by the pressure difference at the platform and results in a short dangerous wind gust at the entrance of the platform.

- A freight train, as modeled in this study, generates two standing vortices in the expansion zone behind the last wagon. The velocity magnitude of the vortices increases during the period the train runs through the tunnel. However, this wave stays straight behind the train and does not deflect sideways towards the platform. Therefore, no dangerous wind velocities are noticed during the period a freight train passes an underground railroad platform.

references
The European project “Climate for culture” (Cfc) investigates the impact of the threat of climate change on cultural heritage (Climate for culture, 2009). Climate change will result in an increase of air temperature and rainfall intensities for the Netherlands in winter (Klein Tank and Lenderink, 2009; Sluijter, 2011). Climate change also threatens cultural heritage (Sabbioni et al. 2009), which was investigated in the European project: Noah’s Ark: “Global Climate Change Impact on Built Heritage and Cultural Landscapes”. Not only the interior and the collection are important to preserve for future generations, but also monumental buildings themselves. Frost damage may disintegrate masonry.

Frost damage can be caused by several mechanisms to porous mechanisms including the increase in volume as a result of the phase change of water into ice (Scherer and Valenza, 2005). Three conditions must occur simultaneously (Hayen, 2008):

1. The temperature should be lower than the freezing point of water. The temperature doesn’t have to be exactly 0°C.
2. The material should be wet.
3. The material should be sensitive to frost.

Freezing in calcium silicate brick can happen when the moisture content is close to, or higher than capillary saturation (Sedlbauer and Künzel, 2000). The capillary saturation level in masonry can be reached after a long-term spell of rain. Frost damage occurs when the long-term rainfall is immediately followed by severe frost (Klugt, 1999), as excessive internal stresses arise (Scherer, 2006). Winters with these climatic circumstances are indicated as so-called “typical frost damage winters”. Examples of typical frost damage winters in the Netherlands are 1962/1963, 1978/1979 and 1981/1982 (Klugt, 1999).

In the Netherlands a method of testing for the bearing of frost damage exists under different air temperatures and moisture loads, which is described in NEN 2872 (1989) and the national assessment guideline, BRL 1007 (IKOB-BKB B.V., 2010). The aim of the freeze-thaw test is to examine if bricks are suitable for practical applications with appearance of high moisture loads (bricks for outdoor applications) or even extremely high moisture loads (bricks which are continuously in water).

coupled heat and moisture transport

This study shows that modeling of coupled heat, vapor and water transport is a method to predict the risk of frost damage. The heat and moisture transport is coupled because the transport is interdependent (Wit, 2009). The validity of the heat and moisture model has been proven by Benchmarks, verificated with similar studies (Schijndel, 2008). Heat and moisture flow rates should be calculated for porous bricks to determine temperatures and moisture contents in the material. For this purpose boundary conditions are necessary at the inside and outside boundary of the construction. Internal boundary conditions are assumed to be constant. The external boundary conditions are:

1. climate data of the KNMI for years 1971 to 2011. From these data typical frost damage winters could be determined.
2. climate data determined with REMO for climate scenario A1B for the years 1971 to 2011. REMO means Regional atmospheric Model. The weather data are compiled by Max Planck Institute.
3. future climate data from 2059 to 2099, also determined by REMO. The future outdoor climate scenario has been described by Huijbregts (2012).

From 2 and 3 should follow whether the risk for frost damage will increase or decrease.
The occurrence of frost damage has been tested with the heat and moisture model using four case studies. The following variants were examined: the composition of the construction, the orientation and the heat and moisture model.

In figure 1 calculated temperatures ($\theta$) and moisture contents ($w$) over the cross section of the construction are presented for a time on January 22, 1979.

Close to the outer surface of the construction a temperature ($\theta$) occurs which is lower than 0°C and simultaneously the moisture content ($w$) is higher than capillary saturation ($w_{cap}$). Under these conditions there is a probability of frost damage in brick. Frost damage arises mainly at the exterior surface of the construction. Temperatures ($\theta$) and moisture contents ($w$) that occur 1 mm below the outer surface of the construction for the months of January and February of 1979 are presented in figure 2.

Eleven times the conditions are as such that there is a chance for frost damage. The depth of the risk of frost damage seen from the external surface into the construction as a function of time is illustrated in figure 3.

Simulated are four case studies with climate data from the past to the present (KNMI and REMO) and with future climate data (REMO).

conclusions
The following conclusions can be drawn. Based on the results from simulations of the case studies with a heat and moisture model and climate data determined by REMO, it is expected that the risk of frost damage decreases by an order of magnitude of 70%. It follows from literature that a calcium silicate material is sensitive to frost. For the occurrence of frost, the temperature should be lower than the freezing point of water, while simultaneously the moisture content should be close to or higher than the capillary saturation. Frost damage occurs during an outdoor exposure where a prolonged rainy period is immediately followed by severe frost. Results of simulations of the case studies with KNMI climate data indicate the most risk for frost damage to occur during the winters 1978/1979 and 1981/1982. It follows from literature that these winters in reality, indeed have been observed as typical frost damage winters.

recommendations
Try to make a correlation between the depth where possible risk of frost damage can occur in brick and the outside air temperature and rain intensity just before the occurrence of frost damage.

The developed heat and moisture model can be used to investigate possible frost damage in other areas in Europe, so by applying other climate data research.
3. depth of the risk of frost damage seen from the outer surface into the construction for the months January and February of 1979

references


Underground buildings have been used in our civilization for thousands of years. Examples of this can be found in the town of Matmata in Tunisia or the Shianxi Province in northwestern China. This concept keeps attracting the attention of designers due to a variety of reasons. Underground buildings are pointed out as alternatives to conventional aboveground buildings for reducing the total energy requirements (Mumin, 2001; Wang and Liu, 2002; Barker, 1986), while alleviating land use and location problems (El-Hamid and Khair-El-Din, 1991; Carmody and Sterling, 1983; Godard, 2004; Admiraal, 2006). The energy performance of underground buildings with regard to heating and cooling demands is a function that concerns several aspects, such as building function (influencing internal heat gains and operation schedules), building materials, building size and shape and climate.

The energy performance of underground buildings was studied in the past using various techniques, but in spite of the large amount of research conducted in the past on the energy performance and heat loss to the ground of underground buildings, the results are not directly included in guidelines for development of underground facilities. In particular, there is no overview of the potential energy saving for heating and cooling in underground buildings when compared to aboveground buildings in a variety of climates and building functions, with uncertainties in building specifications.

This study provides a comparative analysis of the calculated annual energy demand of aboveground and underground buildings, aiming at the evaluation of energy saving potentials by the use of underground buildings. The uncertainty of input parameters is taken into account in the calculation and a sensitivity analysis is carried out.

**methodology**

The research procedure for the investigation involves three steps: pre-processing, calculation and post-processing. In the pre-processing stage, input parameters were defined, such as the internal gains, ventilation rate and conductivity of walls. Values for these parameters were obtained from literature and were processed into samples using Latin hypercube sampling (LHS). 200 configurations were tested for all 540 cases, which were defined based on combinations of building position (aboveground or underground), climate (fifteen different climates), building function (six functions considered) and building depth (three depths of buildings, as the underground temperature changes with the depth). In the calculation stage, the annual energy demand was calculated using the monthly method described in EN-ISO 13790 (EN-ISO 13790, 2008). In the post-processing stage, the annual energy demand and influence of the variable input parameters are analyzed using uncertainty and sensitivity analysis, respectively.

**results and discussion**

**annual energy demand comparison**

A preliminary analysis of the results shows that the differences in annual energy demand for different underground depths are relatively small (less than 15 kWh/m²y, and on average 2 kWh/m²y). Therefore this section only reports values calculated using temperatures at a depth of 10 m. Table 1 shows the average values of the annual energy demand (kWh/m²y) of underground buildings, the colors indicating the energy demand (white to red – small to large energy demand). Results show that a variety of the underground building cases have a low annual energy demand. Some cases in Table 1 present high values of annual energy demand but these values should be analyzed in comparison to the performance of aboveground buildings. This comparison is available in table 2, which shows the difference between aboveground and underground buildings, i.e. the reduction in energy demand when using the underground option. Table 2 is also colored according to the energy reduction, with white meaning no reduction, green indicating the reduction level and red marking cases with an increase in energy demand in the underground building when compared to the aboveground option. Results in table 2 show energy saving potential in all climates and in most building functions, with exceptions in building functions with high internal loads, such as education facilities and hospitals, in mild climates.

The low annual energy demand for these underground building cases, which can be seen in a large range of climates, is a result of the balancing of energy flows. Due to the building being underground, the transmission losses are stable throughout the year. This stable behavior cannot be found in the aboveground situation, where the behaviour varies due to the seasonal weather changes. Building functions with low internal gains, e.g. domestic and industrial, have a higher saving potential in warm climates, while building functions with high internal gains perform better in cold climates. Building functions with the highest energy reduction are: domestic, industrial
<table>
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1. average annual energy demand (kWh/m²y) of the underground building for various climates and building functions

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<th>Sport</th>
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2. difference between average annual energy demand (kWh/m²y) of the aboveground and underground buildings for various climates and building functions
and office, all with an average saving of around 70% in various climates. Other functions (educational, hospital and sport) have average savings between 25% and 40%. The saving potential is higher in severe mid-latitude and polar climates, with average savings around 66%. This is promising for the use of underground buildings in regions with around 10% of the global population. In the other climates (that are home to around 90% of the global population), the average reduction is around 42%.

heat balance analysis of a case with high energy saving potential

The balance of the energy losses and gains in each case defines whether a comfortable temperature can be maintained without any requirements for heating or cooling. An example of balancing energy flows is given in figure 3 for a domestic building in a moderate mid-latitude climate (Cfa). Figure 3 (B) shows the heating and cooling set point temperatures and the ground temperature for this case. The heating set-point and the ground temperature are almost identical, around 20°C, and this building function has small internal gains. Therefore, temperature variations in the building are minimal, transmission losses are negligible and the building requires relatively little energy for space conditioning (2 kWh/m²y). Figure 3 (A) shows the same sort of information for the aboveground building, where a fluctuation of around 13°C in the outside air temperature (AB temperature) is observed throughout the year. In this case, the difference between set-points and outdoor air temperature results in much higher transmission losses than in the underground building. In the summer, the transmission losses are combined with solar gains increasing the energy demand of these buildings in comparison to the underground option.

rationale of the energy balance of a building

Understanding the energy balance of a building is very important to comprehend the results and their relation
to different combinations of climates and functions. The rationale for the energy balance is that the annual energy need/demand of a building depends on the deviation from the interval between the heating and cooling set-point temperatures. The presented results show that, there are some underground building cases with a near-zero energy demand. The prime reason for this is that the underground temperature maintains a stable value within the set-point interval throughout the year. This suggests that no energy is required to keep the internal temperature at a comfortable level, unless the internal gains cause an imbalance. Therefore, the underground temperature is very important in achieving a high energy reduction. In contrast, the aboveground building is exposed to outside temperatures with larger daily and seasonal temperature fluctuations that deviate from the interval, requiring more energy to maintain a comfortable internal temperature. Furthermore, certain climates have underground temperatures that are below the heating set-point. Depending on the range of this deviation, extra energy for heating is required to maintain the comfortable internal temperature. In these cases it can be advantageous to have a building function with high internal gains that nullify large amounts of transmission losses to balance the equation. In hot climates (high underground temperatures), internal gains are therefore superfluous and would only increase the cooling demand. In contrast to cold climates, however, internal gains are useful to reduce the heating demand. A sports building function (high internal gains) is therefore inefficient in a warm climate, but efficient in a cold climate. For a domestic building function (low internal gains) the situation is reversed. These results were calculated without using hourly user schedules (such as for the temperature set-points and occupancy pattern) throughout the day. This may cause a day- and nighttime fluctuation that could influence the energy demand for a building in certain climates.
It can be concluded that the energy saving potential in the underground building depends mainly on a combination of two factors: climate and internal gains. The first factor determines the outdoor air temperature in aboveground buildings and the underground temperature in the ground. The second factor affects the match between underground temperature and heating and cooling set-points.

**sensitivity analysis**

By analyzing the influence of design and uncertainty parameters on the annual energy demand, strong correlations can be identified. This can be helpful to determine which level of design is required to attain the highest performance. Sensitivity analysis was carried out for all cases (climate and building function, aboveground and underground).

Comparison between the climates shows that the dominant parameters are different in each climate. E.g. it can be stated that in the tropical climate, the internal gains indicate a very strong positive correlation to the annual energy demand of aboveground and underground buildings, while in the polar climate, the internal gains correspond to a negative correlation for both aboveground and underground buildings. This indicates that the parameters and direction of the sensitivity of each parameter changes depending on climate and building function. With regard to differences between underground and aboveground buildings, it can be observed that sensitivity has a similar direction and magnitude in both cases (except for parameters that are not applicable to underground buildings). Considering that the sensitivity in underground and aboveground buildings is quite similar, it seems fair to assume that results of existing studies on sensitivity of aboveground buildings can also be adopted for underground buildings if necessary.

**conclusions**

The energy reduction potential of underground buildings has been investigated by making monthly calculations of the annual energy demand. A comparative analysis between aboveground and underground buildings was carried out for various climates, building functions and depths. A sensitivity analysis was made by analyzing variable input parameters and their correlation with the annual energy demand.

Underground buildings have the potential to reduce the energy demand in comparison to a conventional aboveground building, by making use of beneficial soil temperatures and large amounts of earth as insulation. However, the magnitude of this potential depends on the combination of various design elements, such as the balance between underground temperature and internal gains which is very important to achieve a high energy reduction.

The use of uncertainty analysis shows that in most cases, the worst underground building performs better than the best aboveground building. And the use of sensitivity analysis indicates that the same trends can be observed in aboveground and underground buildings, and that no single design parameter is dominant in all climates and functions.

Furthermore, it can be concluded that the depth and variable ground properties have no significant influence on the annual energy demand in underground buildings.

Future work shall focus on the use of more accurate hourly-based building energy models for energy calculation in cases with a high energy saving potential that have been identified in this study. Moreover, considerations regarding ventilation and daylight shall be included. The structure adopted in this study can be adopted for other performance aspects of underground buildings, enhancing our knowledge of the potential of underground buildings by using a more holistic approach.

**references**


Since the mid 1980s, within Eindhoven University of Technology’s (TU/e) field of competence “Physics of Monuments”, a lot of research has been performed on many different types of (historical) buildings. Non-optimal functioning HVAC-systems (Heating, Ventilation, Air Conditioning) and the associated high energy consumption in many museums nowadays, was a trigger for a follow-up PhD study to be started in 2012 (Schellen et al. 2011), elaborating on the recent PhD study of Marco Martens named ‘Climate risk assessment in museums’ (Martens, 2012). The Zeeuws Museum is one of the participating museums in this PhD study, which will investigate the possibilities of energy savings in Dutch museums with preservation of collections, building and comfort of visitors and staff. The museum stores over 30,000 treasures that recall the past of the province Zeeland. The collection includes valuable tapestries, paintings, porcelain, silver, jewelry, archaeological excavations, local traditional clothing, fossils and contemporary art. Besides the permanent collection, the museum also hosts temporary exhibitions on a regular basis.

Since 1972, the Zeeuws Museum is established in the abbey complex, which is located in the centre of Middelburg. After the bombardment of Middelburg during the Second World War, the abbey complex was restored. A part of the buildings has been completely rebuilt after the war. In recent years, several measures have been performed for improving thermal comfort and energy reduction. The museum has been reopened in 2007 after a perennial thorough renovation. Other than architectural work, new climate systems were also installed during this renovation, to inter alia create favorable climatic conditions for collection preservation.

A few months after installation it became apparent that the desired indoor air climate conditions, as described in the HVAC design specifications (Grontmij, 2005), could not be achieved by this extensive climate system, which includes a heat pump, an Aquifer Thermal Energy Storage system (ATES) and seven Air Handling Units. High-risk climate conditions for preservation of the museum collections were observed during the summer season and a lot of energy was consumed for climate conditioning. This type of HVAC system, however, with a heat pump for the supply of cooling and heating energy which is coupled with an ATES, should be fairly energy efficient. Meanwhile, a (large) imbalance in the ATES system arose, which, besides performance reduction, could result in financial penalties or retraction of system license. Earlier investigations and system adaptations did not lead to a solution for these problems.

The goal of this graduate research was to detect the causes of the problems mentioned above, and to find out if optimizations are possible which benefit the indoor climate, energy costs and balance of the ATES system.

The research
These research objectives are mainly achieved by the following activities:
- problem identification
- analyzing of building physics and HVAC-systems
- monitoring of indoor climate and processes in the HVAC-systems, making use of the measurements from the building management system and additional applied temperature and humidity measurement equipment
- implementation of computer simulations to gain insight in the efficiency of the cooling and dehumidification process by cooling coils and the impact of the relevant factors

Prior to this research, a preliminary study (Kersten, 2012) was performed to get insight in the designing of building climate systems which are coupled to an ATES system. Attention was paid to efficiency optimization and identification of the main causes for the poor performance of many existing ATES systems in the Netherlands (IF Technology, 2007; van Wijck, 2012).

Various shortcomings in the HVAC system have been discovered which cause the mentioned problems at the Zeeuws Museum. The observed high indoor relative humidities (1) are the result of deviations in the measurements of the control system, excessively chilled water temperatures and a drop of the indoor air temperature during the dehumidification process.

Short circuits in the capacity devices of most cooling coils were discovered, which result in small temperature differences between the supply and return of the chilled water flow. The combination of a low temperature returning chilled water flow and the relative high temperature in the cold well of the ATES system, ensures that the ATES system hardly contributes to the supply of ‘cold’ energy.

In fact, during cooling/dehumidification demand, both cooling power and energy which is generated by the heat pump is used for the supply of cooling energy. The energy generated by the heat pump is insufficient to supply all the cooling demand. The ATES system hardly contributes to the supply of ‘cold’ energy and the supply of cooling energy is limited by insufficient energy generated by the heat pump. This can result in an increased energy consumption for the supply of cooling energy, both due to the limited supply of energy from the ATES system and the high energy consumption of the heat pump.
The heat pump is partially lost to the ATES system. This was caused by a high groundwater temperature from the cold well, often even being higher than the returning chilled water temperature. The heat pump is not able to compensate this power loss, whereby excessively chilled water supply temperatures to the cooling coils result in relatively high humidities in the exhibition rooms and long operating times of the heat pump and ATES system.

The unusual high temperature in the cold well of the ATES system is partly caused by unwanted heat injection into the cold well during periods when the system operates in heating mode, which also increases the energy costs for heat generation.

Also a large imbalance between extracted water (and energy) from the cold and warm well of the ATES system causes unwanted warming of the cold well. This imbalance is mainly a result of the extraordinary long operation times in cooling (dehumidification) mode and the unwanted energy losses to the ATES system during cooling and heating mode. In addition, by unfavorable settings in the Building Management System, the heat pump and coupled ATES system are underused for heating the ground floor of the museum. A higher contribution of the heat pump and coupled ATES system during the heating season will lead to a benefit for the energy costs and the balance in the ATES system.

Furthermore, large fluctuations of air temperature and relative humidity in the active conditioned showcases were observed. This was the result of an improper system design, in which the supply air to the showcases is always equal to the (all air conditioned) exhibition rooms located on the second floor. A shutdown of the air exchange to the showcases (5 July) has already led to a significant improvement of the temperature and humidity conditions in the showcases, as can be seen in figure 2.

Before this measure the measured climate in showcase ‘Oost’ satisfies for only 32.7 % of the time the ASHRAE museum climate class ‘As’ (ASHRAE, 2011). The period at the right side of 5 July satisfies this climate class for 98.4 % of the time.

About 70 computer simulations were performed to determine the efficiency of the cooling and dehumidification process by cooling coils in different setups and with varying parameters. Variables are chilled water temperature, temperature and relative humidity set points, infiltration and ventilation rate, number of visitors, with or without preconditioning of the ventilation airflow and the possibility of little humidistatic heating during periods of dehumidification demand.

A basic building model as representation of a common museum exhibition room was used with a varying quality of envelope, in order to increase the general applicability of the simulation results. These simulation results also give an indication of the impact of several system variations and influence factors on the thermal balance in an ATES system (if applied). The simulations are carried out with the Heat, Air and Moisture model ‘HAMBASE’ (de Wit, 2006; van Schijndel, 2007) and the software package Matlab/Simulink (The Mathworks, 2012).
Based on the simulation results and actual performances, one can conclude that the dehumidification process at the Zeeuws Museum is very inefficient and strongly influenced the total energy costs of the museum. The excessively chilled water temperature results in increasing operating hours of the cooling system and the desired relative humidity level cannot be maintained. Besides lowering the chilled water temperature, the simulation results show that the efficiency of the dehumidification process (incl. reheating) could be significantly improved (50-80% energy reduction) by the application of an additional cooling coil which preconditions the ventilation airflow before it is mixed with the recirculating airflow from the exhibition zones (3). This additional coil in the ventilation airflow could also be used to regenerate the heat surplus in the ATES system during winter conditions by preheating the ventilation airflow with the groundwater from the warm well, and thereby reducing the energy costs for heat generation. In case of the Zeeuws Museum, most ventilation air is extracted from outdoor by the same Air Handling Unit, so only one extra coil in this unit would be implemented. The simulation results also demonstrate a significant impact of the indoor air temperature, during the dehumidification process, on the energy consumption and the dehumidification capacity of the climate system. Depending on the system setup and applied set-points for indoor temperature bandwidth, considerable energy savings could be achieved when during periods of dehumidification demands the indoor air temperature was slightly increased within the desired bandwidth. The potential energy savings are about the same as by making use of a pretreat cooling coil. In addition, the maximum desired relative humidity level could also be much better maintained.

In the case of the Zeeuws Museum, an air temperature drop of a number of degrees was measured during the dehumidification process (by the cooling coils). This temperature drop results in a significantly greater need for dehumidification energy and capacity to maintain the maximum permissible relative humidity level. The simulation results also provide insight in the effect of the varying parameters on the yearly balance between (re-)heating and cooling energy demand, which is useful when applying an ATES system.

The main technical causes of the poor museum climate, large imbalance in the ATES system and high energy consumption were found to be:

- short circuits in the chilled water network arising from the wrong selected capacity arrangement controls of cooling coils
- unwanted heat loss in the cold well of the ATES system during the heating season by a poorly controlled automatic three-way valve in the hydraulic system
- misalignment between cold generation and demand by the absence of a surge tank
- deviations in temperature measurements of the Building Management System and decreasing indoor air temperatures during the dehumidification process, resulting in increasing relative humidities
- a large imbalance in the ATES system, making causes reinforce each other
- insufficient utilization of ATES system and heat pump

2. measured air conditions in showcases 'Oost' and 'Zeeland' before and after the closing of the airducts at 5 July; Temperatures (upper graph), relative humidities (middle graph) and specific humidities (lower graph)
during the heating season caused by unfavorable set heating curves of heating supply systems
- The active conditioned showcases are conditioned (only) by the same air handling unit as the exhibition zones of another building level. These exhibition zones and showcases require various air supply conditions to compensate different disturbances and maintain the required air conditions.

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graduates 2012-2013

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ali afrasiabi architecture
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louis cobben architecture
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sander damen architecture
mattijs datema architecture
sean dierden architecture / structural design
cyriel van dongen architecture / structural design
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giel geurts architecture
bastiaan göttgens architecture / structural design
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thomas grievink architecture cum laude
lisanne havinga architecture
bart hellings architecture
eefje hendriks architecture / building technology cum laude
thomas henry architecture cum laude
kristel hermans architecture cum laude
bob l’ herminez architecture cum laude
peter honcoop architecture cum laude
erik hoogendam architecture
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jurjen van der horst architecture
jiazou hou architecture
kim van den hout architecture
nadine huids architecture
mart huijbers architecture
maykel van den hurk architecture cum laude
stephanie van den hurk architecture cum laude
velika iliev architecture cum laude
sanne inghels architecture cum laude
sven jansse architecture cum laude
ryanne janssen architecture cum laude
joël de jong architecture cum laude
karlijn de jong architecture cum laude
danny van kessel architecture cum laude
willeke klomp architecture
wilbert de koning architecture cum laude
maaike krijnen architecture
hanneke godfroij   building technology
rémy houben   building technology
frank janssen   building technology
joost van de koppel   building technology
bertold van der meijden   building technology
jos oosterlee   building technology
jeffrey van der putten   building technology
floris van rooijen   building technology
jan-willem schellekens   building technology
marieke steenbeeke   building technology
rick van veghel   building technology
boaz van der wal   building technology
thomas wijnands   building technology
ellen adolfs   urban design and planning
alke van den berg   urban design and planning
hylke broekema   urban design and planning
michiel cijsouw   urban design and planning
bart claassen   urban design and planning
wilma van delft   urban design and planning
justin elemans   urban design and planning
danny gijzen   urban design and planning
natasha henny holz amorim de sena   urban design and planning
wojtek klomp   urban design and planning
stijn kuipers   urban design and planning
timo largarde   urban design and planning
sharmilee mahadew   urban design and planning
koen van der meijden   urban design and planning
wietse van merode   urban design and planning
maura niessen   urban design and planning
jochem romkema   urban design and planning
onno saes   urban design and planning
gijs van der sman   urban design and planning
nanda sweres   urban design and planning
robin verstappen   urban design and planning
giesselink wolfs   urban design and planning
xin zhang   urban design and planning

building physics and services

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richard claessen   building physics
rinka van dommelen   building physics
chris van dronkelaar   building physics
roel huizinga   building physics
bram kersten   building physics
ke li   building physics
t klaasjan van der maas   building physics
marco maas   building physics
chris van der meijden   building physics
bart merema   building physics
argyrios papadopoulos   building physics
ruben pelzers   building physics
zhengjun qiao   building physics
joep richter   building physics

graduates

cum laude
pieter van de werdt
rick willems
judith wintraecken

real estate management and development
real estate management and development
real estate management and development

structural design

floor van den berg
sake bosma
maarten casteelen
roald damoiseaux
rianne dekker
joost van dun
jáchym van erning
koos fritzsche
rick de goeij
hein de groot
jeroen hendriks
jeroen koeken
stijn reijnjen
tom reiker
johan rensen
marco schmeitz
mark slotboom
harold spies
lianne tas
nikie van veen

structural design
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construction management and engineering

falco van den aker
mustapha akoudad
néné barry
ruud van beek
rudy van beurden
eleni bisseling
eva van bunningen
koen hemink
tim jansen
paul jochems
geert kanter
bertine korevaar
barry kroon
geert lamers
freek van lier

construction management and engineering
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graduates
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ANNEX
SAVING FOR ORDER
construction perspective drawing, made by (according to Arets) Peutz’s draftsman, of the burgerzaal in the townhall of Heerlen
The text *Striving for Order*, published in 1981, that Wiel Arets wrote as a student at Eindhoven University of Technology, shows his fascination for the work of architect Fritz Peutz. Besides his understanding of the oeuvre of Peutz, the content of the text explains as well what Arets himself aspires to achieve, and how his reading of Peutz’ representation of a striving for order puts into words a number of insights he will use in his own way of designing. Arets puts himself in Peutz’ position, a man with experience and vision, in order to be able to see further into the future of his own, possible practice. In his exploration of the historical path, leading to Peutz’ production, Arets seems to have been not so much interested in the complexity of the theory and history in which Peutz should be placed as such, but rather in a possible understanding of a core that he – Arets – wanted to perceive himself, as strongly as possible: an understanding of how this man – Peutz – affected him, in order to be able to learn from him. Plainly put, Arets’ curiosity boils down to the usefulness of Peutz’ work for himself.

Especially one specific discovery becomes programmatic from the moment Arets starts working as an architect. He explains this discovery in this text as:

“It is remarkable that when it came to developing designs he seldom made use of façade views, floor plans or models, but very early – as soon as pen was put to paper – had his draftsmen construct mathematical perspectives from various standpoints he would indicate. He then used these constructed perspectives of the interior and exterior in order to further develop the design. What is noteworthy here is that floor plans often appear on these drawings providing a kind of visual analogy via the reproduction of the ideal image. The contrast between light and dark, thus the influence of light on the space, is in these perspectives of essential importance and is for that reason made carefully visible. Even on his tiniest of sketches Peutz paid attention to this aspect.”

What Arets and fellow student Wim van den Bergh, like Peutz before them, had learnt during prior technical education, as a technique of constructing the perspective, Peutz applied in such a way that the floor plan, from which the perspective is set up, remained present in the final resulting perspective drawing, as an independent layer. This is a given, a means of control, in which Arets, at the time he was writing the text on Peutz, saw potential poietical strength. When he designed a project for Venice, together with Joost Meuwissen, the founder of the Wiederhalle, he instructed his draftsman Gonard Vleugels (also someone who had received a technical education and was taught the old-fashion way of constructing perspective) to make the perspective help lines part of the drawing, in an explicit way. After Arets got his first concrete assignments, he commissioned Wendi Bakker (who at that time had just finished her education at the Domus Academy in Milan) to make oversized perspectives on which the help lines of the perspective construction of the presentation remained visible in an even more explicit manner. In this, the attempts made by Peutz and Vleugels were not only combined, but also intensified by means of a specific technique developed by Bakker, in which, among other things, a risky treatment with boiling water resulted in a visual type of alienation, with both Piranesi-like and Francis Bacon-like effects. The first drawing Bakker made was of the clothing store in Maastricht, at the time it was completed. This is the first drawing of a series that are published in the first monograph of Arets’ work, that appeared on occasion of the Maaskant Award. Frampton qualifies the parallelism of Zwarts’ photos and Bakker’s drawings in that book as “the schismatic character of Arets’ architecture” (p. 10 in the Moleskine book). The first series is precise, using a lot of symmetry, the other is precise as well, but deliberately blurred where the image impression is concerned (Arets refers to them as “oversized perspectives, from a more or less strange perspective”). When studying Peutz’ work, Arets already realised that the parallelism of precision in his work on the one hand and the apparent sloppiness in his perspective drawings on the other (apparent, because it serves as a means of control) was a compelling suggestive scenario that might serve the new postmodern challenge of the moment in time in which Arets wrote his text. This manner of drawing, that Peutz never saw as a form for eventual presentations in books or exhibitions, Arets did see as such, after he had seen the the paper architecture at the Venice Biennale, a year before (1980). In this turning of the historical perspective, he saw the ‘actualisation’ of Peutz’ work.

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1. The Moleskine ‘Inspiration and Process in Architecture’ series “emphasizes the value of freehand drawing as part of the creative process”. In the Wiel Arets volume (2012), the architect is interviewed on the subject; on p. 18 he says: “The oversized 3D drawings I made for a long time; I made them after an initial sketch. I thought about what I wanted to do with a project, and then once my thoughts had matured, I decided to make one of these oversized perspectives, from a more or less strange perspective, in which I tried to capture all the ideas I had so far. These drawings usually took me anywhere from six weeks to two months.” In reality Arets drew none of these “exacting, oversized perspective views” himself. The only detailed drawing he made is an axonometric drawing of the Glass Towers project for Tokyo, 1985, on p. 65. Nevertheless he knew exactly what he wanted when he commissioned these drawings, and defined the starting points, and discussed the results in the manner of a movie maker who asks his camera (wo) man for the special effect he expects to see.

fpj peutz architekt 1916 1966
Striving for order
W. Arets

It is the intent to briefly describe here the development of Frits Peutz’ (1896-1974) work, including the influences of his time period, and how we can judge his work by current architectural standards. The rational and irrational aspects of his thinking shall be reviewed as well as his vision of space in particular.

In this connection it will not be possible to view his work as an architect (such as can be perceived in constructed form) separate from the critical opinions he set down in numerous lectures and unpublished articles.1

His development was built up slowly starting with an accent on painting and continuing with an analogy with music about which he spoke in detail in his inaugural speech at the Eijck Academy on October 2nd, 1950.

The clear point of departure for his entire career is his search for architecture’s basic terminology based upon the precision of essence, not upon classical form-based studies or research into and further development of new techniques. Striving for order intrigued him his entire life and led him to quote Thomas Aquinas’ view that beauty comes from order and must be seen as the essence of his research. “Beauty is the reflection of order. I firmly believe that many modern artists are little more than fashion hounds because they deliberately avoid the Thomistic maxim for Kantian relativities. Perhaps one might impress upon Willem Adriaan van Konijnenburg (1868-1943) the odium of the scholarly, practiced aesthete. Faults in our own superficial age can be found quickly indeed. Yet art must always have something that is old about it; beauty is old too. And for people who believe in God, order is absolute.”2

Despite the fact that Marinus Jan Granpré Molière (1883-1972) had an important influence on education at the Technical University at Delft (where Peutz studied from 1916 to 1925, a period during which De Stijl and the Amsterdamse School strongly influenced architecture) Peutz managed to avoid developing a distinct style. It is thus wrong to include his work as part of a particular trend, as has been done by the translators of Fanelli’s ‘Architettura in Olanda 1900-1940’ for example, which portrays him as an exponent of the Delft School.3

Far better is the approach taken by Merkelbach who presents Peutz’ work as based upon the classics and situates him between Berlage and van der Vlugt.4

Peutz sought his own path in a period during which 8 en Opbouw and the Katholiek Bouwblad were making their views public. He attempted to maintain a certain autonomy with regard to architecture in general and did so by consistently substantiating a formal, theoretical study. This is how his buildings were able to attract attention abroad: they were published in Casabella, Nuevas Formas and l’Architecture d’Aujourd’hui, for example.

When it came to historical research, he went so far as to learn to read and write hieroglyphs in order to emphasize the value of Egyptian art in general and architecture specifically. The role and meaning of the architect in Ancient Egypt led him to a comprehensive (unpublished) study which included a list of each architect engaged in the construction of various monuments. His research into the role of the architect in the past was focused principally on establishing the position of the architect and his theoretical basis of the concrete design.5
He thought the discovery that the Ancient Egyptians saw art as serving greater interests and had no interest in art for itself was important. It was this servile aspect of Ancient Egypt which Oud proclaimed in 1957: “The painter who makes his way to the dominion of architecture often completely misses that the architect is peculiar, that he has to serve.” Adolf Loos wrote on this subject: “The work of art wants to tear people from their complacency. The house must serve complacency... The work of art is revolutionary, shows humanity new paths and thinks about the future. The house thinks about the present... Architecture is not one of the arts; only the gravestone and the monument, everything that serves a purpose, is excluded from the empire of art.”

During his studies Peutz wrote many art reviews and would later write: “On one side Nazarism with a star like Wasmann, the pre-Rafaelism with Rosetti and Toorop, and on the other side impressionism, expressionism, futurism, and Dadaism made me doubt authenticity, sincerity, purpose and the essence in general of art.” In speaking about various works of art Peutz continually sought the monumental, the massive that can also be found in little things, that is, he was searching for the idea that moved the artist to create. He wrote about this: “The comprehension of diverse fields of study makes one a master; seeing the growth of ideas is to be trusted more than the completed work which has outgrown itself.”

We are also able to find and follow the development of this growth of ideas in many of Peutz’ designs. It is noteworthy that his first sketches often deviate completely from the later design as can be seen in the successive development of the church in Wittevrouwenveld in Maastricht, the design of Heerlen’s Raadhuis [city hall], and the design for the V&D building in Heerlen. The initial sketches reflect an image that not only has its origins in the expression of a form, but also contain a transformation. It is thus his ‘ideal’ design, represented by him in this tender stage; it is an abstracted idea, called ‘a modulation of the spirit’ by Peutz. He then went in search of the metaphysical order of the idea and wrote about this: “Enjoying art means permitting oneself to be carried by the rhythm established by the artist in the artwork... To make a good painting means arranging and ordering, posing one color onto another, setting one line against another, sliding one surface against another, mass onto mass. It means giving and taking, a process as if the painter were an architect.”

After idea and order, decoration is the third point he uses to analyze and evaluate various works. He wrote about Scottish art: “The Scots do not know painting as easy illustration or pleasant tale. They feel the thing as ornament which painting can no longer decorate or musically paint; he cannot emphasize his feelings on the canvas or make real his mood via the power of color. They see fundamentally. No tiny particle upon his tableau disturbs the symphony. They apply paint to paint until they make a chord; he drives chord upon chord until a scale of sound is created such that his work springs to live from within.”

It is not possible to see Peutz’ work as a single phenomenon separate from its development which took place within and outside the Netherlands at the beginning of this century. The meaning of Wright, Berlage and architecture theorists such as Brickmann and Schuhmacher – the men who determined the world of architecture at the beginning of this century, also influenced Peutz’ research and work.
The influence Wright had on Peutz’ work ran from stimulation to self-development which we can also perceive in Oud’s work, although formal influences in Peutz’ earlier work are certainly also present. Peutz was also attracted to Wright’s notion of using new materials, such as concrete, in addition to traditional materials, such as natural stone, brick and wood, in order to come up with new solutions to construction problems. He tried to arrive at a new synthesis of traditional and new materials by researching the ‘inner will’ of each material after which it was added as an element to the whole. For example, marlstone was utilized alongside prefab concrete elements and brick alongside steel; this referenced the equality of these materials vis-à-vis one another thus banning any kind of hierarchy. This led to the use of reinforced concrete in some of his churches and a conflict with Granpré Molière who dismissed the use of concrete in church construction thusly: “Reinforced concrete covers everything with a coat of evenness and yet simultaneously returns to communism or a revolt against God, only one reason why it can be called its aesthetic interpretation. We are currently situated deeply within this ugly form of construction. This is why light eludes us: despite some qualities over iron, reinforced concrete’s monolithic character, hidden reinforcement and complex tensions cannot meet the highest requirements of constructive beauty which we must set when building churches.”

Second only to his interest in the classics, it was rather Berlage’s work that kept him most busy during his years of study at Delft. In addition to studying his buildings, such as the Amsterdam Stock Exchange (de Beurs), it was Berlage’s theoretical writings and especially his historical research and thinking on space-idea in architecture (linked to the German architecture theorists Schmarsow and Hildebrand) that appealed to him. Berlage saw the nineteenth century as a period of subjectivism in which no great art could develop due in part to the lack of a firm connection to the spiritual flow of social events. There were individual highpoints, however; he named Goethe, Beethoven and Wagner, but oddly enough none in the plastic arts. This changed at the end of the nineteenth century, however, in part due to material advances. Classical styles were no longer used; gone was the pursuit of general simplification – such as purity of composition, simplicity of ornamentation and functionalism – not only in materials used, but also in the spiritual sense and it was this that deserved to be sought after. England served as his example, such as can be gleaned from Adolf Loos’ writings in which England is frequently presented as exemplar.

In this period Berlage followed Muthesius’ writings and studied the work of Semper and Viollet-le-Duc. The latter’s ‘structural honesty’ and his grid adaptation of drawings of medieval construction, such as the St. Sernin church in Toulouse, influenced Berlage’s designs for de Beurs while Semper’s chapter ‘Einheit und Vielheit’ [unity and multiplicity] was brought to a wider audience thanks to Berlage.

The ‘rational-mystic’ dualism Grassi identified as the source of internal contradictions in Berlage’s work is also clearly discernible in Peutz. These aspects are most prominent in the Raadhuis designs Peutz made between 1936 and 1942 which can likewise be explained by their difficult positioning. Understanding architecture as spatial art, as Berlage had done, would be essential for Peutz’ future research and it is here that he connects with
the German architect theorists Brinckmann and Schuhmacher. Berlage subscribed to the theories of Schmarsow and Hildebrand as published in 1893.\(^9\) & \(^{20}\)

Schmarsow’s theory was based on Semper’s three spatial moments of symmetry, proportion and direction, but in contrast to Semper those of materials as well; he also made the spatial-idea an integral element of architectural aesthetics. The spatial-idea became the new way to define beauty and as such was a logical step in the direction of Hegelian philosophy in which the spiritual idea is elevated to the essence of aesthetics. Schmarsow made the spatial-idea explicit via the movement of the human body, that is, the succession of space and time, as the point of departure of making architecture and replaced Semper’s ‘third moment’ with rhythm. He viewed space and mass as two polarities. Brinckmann combined Schmarsow’s idea with Heinrich Wölfflin’s Einfühlungstheorie and defined the external manifestation of architectonic mass as a consequence of the internal feeling of the enclosed space.\(^{21}\)

This led him to three spatial concepts: free-standing mass enclosed by space, space enclosed by mass, and their interpenetration. Schuhmacher too viewed Wölfflin’s attitude toward architecture as corporal mass with Schmarsow’s attitude toward architecture as the creation of space visualized by means of spatial penetration.

Peutz took over Brinckmann’s notion of art in space (plastic spatial-art) and art of space (three-dimensional spatial-art) and defined architecture as spatial-art in order to build an analogy with music as time-art in and of time. This analogy, which we also find in the work of August Endell, connects to Berlage’s ideas; music as rhythm analogy to architecture means that architecture as time-art and music as space-art can be defined. The analogy between architecture and music is not new, but the way one develops it is essential. According to Peutz, both architecture and music are based upon the plastic-sound relation, and rhythm is based upon the abstracted feeling of space. He then called architecture a game of rhythmic order and defined movement, the ordering principle, as the only musical architectonic principle.

Proportion was the point of departure for the determination of architectonic rhythm in Greek architecture, in the Middle Ages (with its modular triangle system), and also in the Renaissance (based on Roman schemas). For Leon Battista Alberti (1404-1472) in De re aedificatoria libri decem it was about illuminating the music of proportion, ‘tutta quella musica’, as the essence of architecture and to define beauty – what Peutz would call ‘meer’ [more] – of a building as a triad of number (numerous), connection (finitio) and order (collocatio).\(^{22}\)

Peutz presumed that spatial-art and temporal-art are perceived not only by the eye or only by ear, but by a combination of senses. Peutz put forward that it is the architect’s task to provide the correct spatial proportions, to discover the relation of separate units and bring them into harmony, and then to fill this space with pauses and accents. The proportions determine the character of the space, a character that is dependent upon the nature of the building and thereby of essential import for the choice of material and construction principle. This construction is also in part responsible for the proportion of the space and must therefore be given expression in an ‘honest’ way. We can see this in the Huskens
church in Heerlen and the boys’ school in the Wittevrouwenveld in Maastricht, for example. It is noteworthy here that Peutz often worked out several alternatives in which natural stone, wood and steel were all considered as material for construction. In these we can clearly see that the different materials influence the space each in their own way. The choices made regarding construction necessitate that the architect seek a suitable form in which the use of traditional materials such as marlstone, which Peutz often employed because he felt it fit with the region, demanded considerable practical knowledge, and since it was used regularly it was in stock. While new materials such as concrete demanded a great deal of practical knowledge, which he indubitably had thanks to his (albeit incomplete) civil training and his enormous interest in constructive developments, as is evident in his library. Oud wrote in 1957: “It is true that in some aspects of my design I hark back to my old way of working as I have not yet mastered the new, all-encompassing construction.”

Indeed, Peutz would continually use both traditional as well as new materials and employed this evident contrast even in constructive systems which were completely prefabricated such as the O.V.S. school in Kerkrade where he used concrete prefab elements and natural stone next to one another. Peutz saw space as the essence of architecture, wanted to make it conceivable and to this end produced a large number of perspective sketches. It is remarkable that when it came to developing designs he seldom made use of façade views, floor plans or maquettes, but very early – as soon as pen was put to paper – had his draftsmen construct mathematical perspectives from various standpoints he would indicate. He then used these constructed perspectives of the interior and exterior in order to further develop the design. What is noteworthy here is that floor plans often appear on these drawings providing a kind of visual analogy via the reproduction of the ideal image. The contrast between light and dark, thus the influence of light on the space, is in these perspectives of essential importance and is for that reason made carefully visible. Even on his tiniest of sketches Peutz paid attention to this aspect.

For him natural light was a precondition for the creation of architectonic space. Breaking through a wall or the roof is thus also the right way to keep a rein on the quantity of light and thus the spatial quality. This design process only slowly came together into a harmonic whole in which space is seen as the essential element of architecture.

Plato’s philosophy, that every unit can be divided into mathematically proportional parts, was revived in the Renaissance, specifically by Alberti in his ten books on architecture.

Peutz adopted the idea that construction is the composition of separate units turning a multiplicity into a single unit. It is the new relationship these have among themselves when united that is essential. It is not only about spatial relations, but also about the syntactic relations between elements, such as details and windows in a façade. In this connection, the similarities between the treatment of the canvas by the painter, as Peutz describes, and the treatment of a façade as we find in
his work are remarkable. He called the canvas the ‘décor’, an independent element that makes construction possible and comprehensible and that suggestively transforms space in the bordering surfaces as well as fixes the movable; the ‘décor’ is where the components measure, rhythm and melody are situated.27

Peutz sees the holes in the façade stemming from the ‘interior’ as ‘tonic’ and tries to bring them together into a chord. This is very evident in the façade of Heerlen’s Raadhuis where we can see how the details and even the separate natural stone plates, together with the holes compose a whole. The Retraitehuis, a Nieuw Zakelijk building, also has holes in its façade incorporated like a sound within whole.

“In classic, and specifically Greek, architecture the ‘part’ has the function of the musical equivalent of a sound, a tone...for Alberti the pillar is the keynote...in modern architecture, which is a different kind of music, we speak of holes which are sound,” Peutz wrote. With other music he meant jazz which improvises on basic melodies and chord patterns upon a strong rhythmic sub-structure.

His designs from the 1950s, when he made use of prefab elements, express a purity of composition, stemming from the smallest unit, which can be called classical; the material responds in the purest way to the concept plan. The expression of the ‘internal’ is improvised upon the basic structure of prefab concrete elements. Here too we can clearly see how the façade is the result of the ‘internal’, as it were, in that the elements are evidently randomly, yet with complete harmony set with panels where necessary.

It is the ‘more’, the spiritual, that Peutz repeatedly cited in the relation of architecture to the plastic arts, and this idea was central to his professorship at the Jan van Eijck Academy. He viewed the plastic arts as subordinate to architecture, yet from which architecture took the most immaterial component: space.

Peutz: “The younger generation of plastic artists has too little feeling for harmony. They place freedom above alignment, while the latter is the very first requirement for the execution of monumental assignments because wall paintings and glazing belong to the character of construction.”

Peutz felt himself drawn to the work of the painter-theorist Willem van Konijnenburg very early and he would eventually write several articles on him. It was principally his search for the spirit, the inner essence of the conception and order of elements that appealed to Peutz. It is typical that both non-Limburgers (van Konijnenburg came from The Hague) had a fondness for the Limburg landscape, a landscape Peutz described as Limburg-Italian, a comparison which one could call characteristic of his ideas.28 Berlage too was captivated by van Konijnenburg’s work and described the ‘architectonic character’ he recognized in his drawings.29 Peutz wrote about van Konijnenburg: “Romantics of the kind such as van Konijnenburg are subsequently viewed as classic... intuition, spontaneity notwithstanding everything, and a law made natural - van Konijnenburg had all of these in his work...he had a complete imaginative ability which he used to absolutely subordinate the eye line in the service of order, to transpose in the service of music, and in the service of form; every work, every dance composed makes order from chaos and is thus creation; measure is made substance, rhythm an element of life.”
It is this search for the essence and for order that is essential to Peutz’ own work. This framework also explains his interest in the structural and formal elements of the classics and his references to the scientist Alberti whose *re aedificatoria* (1450) ran the gamut of the architectural domain. Le Corbusier too presented studies in which he defined architecture as order and explained that harmony can be achieved by the use of universal laws of proportion. He would first adopt surface, mass, ground plan, and regulating lines as the four most important factors of architecture aesthetics; he first pushed forward the idea of spatial concept as the determining element thereby employing proportion and geometry as immaterial factors.

From an urban development perspective Peutz also established new relations. He attempted to develop the amorphous structure which characterized Heerlen in its industrial, mining period into a consistent unity, one which would include the historical core of Roman and medieval periods in the new structure. The buildings which determine the character of Heerlen are the *Raadhuis* (situated in the ‘Roman section’), the *Glaspaleis* (in the medieval section), and the Cinema Royal and train station (in the ‘mining section’ of the city). The city theater, built in 1959 after an urban development intervention by Prof. G. Holt, was the final dominating contribution by Peutz.

By means of bringing together a few architectonic elements into a unit in structure and form, such as we also saw in Peutz’ work, the result is that classicism reached its historical development and that deviates from the ideas established by the *Modern Movement*. To that extent one can determine that efforts of the Tendenza, in particular Rossi and Grassi, to recover the historical meaning of the city fits with Peutz’ ideas.

Within this framework we can actualize Rossi’s 1966 *Architettura della Citá* and Grassi’s 1967 *La construzione logical dell’architettura* the latter of which investigates the origins and order of architecture to find solutions for current problems and in which he analyzed the work of Berlage and Viollet-le-Duc. They too were searching for a design method which stood above social politics and cultural events – or at the very least did not delve into them as points of departure for the design process.

Peutz called good architecture musical according to its own essence. It is this essence that concerned Plato when he described the link between the lower knowledge of visible, tangible things, the body, and the higher knowledge of invisible ideas, the soul. He endeavored to establish relations between the human body, music, and mathematics. To do so he called upon Pythagoras who was able to realize order as the relational basis for all arts which depend upon numbers.

The ‘soul’, which Peutz called ‘more’, must be seen as a pure, immaterial relation connected to the spatially determinative concept. The search for ‘more’ was seen by Peutz as that which elevated construction to architecture, that elevates the product above business concerns. This could be the core of a critique of the *Nieuw Zakelijken* which ignores this ‘more’, the ‘soul’. They saw the image of the rational analysis of the assignment as a means of expression and saw rhythm, proportion, decoration and color as secondary, thus not of direct importance to architecture as such. Peutz sought a peculiar component of architecture, the continuation of the tradition, and did not concentrate on the metaphors of nature or machine.
It is this classic tendency which played an active role before the Tendenza. It is this research that Tafuri called an ‘objective, logical and analytical method which must precede design.’

Peutz investigated the historical reality of architecture and thus resisted the Modern Movement which he saw as ‘modernistic’ and which did not match his own point of view because of the dominance of functional-materialistic theories. In this light it is not surprising he was invited to show the Retraitehuis at the XIV Triennale in Milan in 1936 (organized by Dr. Giulio Barella) which had been extensively discussed in the November 1934 issue of Casabella.

It was Terragni who combined the search for order and the application of established values based upon the classics (including the use of diverse relational systems) with new achievements. His Casa del Fascio in Como is in this regard comparable to Peutz’ Raadhuis in Heerlen. The Casa del Fascio, built in a period when the fascists were in power, appears to function well in the current democratic establishment, a quality which Oud in 1947 described with reference to Raadhuis as follows: “I know of no city hall in which the democratic [spirit]...is given such complete atmospheric expression as in this so-called Nieuw Zakelijk edifice.”

Yet this characterization of the Nieuw Zakelijk building is remarkable for it is one also made by Kloos in his article on the Retraitehuis and was heavily criticized by Peutz in a letter to Kloos dated March 16th, 1934.

The way Peutz adds plastic art to his buildings, and here specifically the Raadhuis, is comparable to Terragni’s addition of paintings to the interior and exterior of the Casa del Fascio. Because he defined architecture as spatial-art and as space seen as the most immaterial artistic expression, he elevated the architect above the artist, in contrast to the view of the Modern Movement. Peutz here subscribes to the views of Schmarsow and Brickmann who built their ideas upon Hegelian philosophy.

The sculpture Charles Vos made for the Raadhuis must be seen as an addition in the service of the architectonic completion of the building and is absorbed into the pattern of regular lines in order to form an essential component of the total design.

In the residence-office building Op de Linde Peutz came to a remarkable application of his starting points which led to a sensational result in the north façade: it forms a spiral around Charles Vos’ plastic artwork.

The Raadhuis is a design based upon a Roman idea: a classical order has been applied which can be traced back to the volume and façade treatment which are based upon golden section relationships. The immaculate details of both the exterior and interior as well as the use of internal space whose most stunning element is the amphitheater-like staircase, testify to a convincing originally. The symbolic character that Peutz often provided his buildings is remarkable here, as in other of his designs.

The columns on the west side of the building must also been seen in this light. They reference not only the Roman history of the city of Heerlen, whose center was where the Raadhuis now stands, but likewise serve as symbolic key to the design’s background.

In this it provides a link with history, like that in the theme found in Venice Architecture Biennale of last year and which represented by the various designers of the facades of the Strada Novissima.

“The Commission of the Architecture Sector of the Venice Biennale, with the
support of the Critics’ Committee, has entrusted the planning of the ‘Strada Novissima’ to 20 architects from all over the world. Each one of them has been asked to design a ‘Facade’ expressing his own particular sense of form, with special reference to the theme of the ‘Presence of the Past’, that is, the role that has now returned to take on the reflection on history as an active basis for planning.”

This relationship between the present and the past which characterizes Peutz’ work and was ignored by the Modern Movement, is being actualized by current developments in architecture. In this regard one could speak of the column as a very important element in Peutz’ work. Research into the meaning of the column had kept him busy since his days at the university. The first interpretations of these studies were done in 1919 by Wijnands in Heerlen. In his later works, such as the Glaspaleis and the Raadhuis, their execution is an essential component of his architectural language.

The column is combined again and again in new configurations with other elements such as the wall, the ceiling and the staircase. Peutz’ research sought the symbolic and the architectonic bases which contain the diameter of the column as a spatially structuring element; he also sought to illuminate its constructive possibilities. In the mushroom construction we recognize these three facets in a very evident way. Yet he did not forget the classical tripartite: foundation, column and capital. It is thus remarkable that on one hand he chose the mushroom construction which made a flowing transition between the column and the floor, yet on the other hand made this transition clear by giving the capital a different color.

The continual redefinition of the points of departure and research into and further development of the basic terminology mark all of his buildings down to the very last one. He described this himself in an article with reference to van Konijnenburg’s work: “A great master is one who enriches each of his works spiritually, whose every completion is provocation for the erection of a new building. His art is irresistible growth. He preserved rule and law in order to rein in his passion, in order to repress the non-artistic and chaotic aspects of his expressions which inevitably muddy summery ripeness and abundance”.

translation from dutch: David Lee
In addition to many published articles begun during his student days, in his archive lie unpublished articles and dissertation which he prepared for lectures including his speech to the Jan van Eijck Academy. Unless otherwise indicated, the citations listed here are taken from the unpublished writings.

1. In addition to many published articles begun during his student days, in his archive lie unpublished articles and dissertation which he prepared for lectures including his speech to the Jan van Eijck Academy. Unless otherwise indicated, the citations listed here are taken from the unpublished writings.


4. This via Merkelbach in 1948 in an article in Vrije Volk which cannot be dated with specificity.

5. F.P.J. Peutz, ‘De geschiedenis van den architect’ Boukundig Weekblad #19, 1941.

6. J.J.P. Oud, ‘Mein Weg in De Stijl’ 1957; a translation by Annie Oud-Dinaux was published in Plan, pp. 16-25, nr. 6, 1981.


8. F.P.J. Peutz, ‘De afneming van het kruis’ [The decline of the cross].


11. F.P.J. Peutz, De Maasbode, 28 May 1921.

12. F.P.J. Peutz, De Maasbode, 17 March 1921


15. It is precisely the geometric basis of his work which typifies the architectural character and puts him in a position to paint a wall or decorate a window’.


17. “It is precisely the geometric basis of his work which typifies the architectural character and puts him in a position to paint a wall or decorate a window”.

18. Schouwburg Heerlen #398 in cooperation with Ir. Bijvoet who was associated with G. Holt from 1948.


Translator’s note: here is left away what was in Dutch added as ‘onder andere’ ("...die berusten op onder andere gulden snede verhoudingen.")


40 Villa Wijnands Heerlen, p. 20, #2; ‘Glaspaleis’ Heerlen p. 148, #55; Raadhuis Heerlen, p. 195, #75.
cube DDW 2013, vertigo staircase room (photo niels groeneveld)
The Design Research Yearbook of the Built Environment faculty at Eindhoven University of Technology presents a selection of graduation projects. In the case of architectural design, the format of the research is the graduation studio in which a common research project is carried out during a single semester before each student designs an individual graduation project during a subsequent semester. The research conducted by each graduation studio is described in this book and represented by one or two projects. The research projects in design systems, building physics and construction design are defined by themes staff and PhD researchers work on and whose subthemes are worked out in individual graduation projects.
bouwen im bestand
rinse tjeerdsma

exploring thatch
wenlei ma

exploring mass
elisabetta bono

conflict in motion
kenny vonk

interplay
sjoerd raaijmakers

... at first sight
maaike krijnen

ilhas: filling up the gaps
natasha henny holz and amorim de sena

north in the wind
jachym van erning