ETH zürich

Engineering for Development (E4D)
Summer School, 4 - 22 July 2016
at TU Delft, The Netherlands

Sand: an (in)finite resource?

The programme revolves around the depleting resource sand and the question of how to develop alternative building materials for future cities.

ETH Global

TU Delft

DIRK E. HEBEL · ETH ZURICH · ASST. PROFESSORSHIP · ARCHITECTURE · CONSTRUCTION ·

Content

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cover image: Delftland Sand Engine at the Dutch coast by Zandmotor, public domain.

Introduction

Background

The summer school is part of the programme "Engineering for Development (E4D) - Science & Technology for the South". The goal of this programme is to promote the development of products or methods which are directly relevant for improving the livelihoods of poor people in developing countries.

The E4D programme has evolved from a scholarship scheme supported by the Sawiris Foundation for Social Development. Since 2008 it has awarded two doctoral scholarships annually. Since 2014 the scope has been expanded to include a series of schools, the first of which took place in January 2015.

Structure of the E4D Summer School

The E4D summer school will be composed of 30 graduate students, coming from ETH Zurich, from academic institutions of the IDEA League and from other academic institutions around the world, particularly in developing countries. They will be joined by faculty members and external experts from fields of expertise related to the summer school topic. The master and doctoral students will come from different disciplines related to the E4D topic.

The summer school will take place at TU Delft, The Netherlands. The aim of the E4D summer school is to foster interdisciplinary exchange on sand as a resource being rapidly depleted. During the first week, students will be introduced to the topic through a series of input speeches, lectures and symposia. The second and third week will focus on workshops along three lines of investigation.

The workshops will provide students with hands-on opportunities to work in an interdisciplinary and intercultural team and to assess alternatives to the chosen topic. Full attendance and submission of a presentation for the final idea competition is required.

Topic of the E4D Summer School

The E4D summer school 2016 aims to develop an integrated vision to a global challenge of today's construction industry. The programme revolves around the depleting resource sand and the question of how to develop alternative building materials for future cities. Invited experts from around the world will share their knowledge and give insights in their field of research. In the workshops the acquired knowledge will be tested and applied. The results will be evaluated under the concept of stocks and flows of energy and material to assess their contribution towards sustainable development.

Workshops along three lines of investigation will be held:

(1) Bio-cementation
(2) Crystallization
(3) 3D printing with sand

ETH Global, ETH Zurich

ETH Global is the unit for international relations at ETH Zurich. It fosters international partnerships in research and education and enhances the institution's visibility abroad. ETH Global is responsible for implementing the global strategic goals of ETH Zurich and cooperates with other offices working with international issues. Its crosscutting mission complements the international relations of research groups, departments or administrative units at the institutional level.

Asst. Prof. Dirk E. Hebel, Chair of Architecture and Construction

The Professorship of Architecture and Construction Dirk E. Hebel at ETH Zürich in Switzerland and at the Future Cities Laboratory in Singapore concentrates its research on alternative construction materials and their application in specific contextual settings. The Chair takes into account the availability of materials, human resource capacities, and skills to develop innovative approaches on the field of architecture and construction. The Chair has developed the curriculum of the programme of the E4D Summer School 2016 and is responsible for its content.

Sawiris Foundation for Social Development

The Sawiris Foundation for Social Development sponsors the E4D Summer School. The Sawiris Foundation was founded on the belief that development is only sustainable when its beneficiaries are equal partners in the process.

The Sawiris Foundation supports initiatives that encourage job creation through training, education and access to microcredit. The Sawiris Foundation also enhances efforts to improve health and further the endeavors of local communities to improve infrastructure and gain access to basic services — two important prerequisites for higher productivity and the increased empowerment of citizens.

TU Delft

Delft University of Technology, also known as "TU Delft" (from the Dutch name Technische Universiteit Delft), is one of the leading universities in Europe and, like ETH Zurich, member of the IDEA League. The department of Civil Engineering and Geosciences at TU Delft hosts the E4D Summer School 2016.

Schedule Week 1

MONDAY | JUL 4

SAND: AN (IN)-FINITE RESOURCE?

10:00 – 12:00 **TU Delft Campus Tour**
Yask Kulshreshtha
TU Delft

12:30 – 13:45 **Catering Lunch**

14:00 – 14:45 **Welcome**
Barbara Becker, *ETH Zurich*
NN, *TU Delft*

15:00 – 15:45 **Introductory Lecture**
Dirk Hebel
ETH Zurich

16:00 – 17:30 **Film Screening: *Sand Wars***

Discussion: Sand: an (in)finite resource?
Aurel von Richthofen
ETH Zurich

18:30 – 19:30 **Drinks and Appetizers**

Dinner

TUESDAY | JUL 5

GEOLOGY OF SAND

09:00 – 10:00 **Origin, Transport, Sorting and Deposition**
Bas den Brok
Swiss Topo

10:15 – 11:15 **How to Find Suitable Sources of Sand**
Thijs Oomen
Van Oord

11:30 – 12:30 **The Industrial Production of Sand**
Bas Vos
Boskalis

Lunch

SAND AND SOIL

14:00 – 15:00 **Sand as a Construction Material**
Chris Dykstra
Boskalis

15:15 – 16:15 **Local Subsurface Characteristics in Delft**
Ad von der Spek
Deltares

16:30 – 17:30 **Delft City Tour**
Leon Van Paassen
TU Delft

Dinner

WEDNESDAY | JUL 6

FIELD TRIP 1

09:00 – 17:30 **Reclamation projects: Sand Engine & Maasvlakte, the Netherlands**

Dinner

THURSDAY | JUL 7

BUILDING WITH SAND

09:00 – 10:00 **The Morphodynamical Perspective**
Axel Winterscheid
The German Federal Institute of Hydrology

10:15 – 11:15 **Sand Castle Building**
Piet Lubking
UNESCO-IHE / Deltares

11:30 – 12:30 **Transforming Sand to Sandstone**
Jason DeJong
University of California, Davis

Lunch

SAND AND THE BUILT ENVIRONMENT

14:00 – 15:00 **Basics on Concrete Material Science**
Robert Flatt
ETH Zurich

15:15 – 16:15 **Material Properties of (Sustainable) Concrete**
Henk Jonkers
TU Delft

16:30 – 17:30 **Urban Design with the Subsurface**
Fransje Hooimeijer
TU Delft

18:30 – 20:30 **Intercultural Student Dinner**

FRIDAY | JUL 8

ALTERNATIVE MATERIALS

09:00 – 10:00 **Developing Alternative Materials**
Dirk Hebel
ETH Zurich

10:15 – 11:15 **Biocementation - Self Healing Concrete**
Henk Jonkers
TU Delft

11:30 – 12:30 **Waste Based Bricks**
Ward Massa
Stone Cycling

Lunch

INNOVATIVE APPROACHES

14:00 – 15:00 **Designing with Alternative Materials**
Elvin Karana
TU Delft

15:15 – 16:15 **Fungal Futures: Growing Domestic Bio-Landscapes**
Maurizio Montalti
CorpusColi

16:30 – 17:30 **Recycling Building Components**
Lionel Billiet
Rotor

Dinner

SATURDAY /SUNDAY JUL 9/10

07 08 09 10 11 12 13 14 15 16 17 18 19 20 21

Schedule Week 2&3

MONDAY | JUL 11

LIFE CYCLE ASSESSMENT

09:00 – 12:30 **Planning for the Future: Green and Sufficient**
Dimitra Ioannidou
ETH Zurich

Lunch

WORKSHOP 1

14:00 – 17:30 **Workshop 1 «coRncrete»**
Yask Kulshreshtha
TU Delft

Dinner

TUESDAY | JUL 12

09:00 – 12:30 **Workshop 1 Biocementation**
Henk Jonkers and Leon Van Paasen
TU Delft

Lunch

14:00 – 17:30 **Workshop 1 Chemical Cementation**
Henk Jonkers and Leon Van Paasen
TU Delft

Dinner

WEDNESDAY | JUL 13

FIELD TRIP 2

09:00 – 17:30 **Open-pit mine Tagebau Hambach, Germany**

Lunch

Dinner

THURSDAY | JUL 14

WORKSHOP 2

09:00 – 12:30 **Workshop 2 Sand Works**
Ahmed Hussein
Ecole Nationale Supérieure d'Architecture Paris-Malaquais

Lunch

14:00 – 17:30 **Workshop 2 Sand Works**
Ahmed Hussein
Ecole Nationale Supérieure d'Architecture Paris-Malaquais

Dinner

FRIDAY | JUL 15

09:00 – 10:00 **Can We Build with Seawater?**
Eric Geboers
The Salt Project

10:15 – 12:30 **Workshop 2 Sand Works**
Ahmed Hussein
Ecole Nationale Supérieure d'Architecture Paris-Malaquais

Lunch

14:00 – 17:30 **Workshop 2 Sand Works**
Ahmed Hussein
Ecole Nationale Supérieure d'Architecture Paris-Malaquais

Dinner

MONDAY | JUL 18

WORKSHOP 3

09:00 – 12:30 **Workshop 3 3D Printing of Sand**
Clayton Muhleman and Alan Cation
California College of Arts

Lunch

14:00 – 17:30 **Workshop 3 3D Printing of Sand**
Clayton Muhleman and Alan Cation
California College of Arts

Dinner

TUESDAY | JUL 19

09:00 – 12:30 **Workshop 3 3D Printing of Sand**
Clayton Muhleman and Alan Cation
California College of Arts

Lunch

COMPETITION WORKSHOP

14:00 – 17:30 **Competition Workshop**
Aurel Von Richthofen
Felix Heisel
ETH Zurich

Dinner

WEDNESDAY | JUL 20

FIELD TRIP 3

09:00 – 17:30 **Amsterdam, the Netherlands**

Dinner

THURSDAY | JUL 21

09:00 – 12:30 **Competition Workshop**
Aurel Von Richthofen
Felix Heisel
ETH Zurich

Lunch

14:00 – 17:30 **Competition Workshop**
Aurel Von Richthofen
Felix Heisel
ETH Zurich

Dinner

FRIDAY | JUL 22

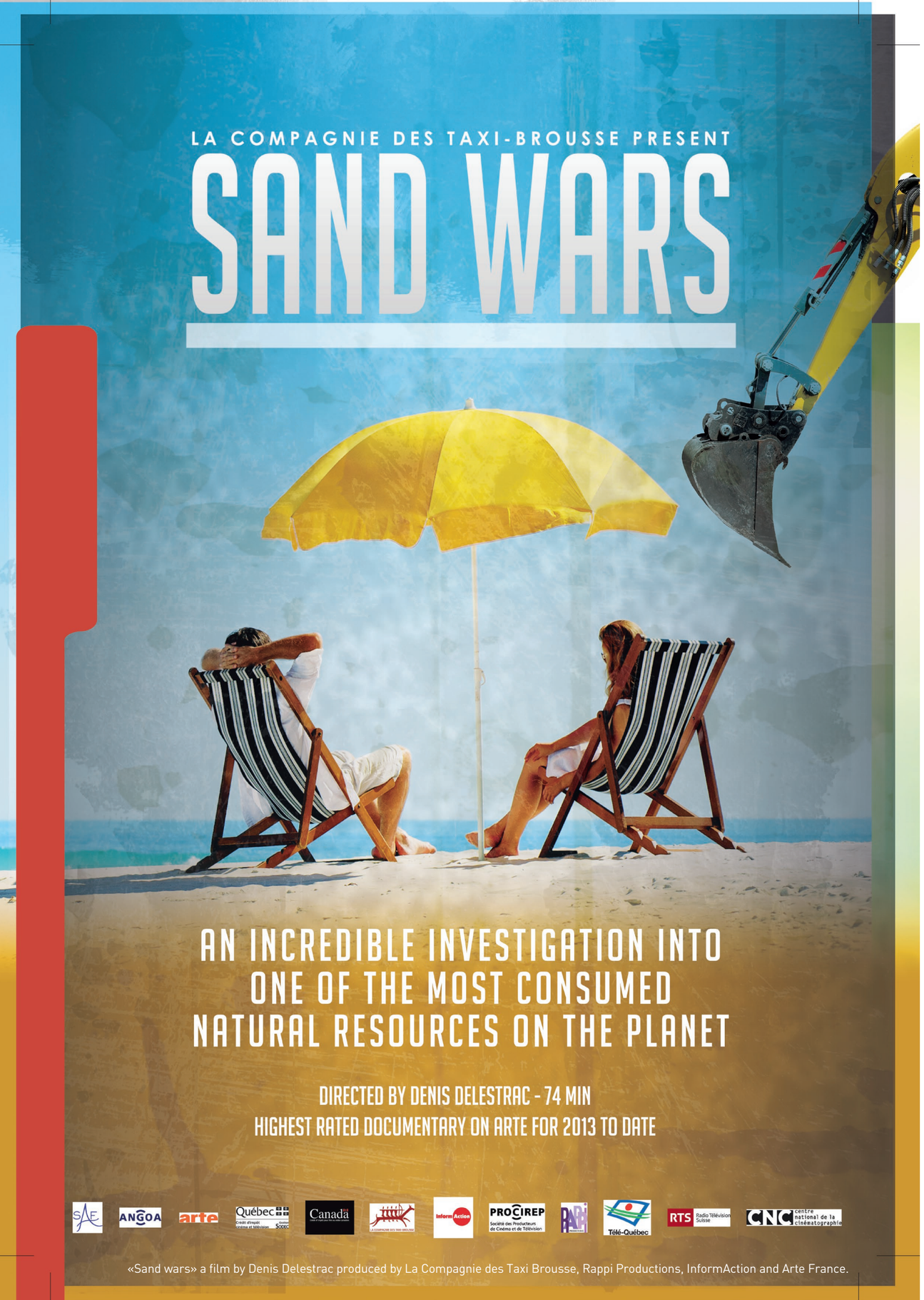
09:00 – 12:30 **Competition Workshop**
Aurel Von Richthofen
Felix Heisel
ETH Zurich

Lunch

14:00 – 17:15 **Presentations of the Competition**

17:30 – 18:30 **Diploma Award Ceromony**

20:00 – 22:00 **Farewell Dinner**



Lectures

Introductory lecture: Sand: an (in)finite Resource? Dirk Hebel

MONDAY | July 4 | 3.00 - 3.45 p.m.

Sand is the most used raw material for production of goods of our planet. It is found in concrete, glass, computers, detergents and even toothpaste. But sand is a finite resource: what took millions of years to become into being through erosion and sedimentation, man is mining at rivers and ocean coasts in a so-far unknown speed. In a matter of a few decades, sand will not be a resource anymore for our construction activities.

The construction industry requires particular kinds of sand that can be found in aquatic environments. Massive mining of natural coastal, fluvial and marine sand has devastating consequences for the environment as well as for the inhabitants. We need to look into alternative sources to reduce our dependency from the finite resource sand – in particular in the construction sector. The demand for sand can be reduced through recycling, substitution and synthesis. The rapid pace of urbanization in Asia, Africa and South America and the urban design challenges that go along with it question the sustainability of current building materials and methods. The areas mentioned above face gigantic building tasks. China alone consumed more cement in three years than the US over the whole 20th century. Developing countries use almost 90% of the global cement production (and twice as much sand as aggregate in concrete) and 70% of the global steel. This is due to the fact that the future urbanization will happen in developing territories.

But if finite resources are no longer an option to build the cities of the future, what alternatives are there? And what roles play research institutions as the Future Cities Laboratory in Singapore and the ETH Zurich?

Dirk E. Hebel

Assistant Professor
of Architecture and
Construction
ETH Zurich

Dirk E. Hebel is Assistant Professor of Architecture and Construction at ETH Zurich and the Future Cities Laboratory in Singapore. Prior to that, he was the founding Scientific Director of the Ethiopian Institute of Architecture, Building Construction and City Development (EiABC) in Addis Ababa, Ethiopia. Between 2002 and 2009 he taught in the chair of Marc Angélil at the Department of Architecture, ETH Zurich, held a Guest Professorship at Syracuse University and taught as Guest Lecturer at Princeton University. The resulting work of his teaching and research has been published in numerous academic journals and book publications, lately BUILDING FROM WASTE together with Marta H. Wisniewska and Felix Heisel.

Further Reading

• *Delestrac, D. (2013). Sand Wars. La Compagnie des Taxi-Brousse.*

• *Milliman, J. D. and Syvitski, J. PM (1992). Geomorphic/tectonic Control of Sediment Discharge to the Ocean: The Importance of Small Mountainous Rivers. The Journal of Geology, pp. 525–544.*

Sand: Origin, Transport, Sorting and Deposition Bas den Brok

TUESDAY | July 5 | 9.00 - 10.00 a.m.

Is sand a finite or an infinite resource? To help answer this question we need to have a look at the geology of sand, at the origin of sand and sand grains. What is sand? Where do sand grains come from? What different kind of sands did nature provide us with? Most of sands we are interested in consist of quartz grains (SiO2). These grains are very hard and mechanically and chemically very stable. They are very old and have been recycled many times during the Earth›s history. They went through numerous cycles of erosion: transport and sorting, deposition, subsidence and lithification, tectonic uplift, and erosion again etc. They all have long and complicated histories and most of them will continue their journey after we mined them, many cycles again.

We need sands with different characteristics. For fracking we need sands with nicely rounded grains. For construction we need sands with angular grains. Salty sands collected from the bottom of the sea are no good for the production of concrete. To make glass we need high purity silica sands. For concrete we need a proper grain size distribution. These different types of sands are formed during the geological processes of erosion and transport by water and wind. During the transport the grains are sorted out in different groups and deposited at different localities. To understand where we find what type of sand and what are the environmental difficulties we are faced with when we want to mine them, we need to look to the various processes and environments where transport and deposition of sands takes place: erosional environments in the mountains and in soils, transport in streams and rivers and their alluvial deposits, deserts with their aeolian deposits, lakes, estuaries, and marine environments including deltas, shore lines, shallow seas and ocean floors.

Bas den Brok

Independant Consultant
Swisstopo

Bas den Brok was born in Venray in a very sandy part of the Netherlands. He studied Geology and obtained his PhD in 1992 at Utrecht University in the field of experimental rock deformation. He was postdoc at the École et Observatoire de Physique du Globe de Strasbourg in France, lecturer at the Institute of Geosciences of the Johannes-Gutenberg University in Mainz in Germany, senior lecturer at the Geological Institute of the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland, and full professor of Structural Geology, Tectonics and Geomechanics, and Head of Department of Applied Geosciences at the German University of Technology in Oman. Since 2014 he works as a consultant for the Swiss Geological Survey making a geological map of the Glarus Thrust area high up in the central Swiss Alps.

Further Reading

• *Greenberg, G., Kiely, C., Clover, K. (2015) The secrets of sand - A journey into the amazing microscopic world of sand. Voyageur Press, Minneapolis, 128 pp.*
• *Padmalal, D., maya, K. (2015) Sand mining - Environmental impacts and selected case studies. Springer-Verlag.*
• *Pettijohn, F.J., Potter, P.E., Siever, R. (1987) Sand and sandstone. Springer-Verlag, 553 pp.*
• *Reading, H.G. (editor) (1996) Sedimentary environments and facies. Wiley Blackwel, 744 pp.*
• *Welland, M. (2010) Sand - A journey through science and the imagination. Oxford University Press, 333 pp.*

How to Find Suitable Sources of Sand Thijs Oomen

TUESDAY | July 5 | 10.15 - 11.15 a.m.

Many reclamation projects around the world require large quantities of sand. These reclamation projects are typically made by Trailing Suction Hopper Dredgers (TSHD), which extract sand from an offshore sand source and sail back to shore where they discharge the sand into the reclamation site. As a result of this working method, the cost price of these reclamation projects depends mainly on the sailing distance and the quality of the sand source. The quality of the sand source determines the loading and discharging time and the sailing distance determines the transit time. In order to submit a competitive price for the construction of reclamation works, it is therefore necessary to know where sand can be extracted and what the quality of the sand source is.

This presentation shows how the most economical sand source can be found. The first step is a desk study on the regional geology. Sea charts are inspected on the presence of sand. Next a sub-bottom profiling survey is carried out to study the structure of the seabed. Analysis of the sub-bottom profiles can indicate structures which may contain sand. To prove the presence of sand a vibrocore campaign is organised. In vibrocoring, a core barrel and an inner liner usually of 6m long are vibrated into the seabed. When the presence of sand is confirmed more vibrocores are added to map the quality distribution of the sand deposit. The final result is a 3D-model of the sand deposit, which supports the management of the marine borrow areas and the deployment of dredging vessels.

Thijs Oomen

Geologist
Van Oord

Thijs Oomen is a geologist for Van Oord, a leading international contractor specialised in dredging, marine engineering and offshore projects (oil, gas and wind). A geologist investigates marine sites for the construction and maintenance of ports, he builds geological models of the sediments and rock to be dredged and characterises the different stratigraphic layers by geotechnical parameters.
One of the main tasks of a geologist in a dredging company is to find suitable sources of sand for reclamation projects. In the past 8 years I have been involved in sand search campaigns around the world (Romania, Bahrain, Dubai, Abu Dhabi, Nigeria, Cambodia, Malaysia and Indonesia) and I gained much experience in the interpretation of geophysical data and the assessment of marine borrow areas.

Further Reading

• *James, J.W.C., Evans, C.D.R., Harrison D.J., Ooms, K., Vivian, C.M.G., Boyd, S.E. (1999). The effective development of offshore aggregates in south-east Asia. British Geological Survey, Technical report WC/99/9. Overseas Geology Series.*
• *Lowag, J., van den Heuvel, M. (2000). Advanced sub-bottom profiler equipment for soil investigation campaigns during dredging projects. Port Technology International, Vol. 17, 2000, 4 pages.*

The Industrial Production of Sand Bas Vos

TUESDAY | July 5 | 11.30 a.m. - 12.30 p.m.

Although not many people realise it, sand is a very important natural resource in our economy. Sand is mined in many areas in the world and is used for building materials such as concrete, asphalt and fine mortar, for the construction of reclamations, highways, railroads, housing development and for coastal defence, Clean quartz sand sources are used for example in computer chips, glass production, porcelain, in the chemical industry, in cleaning powders and abrasive powders.

There is a wide variety in the types of naturally occurring sands, for example in terms of mineralogy, grain size distribution, grain shape and particle weight. The behaviour of sand as a building material is influenced by each of these properties, as well as excavation, transport and placement methods. Engineering behaviour of the placed material depends on the loading conditions and rate of loading, sudden disturbances like earthquakes can change the material integrity dramatically.

Boskalis is a dredging contractor with more than a 100 years of experience using sand as a building material for civil engineering purposes. The presentation will answer questions such as: Where do we find these sand resources? How do we choose excavation and transportation techniques? What are the volumes and costs at which we can produce these materials? How do we predict the behaviour of the material in the construction and what treatments can we apply to improve the functionality of the material?

Bas Vos

Senior Engineer, Deputy manager
Hydronamic, Boskalis

Bas Vos studied Engineering Geology at the Faculty of Applied Earth Sciences at the TU Delft. After his graduation in 2002 on modelling block size distributions in rock masses, he started working for Boskalis' in-house engineering consultant Hydronamic. As a geotechnical engineer, Bas has been involved in many construction projects in the Netherlands and abroad, such as the A2 Highway between Amsterdam and Utrecht, Khalifa Port in Abu Dhabi, the St. Petersburg Flood Barrier in Russia, Gate LNG Terminal in Rotterdam and recently the A4 Delft – Schiedam highway. Bas is currently combining his work as deputy manager with that of a senior geotechnical consultant for different tenders and as a design leader for a flood protection project near Rotterdam. Next to his work for Boskalis, Bas is active for the DAP foundation, raising funds for research into the use of deep geothermal energy and establishment of a geothermal well at the TU Delft campus.

Further Reading

- *Bray, R. N., Bates, A.D., Land, J.M. (1996). Dredging, A Handbook for Engineers. Arnold.*
- *Van't Hoff, J., Nooy van der Kolff, A. (2012). Hydraulic Fill Manual: for dredging and reclamation works. Leiden, The Netherlands : CRC Press/ Balkema.*
- *Grotzinger, J.P., Jordan, T.H. (2014). Understanding Earth. New York, W.H. Freeman.*

Sand as a Construction Material Chris Dykstra

TUESDAY | July 5 | 2.00 - 3.00 p.m.

Sand is a naturally occurring geologic material composed of particles of rocks and minerals, sometimes of biogenic origin. According to the usual particle size definition sand is composed of particles larger than 0.06 mm and smaller than 2 mm. However, the term sand is also used to describe a soil of which the majority of the particles fall in the sand-size range.

The mechanical properties of sand are to a large extent determined by its relative density (also called density index). Each sand has a minimum density (loosest packing of the grains) and a maximum density (most compact packing). The actual in situ density of the sand relative to its minimum and maximum density determines to a large extent its mechanical properties such as shear strength and stiffness; a higher relative density leads to improved strength and stiffness. The particle size distribution (e.g. well-sorted or poorly sorted), particle shape (angularity) and mineralogy all influence the behaviour of sand. The mechanical behaviour of sand also depends on whether the pores in the sand are dry or partially or completed saturated with water. Sand that is completed saturated is particularly susceptible to liquefaction – a potentially disastrous loss of strength - during an earthquake. Sand that is partially saturated exhibits an apparent cohesion which allows steep earth slopes. Frequently a sand will need to be compacted to ensure adequate performance in a structure. An important tool for verifying the quality of the sand in a structure is the (Dutch) static cone penetration test.

Sand is a very common material and is therefore widely used as a construction material for land reclamations and road embankments or housing developments. Each sand does have its own unique properties which the designer needs to be aware of. One of the most important of these is the difference between silicate sands and carbonate sands. Both are very good construction materials but carbonate sands are more prone to crushing than silicate sands and this needs to be accounted for during quality control testing.

Chris Dykstra

Geotechnical Engineer
Boskalis

Chris Dykstra graduated from the Delft University of Technology in 1979 with a MSc degree in Mining and Engineering Geology. Chris has over 30 years of experience with Boskalis in the dredging industry, initially mostly in Research & Development and later in the Engineering Department. For the past 20 years he has been concerned especially with geotechnical aspects of the more complex turnkey projects involving design, construction and maintenance. Projects include both dredging (reclamation) and infrastructural projects (roads and dikes). Special interests are the evaluation of relationships between geotechnical parameters and settlement modelling of soft organic soils. Recent activities include in-depth analysis of stiffness and settlement in granular fill materials as related to pavement design for ports. Chris has been lead geotechnical design engineer for many projects, from the design stage through construction, monitoring and final handover to the client.

Chris is currently involved (as expert member) in a number of Dutch national committees relating to geotechnical design of infrastructure on soft soils. These include Quality Of Soft Soil Sampling (CUR), Undrained Shear Strength Approach to Dike Design (Deltares/RWS) and Use of Clay in Dikes. Chris is also currently member of a EN committee involved in drawing up a Euro Code for Hydraulic Fill constructed with sand.

Local Subsurface Characteristics in Delft

Ad van der Spek

TUESDAY | July 5 | 3.15 - 4.15 p.m.

The city of Delft is situated on the northern boundary of the Late Pleistocene – Early Holocene valley of the river Rhine. This valley has been filled in predominantly with fine-grained sediments since most of the alluvial sands transported by the river were trapped in the upstream part of the alluvial plain. The river built a small bay-head delta in the (by then flooded) valley that is partly situated underneath the city. North of the river valley a large tidal basin formed due to the rapid rise in sea level. In the middle Holocene the main distributary of the river switched to the north and the valley filled in with peat deposits. The river Meuse was still debouching in the valley, but this river discharges comparatively little water and sediment. The tidal basins north of the valley were filled in with predominantly marine sediments and peats. With the infilling of these basins the connecting tidal inlets closed and subsequently a pro-grading barrier sequence formed. The latter was fed by a supply of reworked sediments that had been left behind in the inshore zone by the rapidly receding shoreline. About 2500 years ago, a brook draining the peat swamps north of the Meuse estuary changed into a tidal creek that run far inland. This creek with the name Gantel, deposited sandy levees on which later on the city of Delft was built. Around that same moment in the past the river Rhine switched back to the south, re-occupying its earlier valley. In the medieval period the Gantel silted up and was subsequently closed off from the estuary with a dike.

Ad van der Spek

Programme leader
Eco-morphodynamics
Deltares

Dr. Ad van der Spek is a senior marine geologist specialising in long-term coastal morphodynamics. He has been working with Deltares, TNO and the Geological Survey of The Netherlands RGD for over 25 years and participated in both national and international research projects. He represents Deltares in the Netherlands Centre for Coastal Research NCK and works as senior researcher at the Physical Geography department of Utrecht University. He is lecturing and supervising students at UNESCO-IHE and the Coastal Engineering Section of Delft University of Technology. His research supports the Dutch national coastal nourishment policy and he is a member of the Netherlands Expertise Network for Flood Protection ENW. His research interests include long-term coastal morphodynamics, reconstruction of coastal evolution, dynamics of beach barriers and tidal basins, sea-bed dynamics, bio-geomorphology and large-scale catchment-to-coast sediment budgets.

Further Reading

- *Beets, D.J., van der Spek, A.J.F. (2000). The Holocene evolution of the barrier and the back-barrier basins of Belgium and the Netherlands as a function of late Weichselian morphology, relative sea-level rise and sediment supply. Geologie en Mijnbouw / Netherlands Journal of Geos., 79, 3-16.*
- *Hijma, M.P., Cohen, K.M. (2011). Holocene transgression of the Rhine river mouth area, The Netherlands / Southern North Sea: palaeogeography and sequence stratigraphy. Sedimentology, 58, 1453-1485.*
- *Hijma, M.P., et al. (2009). From river valley to estuary: the evolution of the Rhine mouth in the early to middle Holocene. Netherlands Journal of Geos., 88, 13-53.*
- *Middelkoop, H., et al. (2010). The Rhine delta – a record of sediment trapping over time scales from millennia to decades. Journal of Soils and Sed., 10, 628-639.*
- *van der Meulen, M.J., et al. (2007). Regional sediment deficits in the Dutch lowlands: implications for long-term land-use options. Journal of Soils and Sed., 7, 9-16.*

The Morphodynamical Perspective Axel Winterscheid

THURSDAY | July 7 | 9.00 - 10.00 a.m.

In the physical environment of a river it is all about material and energy. Water depth, water flow fields, sediments and the river›s bathymetry continuously interact. Climate, topography, geology, soils and the vegetation cover determine the availability of riverine physical resources: water and sediments. In response to interferences, the river is constantly changing its shape and geometry and thereby it tends to return to a state of equilibrium; this we call morphodynamics.

Human interventions have a historic and ongoing impact on the morphological state of rivers. An early interference was the construction of embankments resulting in a loss of floodplains and a subsequent loss of storage areas for fluvial sediments. Today, the navigation channels in rivers and estuaries have been deepened and straightened for larger vessels to reach a well-developed infrastructure of harbours located far inland. A wide spread of measures and actions is necessary to build and maintain this infrastructure; each one of them is forcing the river to adapt. Any transformation of the system›s state means intensified morphodynamics. Any loss of sediments causes the river to make new sediments available by eroding the river bed or the lateral banks. Such a reaction we describe as a longer-term morphological change.

Despite the available amounts of sand (and gravel) in rivers may seem very large, many examples exist to demonstrate that intervention is causing subsequent morphodynamical reactions. If you care the reaction on sand cannot be considered as (in)finite resource. Rivers need sediments to maintain its natural function and hydromorphological conditions. Sediment management plans are therefore important tools to balance the human demand for sand and to mitigate effects on nature. Three case studies from the rivers Rhine and Elbe will be presented to substantiate this morphodynamical perspective.

Axel Winterscheid

Team leader for
morphodynamics
The German Federal Institute of Hydrology (BfG)

Axel Winterscheid is a civil engineer specialised in the fields of morpodynamics, sediment transport, water and sediment management. Before moving to the German Federal Institute of Hydrology (BfG) in 2009 he stayed at the Technical University Darmstadt where he earned his doctoral degree in 2007. Today at the BfG, he is team leader for morphodynamics in the Department «Geology, Groundwater and River Morphology». His particular research interests are estuarine morphodynamics, sediment budgets and the morphological effects of dredging. As interdisciplinary knowledge and working experience has become more important he decided at an early stage of his career to set a particular focus on environmental sciences to broaden the traditional engineering perspectives. For example, in his PHD-Thesis he investigated the potential of scenario techniques in developing strategies for flood risk management. Prior to this, he was investigating the biological effects on morphodynamics in the Wadden areas using cerastoderma edule as an example.

Further Reading

- *Rijn, L.C. van (2007). Manual sediment transport measurements in rivers, estuaries and coastal seas. Aqua publications, The Netherlands.*
- *Giosan, L., Syvitski, J., Constantinescu, S., Day, J. (2014). Protect the world's deltas. Nature Comment, Vol. 516, pp. 31-33.*
- *SedNet (European Sediment Network), (2015). Moving Sediment Management Forward - The Four SedNet Messages. SedNet.*
- *Heininger, P., Cullmann, J. (eds.) (2015). Sediment Matters. Springer Verlag, Heidelberg.*

Sand Castle Building Piet Lubking

THURSDAY | July 7 | 10.15 - 11.15 a.m.

Many physical properties of sand can be personally experienced during a family day at the beach. Within living memory children have known intuitively that moist, densified sand produces a strong sand castle; they never bothered too much about the exact degrees of compaction or saturation.

During the past century the physical behaviour of moist, dense sand is investigated within many different disciplines. In soil mechanics the strength and stiffness of the material was analysed and in soil science the interaction of water and silica particles was studied, while in earthworks and road engineering the mechanical properties of moist, densified sand were tested in the laboratory and in the field. Nevertheless the qualitative and especially the quantitative influence of the water content on the strength of the moist sand remained disputable.

In the last decennium of the 20th century the creation of often spectacular and artistic sand sculptures became an international hype. However the builders hardly took advantage of the knowledge gained in the respective disciplines mentioned above, and formulated their own, frequently incorrect guidelines. Only during the past decennium the fundamental and applied research of the physical behaviour of mixtures of granular matter and fluid into the real interaction of water and silica in the pores of a sand mass was revealed and even quantified. The research of, among others, the Max Planck Institute and the Massachusetts Institute of Technology indicated that the influence of water on the strength of the sand mass is constant over a relative large range of water contents.

These results confirm that the centuries-old children's approach of sand castle building is correct: given a certain sand type it turns out that the strength of the castle is dominated by the presence of water, but the applied water content is practically irrelevant.

Piet Lubking

Course Leader
Postacademic Education Delft (Retired Specialist R&D in Deltares and Associate Professor UNESCO- IHE Delft)

Piet Lubking is a Dutch civil engineer who started working in 1966 at the Delft Soil Mechanics Laboratory (later GeoDelft and now Deltares) as a consultant and later on as head of the Hydraulic Structure Department. From 1992 to 2004 he worked as a Senior Specialist in the Applied Research and Development department of GeoDelft and as an Associate Professor at UNESCO-IHE. He was a member and rapporteur of several CROW-committees on the construction of sand subbases and the PIARC-committee TC12 (Earthworks, Drainage and Subgrade). He published several books on sand in civil engineering applications and many articles in technical magazines and proceedings of congresses. Nowadays he is retired but still acts as a course leader of the masterclass «Hands in the soil» of the Postacademic Education Delft.

Further Reading

- *Relevant tests in soil mechanics and soil science: Unconfined compression test on clay or sand samples, Soil water retention curve (pF-curve), and Proctor-curve of a sand sample.*
- *Bilz, P. (1983). Abschätzung der Kohäsion nicht bindiger Lockergesteine. Bauplanung und Bautechnik 37, Heft 7.*
- *Seemann, R., Brinkmann, M., Herminghaus, S. (2009). Auf Sand gebaut - die Physik feuchter Granulate. Physik Journal 8, nr.11; Wiley-VCH Verlag, Weinheim.*
- *Wierenga, L. (2009). Sand castles made simple. Stuart, Tabori & Amp; Chang Inc.*

Transforming Sand to Sandstone Jason DeJong

THURSDAY | July 7 | 11.30 a.m. - 12.30 p.m.

Loose, erodible, liquefiable sand in its naturally deposited state is an incompetent material upon which to build civil infrastructure. It pervasively exists along rivers and seashores, in deltas and reclaimed land, and in deserts – all places where large populations exist and continue to expand. Therefore, these loose sandy deposits must be improved prior to, or after, the construction of civil infrastructure in order to ensure society's safety. Conventional ground improvement technologies, wherein the relevant soil properties are improved to ensure adequate performance, are largely brute-force construction derived methods. This presentation will present an alternative approach in which native bacteria are used to precipitate calcium carbonate at the particle contacts of individual sand grains. When treated throughout a body of sand, a sandstone-like material is formed with the desirable engineering attributes of increased dilation, strength, stiffness, and density, and decreased permeability and liquefaction resistance.

Further Reading

- *DeJong, J.T. (2015). Sustainable Biogeotechnics. ASCE Geo-Institute Geo-strata, pp. 24- 32.*
- *DeJong, J.T., Mortensen, B.M., Martinez, B.C., and Nelson, D.C. (2010). Bio-Mediated Soil Improvement. Ecological Engineering, Vol. 36, pp. 197-210.*
- *DeJong, J.T., Soga, K.S., Kavazanjian, E., Burns, S., van Paassen, L., Al Qabany, A., Aydilek, A., Bang, S.S., Burbank, M., Caslake, L., Chen, C.Y., Cheng, X., Chu, J., Ciurli, S., Fauriel, S., Filet, A.E., Hamdan, N., Hata, T., Inagaki, Y., Jefferis, S., Kuo, M., Laloui, L., Larrahondo, J., Manning, D.A.C., Martinez, B., Montoya, B.M., Nelson, D.C., Palomino, A., Renforth, P., Santamarina, J.C., Seagren, E.A., Tanyu, B., Tsesarsky, M., Weaver, T. (2013). Biogeochemical Processes and Geotechnical Applications: Progress, Opportunities, and Challenges. Geotechnique, Vol. 63, No. 4, pp. 287-301.*
- *Bernardi, D., DeJong, J.T., Montoya, B.M., and Martinez, B.C. (2014). Bio-bricks: Biologically cemented sandstone bricks. Construction and Building Materials, Vol. 55, pp. 462-469.*

Jason DeJong

Director of Soil Interactions Laboratory
University of California, Davis

Jason T. DeJong is a Professor at the University of California, Davis. He received a BSc. from UC Davis and an MSc. and Ph.D. from the Georgia Institute of Technology. His work has been funded through more than US$7 million in grants and results have been disseminated through more than 125 publications. His work has been recognized through the ASTM International Hogentogler Award (2x), the ICE TK Hsieh Prize, the ASCE Huber Research Prize, the ASCE Casagrande Professional Development Award, and the Prakash Research Award, among others. Through the Soil Interactions Laboratory Prof. DeJong directs research in the areas of bio-mediated soils processes, integrated site characterization, behaviour of intermediate and gravelly soils (iBPT), earthquake engineering, sustainable geotechnical practice, and deep foundations. In 2015 Prof. DeJong and colleagues at UCD, ASU, GT, and NMSU were awarded an NSF Engineering Research Centre for Bio-mediated and Bio-inspired Geotechnics. The goal of the centre is to advance and integrate biogeotechnics into mainstream geotechnical practice through technical discoveries and development of a new geotechnical engineering workforce.

Basics on Concrete Material Science and their Implications Concerning the Use of Sand

Robert Flatt

THURSDAY | July 7 | 2.00 - 3.00 p.m.

Concrete is the material most used by man after water and is irreplaceable for innumerable large infrastructure developments. From the point of view of natural resources, ecology and economy, it is virtually impossible to imagine substituting concrete by any other material1. However, because of the large volumes used, its total energy and CO2 footprint is important. This material therefore needs to be improved and small steps can have a big impact, once again because of the large volumes involved.

In this lecture we will examine the main factors that condition the engineering properties of concrete, its durability as well as its environmental footprint2,3. Aspects of mix design will be discussed in this context, with a focus on not forgetting the amounts of material that are needed on a global scale4. The role of sand in this global picture will be highlighted from a material and processing point of view. The importance of particle size distribution in terms of optimization of a granular skeleton will be more specifically highlighted5.

Robert J. Flatt

Full Professor, Chair for Physical Chemistry of Building Materials
ETH Zurich

Robert J. Flatt is Professor for Physical Chemistry of Building Materials at ETH Zurich since 2010. Before that he was Principal Scientist at Sika Technology AG. for 8.5 years and postdoctoral researcher at the Princeton University for 2.5 years. He owns a master in Chemical Engineering and a PhD from École Polytechnique Fédérale de Lausanne (EPFL), Switzerland. A main research topic is the working mechanisms of chemical admixtures, which can be considered as the "spices" of concrete. On this front he is laying the scientific basis for the molecular design of chemical admixtures to achieve targeted improvements of macroscopic properties, in particular for reducing the environmental footprint of concrete. Recently, Robert co-edited the book "Science and Technology of Concrete Admixtures" with Prof. Pierre-Claude Aïticn. He has also received several awards including the RILEM Medal and was recently elected fellow of the American Ceramic Society.

Further Reading

- *Wray, P. (2012). Straight talk with Karen Scrivener on cements, CO2 and sustainable development. Am. Ceram. Soc. Bull. 91, 47–50.*
- *Habert, G., Billard, C., Rossi, P., Chen, C. & Roussel, N. (2010). Cement production technology improvement compared to factor 4 objectives. Cem. Concr. Res. 40, 820–826.*
- *Flatt, R. J., Roussel, N. & Cheeseman, C. R. (2012). Concrete: An eco material that needs to be improved. Journal of the European Ceramic Society, vol. 32, pp. 2787–2798.*
- *Aïtcin, P.-C. (2016). Science and Technology of Concrete Admixtures. Woodhead Publishing, pp. 3–13.*
- *Larrard, F. de. (1999). Concrete Mixture Proportioning: A Scientific Approach. CRC Press.*

Material Properties of (Sustainable) Concrete Henk Jonkers

THURSDAY | July 7 | 3.15 - 4.15 p.m.

Civil engineers and architects must consider different aspects when choosing a material for construction: functional performance, aesthetics, and financial and environmental costs. Use of construction materials and civil engineering-related processes have an impact on the environment. However, the environment also influences the performance and service life, i.e. the durability, of construction materials. Therefore besides of aforementioned aspects, also durability characteristics which can be strongly influenced by the particular environment in which the material has to perform, determine the choice for a material in a particular construction and environment.

In what way do specific environmental conditions affect the durability of typical construction materials? The engineer must take the concrete different environmental classes into consideration when defining the required concrete mixture composition and final concrete characteristics. Certain environmental elements, either derived from natural-, industrial- or civil engineering processes affect material properties such as durability characteristics. Thus, it can be concluded the environment and civil engineering activities, including construction materials applications, mutually influence each other.

Knowledge of chemical processes and bio-chemical reactions happening in the environment results in a better understanding of what amounts and types of harmful elements (both for construction materials and natural ecosystems) can be expected in a certain environment. Natural elements often occur in different forms, each featuring specific properties, resulting in different effects on either materials or environment. The conversion processes of elements such as carbon, nitrogen and sulphur, are often cyclic in nature, either on local or global scales. Knowledge of natural element cycles increases our understanding of material durability performance.

Henk M. Jonkers

Associate Professor, Chair bio-based construction materials
Delft University of Technology

Henk Jonkers studied Marine Biology at Groningen University, the Netherlands, were he also obtained his PhD in Marine Microbiology in September 1999. After working for 7 years as research scientist in the Microsensor Research Group at the Max-Planck-Institute for Marine Microbiology, Bremen, Germany, he joined as associate professor the Materials & Environment section of the Faculty Civil Engineering & Geosciences of the Delft University of Technology where he is now chairing the bio-based construction materials & sustainability group. His interests and currently running research projects include the development of sustainable bio-based construction materials, self-healing materials, and quantification of sustainability by applying life cycle assessment (LCA) tools.

Further Reading

- *Sierra-Beltran, M.G., Jonkers, H.M. and Mera-Ortiz, W. (2015). Field Application of Self-healing Concrete with Natural Fibres as Linings for Irrigation Canals in Ecuador.*
- *Sierra-Beltran, M.G. and Jonkers, H.M. (2012). Development of bio-based mortar system for concrete repair. Concrete Repair, Rehabilitation and Retrofitting III, Taylor & Francis Group, London, ISBN 978-0-415-89952-9.*

Urban Design with the Subsurface Fransje Hooimeijer

THURSDAY | July 7 | 4.30 - 5.30 p.m.

Urban designers are often accused of limiting their view of the subsurface to the back of their drawing paper, even though the subsurface not only fulfils numerous functions that are crucial to urban construction such as infrastructure, load-bearing capacity, heat and water supply but also contains the natural system upon which urban quality and health depend. Given the current background of climate change, energy transition and the financial crisis, these issues about subsurface functions have become more important for different reasons. The subsurface stores water and plays a role in cooling the city, geothermal heat is renewable energy and using the subsurface intelligently can be financially rewarding. In addition, urban renewal is preferable to land take (in greenfield areas). Urban areas are not empty below the surface level: the subsurface is already being used in many ways. 'Urban design with the subsurface' should be considered a new frontier in urban planning and design. Urban projects are often hampered by the fact that responsibilities, tools and knowledge about subsurface engineering and urban planning and design are not integrated: these domains are interdependent, but they are organized on sectoral lines. Urban designers usually focus on opportunities for generating socio-economic benefits, and subsurface engineers address the challenge of tailoring subsurface conditions in line with the activities required above the surface.

This presentation goes into the interdependence of the technosphere and biosphere in the subsurface and how they are linked to urban development on the surface. It introduces an eco-engineering perspective, which includes the entire subsurface as a complex system in urban design. It involves an enormous culture change that affects attitudes and the organization of urban projects, and close cooperation between urban designers and engineers..

Fransje Hooimeijer

Assistant Professor
Environmental Technology and Design
Delft University of Technology

Fransje Hooimeijer studied Architecture (BA) Arts and Culture Studies (MA) and has worked as an independent researcher in the fields of architecture, urban design and landscape architecture since 1997. In addition to various publications and exhibits, she has done research for government and corporate clients. She received her PhD in Urbanism from the Faculty of Architecture at the Delft University of Technology (TU Delft) in 2011 with the dissertation explaining the relation between water management and urban design. From 2009-2012, she has worked as a researcher at the TU Delft and at TNO, investigating the technology of urban development in the light of climate change and the energy transition. One of her main research topics is integrating the subsurface system into above-ground spatial development. Since 2012, she has been Assistant Professor in Environmental Design and Technology.

Further Reading

• *Palmboom, F. (2010). Drawing the Ground - Landscape Urbanism Today, The Work of Palmbout Urban Landscapes. Birkhäuser.*

• *Hooimeijer, F.L. (2014) The making of polder cities: a fine Dutch Tradition. Rotterdam: Jap Sam Publishers.*

Developing Alternative Materials Dirk Hebel

FRIDAY | July 8 | 9.00 - 10.00 a.m.

Can a grass replace structural elements made out of steel or timber? Can building materials made out of desert sand or soil and their application be a wide spread alternative building technology? Can a "three-storey-city" be built with local available materials and can the resulting neighbourhoods be as dense as high-rise typologies suggest? Could waste be a future resource for the building sector?

The 21st century will face a radical paradigm shift in how we produce materials for the construction of our habitat. While industrialization has resulted in a conversion from regenerative to non-regenerative material sources, our time will experience the reverse: a shift towards cultivating, breeding, raising, farming, or growing future resources. For centuries, the linear thinking of "producing, using, and discarding" was the dominant method of any industrialized value chain. Recyclability, embodied or grey energy, acceptability for repositioning, sorted reassembly and other terms became evaluation criteria for a more and more sensitized society. A new generation of cultivated building materials easily adopts such a model: not only can a house be grown, it could also be composted after its use.

Next to empirical research, meaning gaining knowledge through observation, the Assistant Professorship of Architecture and Construction Dirk E. Hebel has quantified these hypotheses through scientific engineering and the establishment of new and specialized laboratories. Including other partners, test scenarios and standards have been developed to compare the results to already established building substances. The research has focused on full-scale material applications based on workshop environments, including students and other researchers from various fields and backgrounds.

Further Reading

• *Hebel, D. E., Wisniewska, M. H., Heisel, F. (2014). Building from waste: recovered materials in architecture and construction. Birkhäuser.*

Biocementation – Self Healing Concrete Henk Jonkers

FRIDAY | July 8th 10.15 - 11.15 a.m.

In recent years, a novel type of 'self-healing concrete' is being developed. In these research projects the suitability of very specific but otherwise harmless bacteria are tested for their ability to repair cracks and thus significantly improve the durability of concrete structures. Such a "bio-concrete" would be beneficial for the economy and the environment at the same time, since it would make costly manual repair unnecessary and would minimize the use of raw materials, as structures would last longer.

In nature different varieties of bacteria occur and some are likely well adapted to artificial man-made environments such as concrete. Specialized group of bacteria, the ‹extremophiles›, can live in this extreme environment. Some of these bacterial species are not only known to love extremely dry conditions, but also to be able to produce copious amounts of limestone. This calcium carbonate-based material, as well as other types of bio-minerals produced by bacteria, could serve to seal or heal cracks in concrete.

The functionality of the developed "healing agent", comprising encapsulated bacterial spores and nutrients, has been confirmed in several specific outdoors applications. Due to the positive results and market interest, the TU Delft start-up company "Basilisk Self-Healing Concrete" has been established to further develop the technology and bring it to the market. Three products are currently being developed and tested in practical applications, 1. Self-healing concrete, 2. Self-healing repair mortar, and 3. Spray-able liquid repair system.

Further Reading

• *Jonkers, H.M., Wiktor, V.A.C., Sierra-Beltran, M.G., Mors, R.M., Tziviloglou E., Palin, D. (2015). Limestone-producing bacteria make concrete self healing. Self healing materials - pioneering research in the Netherlands, S. van der Zwaag, E. Brinkman (eds.) IOS Press, pp. 137-148.*

• *Hill, D. (2015). Self-healing concrete uses bacteria to heal cracks. Civil Engineering, pp. 44-45.*

• *Arnold, D. (2011). Self-healing concrete. Ingenia Issue, pp. 39-43.*

Waste Based Bricks Ward Massa

FRIDAY | July 8 | 11.30 a.m. - 12.30 p.m.

The building sector is often seen as highly conservative. Trying to change the habit patterns of how we build and the materials we use when building is a long and slow process. A start-up company on the other hand has to move fast. Investors want results, and they want it yesterday. StoneCycling has the humble goal to change the cornerstone of the building industry; the brick.

Over the last year we've been developing, designing and presenting various WasteBasedBricks such as the Caramel. Truffle, Aubergine and BlackPepper. These are exiting times for StoneCycling. The first building have been built, both in Amsterdam and Rotterdam. Top architecture agencies from all over the world have shown interest in our work. The coming year will be the year of truth. It can take easily three years from talking to an architect until actually building the building. This long stretch of time is extremely challenging for a start-up company. Will we survive?

During this lecture, we will take you along on our adventure and give you an insight on how we are trying to change the way we build, and what effect it has on the market and on ourselves. We will focus primarily on the business adventure and little less on the technical aspects.

Ward Massa

Director and co-owner
StoneCycling

Ward Massa is one of the owners of StoneCycling. Until a few years ago he didn't know much about the building sector; now a bit more. He has a background in political science and political communication, studied at University of Amsterdam and at Delhi University in India. Besides StoneCycling, he is also the initiator of the NewSchool Challenge, a project that aims to develop the self-sustainable low cost school buildings of the future for India. The project is a collaboration between various organisations such as TU Delft, IIT Mumbai, UN Habitat India and UNESCO IHE.

Further Reading

• *Hebel, D. E., Wisniewska, M. H., Heisel, F. (2014). Building from waste: recovered materials in architecture and construction. Birkhäuser.*

Designing with Alternative Materials Elvin Karana

FRIDAY | July 8 | 2.00 - 3.00 p.m.

Materials research constantly evolves to offer novel, superior materials as better alternatives to convention for product design (e.g., bio-based materials, smart materials, recycled and/or recyclable materials, etc.). In parallel, designers increasingly attempt to develop their own materials, to express their personal vision and understanding of 'the matter of design'. Such DIY Materials are created through individual or collective self-production practices, often by techniques and processes of the designer›s own invention (Rognoli et al, 2015). Many emerging materials (whether self-created or not) have superior properties which meet the practical and environmental demands of a product, as well as they captivate people's appreciation through unique experiential qualities (Karana et al., 2014). However, finding meaningful applications for such novel materials, with unfamiliar qualities, is far from straightforward. In this lecture, I will present a couple of design cases illustrating how designers design with such emerging (alternative) materials and reach to meaningful applications, by means of a recently developed method on Material Driven Design (Karana et al, 2015). The cases will vary from mycelium-based materials to cellulosed-bio-plastic composites, from electro luminescent materials to materials made of coffee waste.

Elvin Karana

Associate Professor,
Faculty of Industrial
Design Engineering
Delft University of Technology

Elvin Karana is Associate Professor in the Faculty of Industrial Design Engineering (IDE) at Delft University of Technology (DUT), The Netherlands. She undertook her PhD research at DUT, where she developed a 'Meaning Driven Materials Selection Tool' to support designers in their materials selection activities. Since then, she has been leading a number of research projects focusing on design for material experiences. In her work, she proved the notion of 'materials experience' to be actionable in design thinking and applicable to both in design practice and design research. Elvin is the main editor of "Materials Experience: Fundamentals of Materials and Design" (2014, Elsevier).

Further Reading

• *Karana E., Barati, B., Rognoli V., Zeeuw Van Der Laan, A., (2015). Material Driven Design (MDD): A Method To Design For Material Experiences. International Journal of Design, 9(2), 35-54.*
• *Giaccardi, E., Karana, E. (2015). Foundations of Materials Experience: An Approach for HCI. In Proceedings of CHI 2015. Seoul, South Korea. ACM Press: 2447-2456.*
• *Karana E., Pedgley O., Rognoli V., (2014). Materials Experience: Fundamentals of Materials and Design, 1st Ed., Butterworth-Heinemann: Elsevier, UK. (http://store.elsevier.com/Materials-Experience/isbn-9780080993768/)*
• *Karana E., Pedgley O., Rognoli V., Korsunsky, A. (2016). Emerging Material Experiences, Special Issue Editorial, Materials & Design.*
• *Rognoli, V., Bianchini, M., Maffei, S., Karana, E. (2015). DIY Materials. Materials & Design, 86: 692-702.*

Fungal Futures: Growing Domestic Bio-Landscapes

Maurizio Montalti

FRIDAY | July 8 | 3.15 - 4.15 p.m.

One of the main challenges of the current century is to transform our consumption oriented economic system into an ecologically-responsible, conscious and self-sustaining society. It is therefore paramount to envision and to develop alternatives tackling the urgent issues characterising collective communities worldwide. One of these being waste generation and the subsequent environmental impact originated by oil-based/synthetic/toxic compounds (plastics), as well as by consumer's behaviour.

By entering a direct partnership with micro-organisms (e.g. fungi), a range of novel opportunities is created, allowing to envision and test a radical paradigm shift, offering a different insight into the objects of our everyday life and the materials they consist of, as well as into the way production systems could be conceived and reinterpreted. Hence, the mycelia ("root-system" of fungi) of selected fungal species are to be looked at as the main actors, responsible for favouring the growth of harmless materials, products and systems. One main quality lies in valuing existing, organic wastes, transforming them into a vast array of novel matters, each characterised by diverse qualities and suitable for different applications. The resulting "cultivated" objects are 100% natural, fully compostable and resulting from waste streams (i.e. Circular Economy), tangible signifiers of the way in which materials must and will change in the upcoming future (i.e. bio-technological revolution) and of how manufacturing processes and techniques will modify accordingly.

By discussing a number of projects outlining such transformative processes, we will explore and possibly demonstrate how working with living organisms and systems can lead to ground-breaking, innovative outcomes. Thus, contributing to positively impact at large, affecting both industry and consumer's behaviour and balancing the role of the individual with the ecosystem the individual is part of.

Maurizio Montalti

Designer, researcher
and entrepreneur
Officina Corpuscoli and Mycoplast

Officina Corpuscoli (OC), founded by Maurizio Montalti in 2010, is an Amsterdam-based transdisciplinary design practice, seeking to reveal unorthodox relationships among existing paradigms. By distilling research and analysis and materialising relevant facts, OC's goal is to create conditions that allow for a resonant critical experience, by the synthesis of ideas through design. OC actively engages in collaborating with professionals from other disciplines, while providing creative consultancy and developing commissioned and self-initiated projects, mostly inspired by and in direct collaboration with living systems and organisms. OC's work has been widely shown in multiple museums, exhibitions and festivals, both nationally and internationally. Maurizio is also the co-founder of Mycoplast, a company focused on industrial scale-up of mycelium based materials, services and products. Further, he is involved in education, heading the MAD Master at Sandberg Instituut, and conducting research in affiliation to Design Academy Eindhoven and Utrecht University, as well as teaching, lecturing and mentoring in different national and international academies and universities.

Further Reading

- *Stamets, P. (2005). Mycelium Running: How Mushrooms Can help Save The World. Ten Speed Press.*
- *Tabellini, G. (2015). Mycelium Tectonics. Alma Mater Studiorum Bologna. http://mycelium-tectonics.com/*
- *Holt, G. A., et al. (2012). Fungal Mycelium and Cotton Plant Materials in the Manufacture of Biodegradable Molded Packaging Material: Evaluation Study of Select Blends of Cotton Byproducts. Journal of Biobased Materials and Bioenergy, vol. 6, pp. 431-439.*
- *Montalti, M. (2016). Fungal Futures: Growing Domestic Bio-Landscapes. http://www.fungal-futures.com/*

Recycling Building Components Lionel Billiet

FRIDAY | July 8 | 4.30 - 5.30 p.m.

If one were to run statistics on what causes a building element to be discarded, there is a big chance that "damage by use" would only score a few percent. In most cases, building components evacuated during a demolition are still mostly functional. Triggering the demolition, then, will be a real estate operation, for instance, or the taste of a new tenant. The question is then: can a sound component survive the demolition of the building it was part of?

This lecture will present the work of Rotor on the reuse of building products. It will dwell in particular on how to organize the recirculation of building elements that are candidates for reuse because of their economic, cultural or functional value.

Rotor gathered hands-on experience in organizing large-scale reclamation operations in post-war buildings. In some cases, these operations concerned interior finishing touches from anonymous contemporary office spaces: partition walls, doors, raised floors, lightning fixtures, technical and sanitary equipment, etc. In other instances, the dismantling operations took place in buildings with direct heritage value, mostly dating from the postwar decades and linked to the modernist movement in architecture.

Lionel Billiet will discuss the many factors determining the reuse potential of a building component. One crucial factor is the existence (or absence) of an established market allowing to bring the component from the deconstruction site to the next user. Different paths to a further development of component reuse as a mainstream practice in construction will be examined and confronted to the many direct challenges.

Lionel Billiet

Project leader
Design Engineering
Rotor Brussels

Lionel Billiet (1986, Brussels) joined Rotor after graduating as a bio-engineer at the Vrije Universiteit Brussel (VUB) in 2010. Within Rotor, Lionel mainly works on topics related to the reuse of building elements, and on construction and demolition waste. In 2013, he was in charge of Rotor's Opalis project, the first exhaustive study of the professional sector for reclaimed building materials performed in Belgium, which resulted in the website www.opalis.be. Lionel also played a key role in launching the spin-off Rotor Deconstruction, an innovative salvage company active in the reclamation of interior components from post-war tertiary buildings. In 2015, this spin-off allowed to divert more than 400 tons of reusable building elements from the waste container. Lionel also carries out consultancy missions and advises professional building actors on reuse through workshops and lectures.

Further Reading

- *Rotor, (2015). Vade-mecum pour le réemploi hors-site, Comment extraire les matériaux réutilisables de bâtiments publics?, Brussels, http://rotordb.org/project/2015_Vademecum_Deconstruction*
- *Addis, B., (2006). Building with reclaimed components and materials: a design handbook for reuse and recycling, London: Eartscan.*
- *Wrap (2013). Reclaimed products guide. A guide to procuring reclaimed building products and materials for use in construction projects, United Kingdom, http://www2.wrap.org.uk/downloads/Reclaimed_building_products_guide.edb459e7.5259.pdf*
- *Locus Foundation (2015). Rotor, in Global Award for Sustainable Architecture – Symposium Press Pack, Paris, pp. 22-27.*

Planning for the Future: Green and Sufficient Dimitra Ioannidou

MONDAY | July 11 | 9.00 a.m. - 12.30 p.m.

What are the CO2 emissions from transporting stone tiles from China? How is the use of electricity from hydropower plants and from coal thermal power stations related to the ozone depletion? Life Cycle Assessment (LCA) is the most common method used to assess the environmental impact of products. It is increasingly used in the design process to compare the environmental behaviour of alternative products, by accounting for the whole life cycle from the time of extraction of the raw materials till the time of disposal or recycling of the final product (or till the demolition of the building). In this session, we will explore the basics of this method and will learn how to perform a LCA through a real case study.

The second part of the session focuses on resources. Sand and gravel are considered infinite on a global scale. However, in many parts of the world with an intense construction activity they are overexploited and face the risk of depletion. Therefore, a sustainable design and development should take into account how critical these resources in every location are. Some of the parameters to be taken into account are the accessibility of the resources, their importance for the local economy and the possibility of substituting them in the case of depletion. We are going to delve in the details of indicators and methodologies developed to assess the risk of resource depletion.

Dimitra Ioannidou

Doctoral candidate
Chair of Sustainable Construction, ETH Zurich

Dimitra Ioannidou is a civil engineer from the National Technical University of Athens (2006) with a Master of Science in Construction Engineering and Management from Stanford (2008). From 2009 to 2013, she worked in the construction industry from different positions. Since February 2013, she is conducting research at ETH Zurich towards her doctorate. Her study deals with the sustainability of stone used in construction and with resource depletion.

Her research interests focus on the life cycle assessment and thermal behavior of structures and the environmental, economic and social impacts of using stone in construction. Her contribution has been instrumental in the development of a new indicator for evaluating the accessibility of construction aggregates and of a new method for assessing the economic flows in construction projects.

Further Reading

- *Ioannidou, D., Nikias, V., Brière, R., Zerbi, S., Habert, G. (2015). Land-cover-based indicator to assess the accessibility of resources used in the construction sector. Resources, Conservation and Recycling, 94, 80-91.*
- *Graedel, T.E., Barr, R., Chandler, C., Chase, T., Choi, J., Christoffersen, L., Friedlander, E., Henly, C., Jun, C., Nassar, N.T., Schechner, D. (2012) Methodology of metal criticality determination. Environmental science & technology, 46(2), 1063-70.*
- *Sonnemann, G., Gemechu, E.D., Adibi, N., De Bruille, V., Bulle, C. (2015). From a critical review to a conceptual framework for integrating the criticality of resources into Life Cycle Sustainability Assessment. Journal of Cleaner Production, 94, 20-34.*
- *Baumann, H., Tillman, A.M. (2004). The Hitch Hiker's Guide to LCA. An orientation in life cycle assessment methodology and application. Studentlitteratur AB, Lund, Sweden. Chapters 1, 3, 4 (p. 97-112), 5 (p. 129-147).*

Can We Build with Seawater?

Eric Geboers

FRIDAY | July 15 | 9.00 - 10.00 a.m.

When looking at the location of deserts and areas facing desertification we notice two things: there is plenty of energy available in the form of solar power. Secondly, and paradoxically, many dry areas are close to large bodies of water: salt water. About a year ago we launched a proposal to separate seawater into fresh water and salt using the power of the sun. The fresh water can be used to combat desertification, while the salt will be used to make a new kind of architecture: Salt Architecture.

We developed a new generation bio-based material made with 90% salt and low energy consumption. It is strong enough to build two-storey structures. We are currently doing applied research in our Salt Lab in Rotterdam, with the goal of scaling it up in desert environments.

The lecture will focus on the production, integration, application and aesthetic possibilities of this salt-based material, from the molecular scale to its potential impact on a global scale. We will explore the whole process from seawater to architecture, going over issues as local production and life cycle, the practicalities of construction, sustainability, costs, material efficiency and architectural possibilities.

Eric Geboers

Architect
The Salt Project

Eric Geboers is a Dutch architect, who graduated from the TU Delft in 2015 at the Faculty of Architecture. Before graduation he studied architecture at the University of Melbourne and the Universitat Politècnica de València, and worked as a representative in Xiamen, China for Dutch architecture firm AULa. His graduation thesis ‹The Salt Project› won numerous awards, both Dutch and international, and was featured in publications all over the world. Since graduating, he continued his research towards creating a building material from seawater as a business while collaborating with the TU Delft. Eric is inspired by the ideas of bio-mimicry: applying processes, patterns and collaborations found in nature to come to practical solutions, and interested in integrating waste streams and using local means for production in the built environment.

Further Reading

- *Geboers, E. (2016). The Salt Project van Eric Geboers. http://www.architectuur.nl/architect-2/the-salt-project-van-eric-geboers/*
- *Kulshreshtha, Y. (2015). CoRncrete: A bio-based construction material. http://repository.tudelft.nl/view/ir/uuid%3A0919b058-4499-493f-b024-88c948ade7ff/*
- *Geboers, E. (2015). The Salt Project. http://repository.tudelft.nl/view/ir/uuid%3A528c3ddc-8a7e-4b95-89a3-60185109e674/*

«Sand wars» a film by Denis Delestrac produced by La Compagnie des Taxi Brousse, Rappi Productions, InformAction and Arte France.

Workshops

As has been shown in the opening week, materials, energy, space, human capital, etc. can all be considered resources. And ideally, in a circular economy none of these reserves would go to waste. After the applied experience of the three workshops, (1) Bio-cementation, (2) Crystallization and (3) 3D printing with sand, the Summer School will conclude with a competition workshop. The challenge for the competition workshop is to identify one such resource and (re-)introduce it to a circular metabolism.

The competition workshop will ask the participants to apply some of the discussed concepts (resource scarcity, life-cycle assessment, alternative construction materials) through the design and development of their own alternative construction material. While the Summer School focusses on sand as a scarce resource, the question of sustainable use of resources is not isolated nor restricted to one material.

The steps in the competition workshop are:
Identify a scarce resource (natural, artificial, energetic, waste product, space, etc.) and describe the pressure this resource exercises on an ecosystem, as well as the consequences of the 'conventional' continuous exploitation or waste accumulation.
Speculate on the potential of this resource and identify why it has not been used circular so far? Explain your approach to activate it and describe the external parameters necessary to make this approach viable.
Assess the resource in terms of renewability, sustainability and innovation character.
Apply a transformation technique (acquired in the Summer School or self-designed) to the resource and produce an object that could be considered a building material. Develop and document this technique or tool.
Present the results as a slide-show as documentation of the process and as a physical material sample (or model in case of spatial, energetic or other abstract resources) to the jury.

The evaluation criteria are:
Identification of the resource and stringency of argumentation
Evaluation and life-cycle assessment of the material
Ingenuity of the transformation technique
Innovation of the material and sustainability potential
Clarity of the presentation and documentation

The goal of the workshop is a hands-on experience with the theoretic and practical content of the Summer School. A jury will discuss the innovative and creative proposals together with the whole group, concluding the program of the School.

Competition Workshop Responsibles

Aurel von Richthofen
Module Coordinator: Alternative Construction Materials, Future Cities Laboratory
Assistant Professor of Architecture and Construction Dirk. E. Hebel

Felix Heisel
Researcher and teaching assistant
Assistant Professorship of Architecture and Construction Dirk. E. Hebel

Further Reading

• *Baccini, P. Metabolism of the Anthroposphere: Analysis, Evaluation, Design. 2nd ed. Cambridge, Mass: MIT Press, 2012.*
• *Hebel, Dirk E., Aurel von Richthofen. "Sand Lab: Transforming Desert Sand Into Glass." FCL Gazette, no. 24 (May 30, 2015). http://www.fcl.ethz.ch/assets/Gazette-24.pdf.*
• *Hebel, Dirk E., Marta H. Wisniewska, and Felix Heisel. Building from Waste: Recovered Materials in Architecture and Construction. 1st ed. Berlin: Birkhauser, 2014.*
• *Schulz, Niels B. "UNU-IAS Working Paper No. 136 - Contributions of Material and Energy Flow Accounting to Urban Ecosystems Analysis: Case Study Singapore," 2005. http://archive.ias.unu.edu/binaries2/IASWorking-Paper136.pdf.*

Workshop 1

Part 1 - CorNcrete

Description

Natural biomaterial derived from plants such as corn starch is widely used as a cooking ingredient. The renewability and bio-degradability of starch make it also an interesting material for the industrial applications. This workshop introduces the application of corn starch in the production of a novel construction material, named CoRncrete. CoRncrete is prepared by a simple and fast process.

Goals

To understand role of a natural polymers in enhancing the mechanical properties of sand.

Outcomes

The workshop will introduce participants with production process and properties of fresh and unhardened CoRncrete.

Approach and methods

Building with CoRncrete is fun and not that different from building sand castles on the beach. In this interactive workshop, participants will initially explore the bizarre fluidic properties of fresh CoRncrete. Afterwards, they will select or prepare moulds of desired shape and size. They will prepare the hardened CoRncrete sample by a heating process. Finally, the hardened material will be tested for compressive strength.

Further Reading

• *Kulshreshtha,Y. (2015). CoRncrete: A bio-based construction material. Master thesis, Civil Engineering and Geosciences, Delft University of Technology. http://repository.tudelft.nl/view/ir/uuid%3A0919b058-4499-493f-b024-88c948ade7ff/*

Part 2 - Bio-based cementation

Description

Recent development in science has shown wide range of application for bio-based cementation in Geo- and Civil Engineering applications such as ground improvement by microbial induced carbonate precipitation (MICP) in order to mitigate liquefaction, prevent erosion of slopes or suppress to wind-blown dust from dry surfaces and in self-healing of concrete. In this workshop, participants will get hands on experience with the use of bio-based products and processes to enhance the mechanical properties of sandy soils. This workshop is related to the CoRncrete workshop. In this workshop, participants will learn the technique of ground improvement by in situ bio-cementation using MICP, either chemically or with bacteria.

Goals

To understand the essential aspects of applying biological processes and products to enhance the mechanical properties of sandy soils and construction materials. After the workshop participants are able to identify the main advantages and limitations of several bio-based cementation processes, make lab scale samples of biologically cemented sand and test the quality of their result.

Approach and methods

In this workshop, students will experiment with different cementation techniques on sand specimens, including the ingredients calcium chloride, sodium carbonate, yeast extract, urea, specific strains of ureolytic bacteria. The available equipment allows them to make consolidated sand structures using these different techniques. Furthermore, the performance of the different cementation processes will be evaluated in terms of compressive strength and wear resistance.

Workshop Responsibles

Henk Jonkers
Associate Professor, Chair bio-based construction materials
Delft University of Technology

Leon van Paassen
Assistant Professor Applied Earth Sciences
Delft University of Technology

Yask Kulshreshtha
Research Assistant, Faculty of Civil Engineering & Geosciences
Delft University of Technology

Further Reading

• *Van Paassen, L.A. (2009). Biogrout, ground improvement by microbial induced carbonate precipitation. PhD dissertation Delft University of Technology. http://repository.tudelft.nl/islandora/object/uuid:5f3384c4-33bd-4f2a-8641-7c665433b57b?collection=research*

• *Van Paassen, L.A., Ghose, R., van der Linden, T.J.M., van der Star, W.R.L., van Loosdrecht, M.C.M. (2010). Quantifying biomediated ground improvement by ureolysis: Large-scale biogrout experiment. Journal of Geotechnical and Geoenvironmental Engineering, 136 (12), pp. 1721-1728.*

• *Phillips, A.J., Gerlach, R., Lauchnor, E., et al. (2013). Engineered applications of ureolytic biomineralization: a review. Biofouling 29(6), pp. 715-733.*

Workshop 2

Description

The extraordinary behaviour of sand stimulates us to rethink about its matter, for instance sand is a solid material, it supports the weight of a person; yet it can be poured like a liquid by adding water. It turns structurally stable, almost like a solid, then acts like a liquid again when there is much more liquid than sand.

At the intersection of physics, engineering, art and architecture, "Sandworks" workshop explores the astonishing potentials embedded in the behaviour of sand to develop an ecological architectural tectonic prototype. The workshop investigates the sand life cycle, phase changing properties and its self-organization behaviour under gravitational forces to develop a specific set of material and fabrication systems based on sand, salt and water.

Within collaborative teamwork, the participants are encouraged to physically design and fabricate a large wall installation that is part structural, part ornamental in response to specific contextual constraints. The dry intrinsic formations of sand are hardened through a saline solution that turns solid instantly, yet it dissolves in water to redistribute the material back to its nature with zero waste. The 35 degree angle of repose is a simple behaviour of sand that evolves into complex iterations over time revealing the hidden mathematics, physics and geology of granular materials which would inspire the participants to rethink about sand in different disciplines.

Goals

The workshop aims to introduce the participant to the embedded opportunities in materials for sustainable development in architecture while considering the question of material and building lifecycle and lifespan.

Outcomes

The outcomes are the following:
• Reconsideration the notion of temporality in material and building lifecycle and lifespan.
• Theoretical and practical understanding of the physics of sand behaviour.
• Develop a design sensibility based on material behaviour that is driven by a negotiation between matter and applied forces to generate material based structures.
• Hands-on practice of non-linear design systems and material based model of thinking.
• Experiencing physical computing design systems.
• Encouraging interdisciplinary models of development between nature, physics, engineering and design.
• Application of the research techniques of sand distribution and solidification.
• Collaborative design and fabrication of a sand wall installation.

Approach and method

"Sandworks" is a material based workshop that applies digital and physical methods of material computation to design and fabricate a wall installation of solid sand panels through collaborative team works. Participants are encouraged to develop their own designs over a prepared base for the wall installation.

The installation is an ornamental wall structure for external and internal use composed of a number of panels. The wall is made out of predefined Mdf panels which the participants will use as a base to create their own sand patterns and solidify it with the saline solution. Each group will produce a small number of panels based on their local organization strategy in response to the global organization of the other groups to create a coherent installation. The installation has multiple patterns with gaps that create a three-dimensional surface of sand which will be mounted on an internal or external wall.

The wall dimensions are 2.10 x4.00 m, being each panel 30 x 40 cm. Thus, each participant will produce 2-3 panels, using two fabrication techniques: spraying of sand with salt and moulding of a liquid mixture of sand and salt. The students will work on teams of 5-7 persons.

The workshop will be divided as follows:
• Lecture: Theoretical background of material based design focusing on the work of Frei Otto and the current research methods.
• Demonstration of physical design and fabrication techniques (60 min): practical explanation of the dry sand distribution methods and solidification techniques with the saline solution.
• Description of groups' tasks (30 min): large production organization
• Group work (9 hours): Design and fabrication of the wall panels
• Installation and documentation (2 hours).

Ahmed Hussein
M.Arch in Architecture
École Nationale Supérieure d'Architecture Paris-Malaquais / ENCODE Studio

Ahmed Hussein is an architect graduated from the Architectural Association (AA) School of Architecture in London, UK and a tutor and researcher at the Geometry Structure Architecture (GSA) laboratory at Paris-Malaquais. His research interest explores new modes of digital and physical production based on natural and mathematical logic of material systems in architecture, as well as advances in the field of digital fabrication and robotics.

After receiving his MSc. in architecture from the Faculty of Fine Arts at Alexandria University, Ahmed received his M.Arch degree, with project distinction, from the Design Research Laboratory (DRL) at the AA School of Architecture. Currently, he is a PhD candidate at the National School of Architecture Paris-Malaquais teaching and working on the development of sand behaviour towards an ecological architectural tectonic through digital simulation and robotic fabrication. Ahmed is founder and associate architect at ENCODE design studio in Alexandria, where he collaborates to develop the design industry and production in Egypt by linking practice and education through research and prototyping.

Further Reading

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• *Otto, F., Rasch, B. (2001). Finding Form: Towards an Architecture of the Minimal. Page 64.*
• *Kwinter, S., Boccioni, U. (1992). Landscapes of Change: Boccioni›s «Stati d›animo» as a General Theory of Models.*
• *Duran, J. (2000). Sands, Powders, and Grains: An Introduction to the Physics of Granular Materials.*
• *Duran, Jacques. Videos on sand behaviour: https://www.youtube.com/user/GrainsDeBatisseurs/videos*

Workshop 3

Description

This workshop will explore the process of 3D printing sand aggregate concrete over a two day period, including the operation of a concrete 3D printer and the excavation of a stable concrete print. As digital fabrication and computational design techniques proliferate within the architectural profession, experimentation with the creation of novel digital fabrication tools and techniques continues to be a productive driver of design processes. Additive fabrication in particular promises a great variety and depth of techniques that until recently were inaccessible to designers due to the high barrier to entry to custom precision robotics and computational methods. This workshop will cover the opportunities and challenges presented by powder bed, sand aggregate 3D printing as well as the formal and structural potentials that are embedded within the technique.

Outcomes

At the end of this workshop, students can expect to have a functioning practical knowledge of powder bed 3D printing techniques as well as the creation and control of gantry based machines. Students will participate in the use of a sand aggregate 3D printer and the excavation of a large scale concrete 3D print. The efforts of the workshop will result in a structurally robust and formally novel sand aggregate 3D print.

Goals

This workshop will educate its attendees on a number of topics concerning the design, fabrication and function of sand aggregate additive fabrication. While powder bed style printing allows nearly unlimited geometric freedom, the structural performance of concrete prioritizes specific formal strategies over others. Students will explore the opportunities presented by concrete additive fabrication as well as have a working understanding of how powder bed additive manufacturing behaves at architectural scales.

Approach and methods

This workshop will begin with a brief introduction to the research pursued by Alan Cation and Clayton Muhleman during their graduate studies at California College of the Arts and their fellowship at the AutoDesk Pier 9 workshop in San Francisco. After a discussion on the possible architectural potentials of full automated, on-site fabrication, the workshop will collaborate on a 3D print, allowing each of the students to directly participate in its operation and maintenance. At the completion of the 3D printing process, the print will be allowed to cure for 24 hours before being excavated collaboratively by the class.

Clayton Muhleman
Research Associate at the Digital Craft Lab
California College of the Arts

Clayton holds a Bachelor of Design from the University of California at Davis and a Master of Architecture from California College of the Arts (CCA). Clayton's work and research focuses on the design process implications of the proliferation of computational tools and robotics in architecture and the built environment. In collaboration with Alan Cation and studying at CCA under Jason Kelly Johnson and Nataly Gattegno, co-founders and design principals of Future Cities Labs, Clayton›s research while at CCA focused on large scale 3D printing, autonomous fabrication, and artificial intelligence in architecture. Clayton currently holds the position of Research Assistant at California College of the Arts, working with Professors Jason Kelly Johnson and Andrew Kudless, (principal of Matsys), to further the research taking place at the Digital Craft Lab at CCA.

Alan Cation
Architectural Designer and Researcher
California College of the Arts

Alan Cation received his Bachelor of Science in Architecture from Southern Illinois University and his Master of Architecture from California College of the Arts (CCA). His work focuses on computational design, 3d printing, robotics, and artificial intelligence in architecture, including research into seamlessly integrating computational models into physical space at a large scale. His research in collaboration with Clayton Muhleman at CCA, under professors Jason Kelly Johnson and Nataly Gattegno, led to possibilities of 3d printing at a large scale with collaborative mobile robots. Alan continued this research with Clayton at Autodesk Pier 9 where they pursued Artist and Residences, and continued work on larger-scale 3d printing with sand-aggregate concrete. Alan has worked for Andrew Kudless(Matsys) and Autodesk on computational design and robotics work, and he is currently a computational design consultant based out of New York City.

Further Reading

• *California College of the Arts. (2016). Creative Architecture Machines. http://www.creative-architecture-machines.net/*

Silica sand mine, Al Zafarana, Egypt by Aurel von Richthofen.

Participants

Anas Alhowaily
MSc in Urban Development
Technical University Berlin, Campus El Gouna, Egypt

My name is Anas, I am an Egyptian architect. I am 27 years old and I have a Master's degree in Urban Development. I am very interested in the field of sustainable desert urbanization. During the E4D Summer School, I am looking forward to new pivotal insights into how to use technology as a potential trigger for desert sand. I believe that the integration of sand in construction is a great step towards building economically competitive and socially inclusive communities.

Mohit Arora
PhD Engineering Product Development
Singapore University of Technology and Design, Singapore

I am working in the area of urban mining and resource efficiency. Understanding the reuse of building components in a resource constrained urban system is the focus of my research. I expect to learn alternative methods for activating the unusable resources for the construction industry. Various sessions included in the programme will help me to conceptualize applications and limitations of alternative materials. I believe, the E4D Summer School will provide an unmatched platform to meet, learn and collaborate with researchers working in this domain which would positively support my current and future goals of academic research.

Melkamu Teshome Ayana
MSc in Hydraulic and Water Resources Engineering
Arba Minch University, Ethiopia

I am very excited to attend the E4D Summer School! My inspiration to participate arose from the information that I heard from my friends studying the MAS in Sustainable Water Resources at ETH Zurich. Currently I am working as a senior lecturer in Arba Minch University and I am also engaged in different research projects related to natural resources development and climate change. I am looking forward to get in touch with many scholars with different backgrounds and knowledge, and I wish to share experiences on evaluating the environmental, social and economic impacts of sand. This will help me gain knowledge and add value to my background.

Ramit Debnath
MTech in Technology and Development
IIT Bombay, India

Namaste! I am a MTech student at IIT Bombay, India. I am quite excited to be part of this Summer School and to get a flavor of the high level research environment of ETH Zurich. I am currently working on natural ventilation and health of indoor built environment and would like to explore the potential of the vast resource 'Sand' for a sustainable built environment. Moreover, I am very passionate about applying engineering for development through transdisciplinary research. This Summer School will be an ideal platform to interact, network and learn from world class lecturers and peers.

Mariam El-Hussainy
Architecture teaching assistant
Al Azhar University, Egypt

I am a young architect who has come to understand Architecture as a way to make people's life better. It is where art and science meet to form the most efficient yet magnificently beautiful buildings and spaces for human use. I also believe that through applying sustainable strategies in the early design phase we can reach maximum usage of both building and site potentials with minimum cost. I am also pleased that this programme will give me the chance to get to know new people from different countries beside gaining experience in using sand as a sustainable alternative instead of expensive polluting material.

Deena El-Mahdy
PhD Architecture
Cairo University, Egypt

I am interested in participating in this E4D Summer School as my PhD thesis is on material performance, responsiveness and the technology that can turn this material into an advanced high structure by using fabricating tools and machines. I always had a passion for using local material in order to keep sustainability. «Think global, act local» concept can help the developing countries by using their local materials. From this programme I am expecting an experience that will allow me to learn more about 3D printing using desert sand. It will give me a chance to meet people from all over the world and especially experts who I can learn from and enrich my background and knowledge.

Eman Adel El-Sherif
Research assistant
National Institute of Oceanography & Fisheries Alexandria, Egypt

After finishing my Bachelor's degree in geology, I joined the research team in my lab to get more experience. My master's research focused on sustainable development and underlined the importance of specific studies on exploiting black sand rich in precious and exceptional minerals. This Summer School which revolves around the untapped resource sand as a potential alternative building material for future cities and the applications for mobilizing sand for the construction industry is of great use for me. I have a coastal and marine responsibility in aquatic sand mining as a direct cause of erosion that destroys fisheries causing problems for people who rely on fishing for their livelihoods.

Mona Farouk
Architecture teaching assistant
October University for Modern Sciences and Arts, Egypt

I am an architect from Egypt, graduated in 2003. I received my MSc in Integrated Urbanism and Sustainable Design in 2013. My interest in sustainability encouraged me to research about earth as an alternative building material, and to participate in workshops by CRATERRE and the Dachverband-Lehm, where I gained theoretical and practical experience in this topic. I am excited to participate in the E4D Summer School as it fulfills my interest to explore potentials of alternative building materials especially sand, the most abundant material in Egypt, and learn sustainable techniques of improving its properties to be used in construction. It will be a great opportunity to share ideas and experiences with colleagues from various disciplines and countries.

Balaj Fazal
Bachelor in Mechanical Engineering
German University of Technology, Oman

I come from Pakistan but I have been living in Oman since the day I was born. Currently I am having my internship in Mechanical and Industrial Department at Università Degli Studi di Brescia in Italy, working on two projects associated with two leading companies of Brescia. I came to know about the E4D Summer School 2016 by one of my professors who motivated me to join this programme. I was not able to believe when I received an email by the team of ETH Zurich who informed me that my application for the summer programme had been accepted. I am really excited to join this programme and to exchange views with other participants about whether sand is an infinite resource.

Yudhi Dwi Hartono
MSc in Design and Construction Project Management
Chalmers University of Technology, Sweden

During my 4-year education at undergraduate level at the University of Halu Oleo, Indonesia, I had a big interest in construction material issues. Currently I am studying construction management that challenges me to deal with some problems in the construction sector. By joining the E4D Summer School 2016 I hope I can enrich my knowledge related to the advances in science and technology to utilize undervalued materials like desert sand for construction and other applications. Furthermore, having an opportunity to learn and share the experience with other Master's and PhD students from various disciplines will be a priceless experience for me.

Hala Higazi
Architecture teaching assistant
October University for Modern Sciences and Art, Egypt

My name is Hala Higazi, a 24 year old Egyptian with a passion for architecture, and sustainable building engineering. Coming across this programme announcement after completing my MSc in Sustainable Building Engineering last September was an ideal timing as it complements the focus of my previous research and interests. What drew my attention to the programme was its outlook towards a previously undervalued material through integrating advanced approaches and technologies. I am excited to be participating in the Summer School as it will enrich me with knowledge for my future work and studies, and enable me to meet a diverse group of people with common interests.

Joris Hogeboom
MSc Architecture
Delft University of Technology, the Netherlands

I am very excited to be part of this E4D Summer School. Having attained my Master's degree in Architecture from Delft University of Technology on the topic of applying Microbiologically Induced Calcite Precipitation (MICP) to Architecture, I am interested in how design and engineering can mutually benefit each other. Currently I am looking for a research position to investigate sand as architectural building material. From this Summer School I hope to gain some more in-depth knowledge from the experts, as well as a chance to define real world problems and come up with interesting solutions in an international team.

Abdelrahman Ibrahim
MSc in Architecture
Alexandria University, Egypt

I am Abdelrahman Ibrahim, a young and passionate architect; I graduated with a major in architecture from Alexandria University. Currently I am working in preserving and promoting cultural heritage at MOUSEION, Shaboury & Associates. I have always been interested in resources and how to use it efficiently in architecture. So I find the E4D Summer School very interesting and promising with its topic "Sand: an (in)finite resource?" and I believe that it would enrich my knowledge and prepare me for my Master's studies as my next step.

Muhammad Junaidi
MSc Materials Engineering and Nanotechnology
Politecnico di Milano, Italy

My interest in sustainable development directed me to the field of Materials Engineering and Nanotechnology at the Politecnico di Milano. In my second year of Master's study, I have been working on a multidisciplinary project related to additives manufacturing as a green technology. As a person coming from a developing country like Indonesia, I am very excited to participate in this E4D Summer School. It provides me with multidisciplinary professional growth by collaborating with people from different backgrounds in order to promote a new concept in building materials. Furthermore, this programme also gives us the opportunity to immerse in the real scenario and gain more experience understanding the socio-economic context and environment.

Steve Kappenthuler
PhD Chemistry and Business Studies
University of Zurich, Switzerland

In my PhD thesis I am investigating materials for marine construction in the future. I applied for the E4D Summer School since I am interested in gaining deeper insights in long term raw material security of concrete, which is one of the main materials used in marine construction today. Furthermore I have had little engineering training during my studies and I am looking forward to stepping into this field of science and getting some hands on experience during the workshops. Last but not least I love traveling and am excited to meet new people from all around the globe.

Harshal Kate
MTech in Technology and Development
IIT Bombay, India

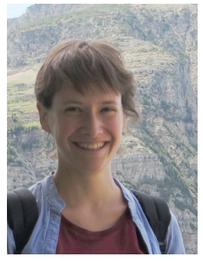
I am currently pursuing a MTech in Technology and Development at the Centre for Technology Alternatives for Rural Areas at the Indian Institute of Technology Bombay, India. I have been selected for a Ministry of Rural Development Fellowship for Research in "Rural Development." Attending this Summer School, I shall try to implement my learnings during this fellowship programme. I would like to investigate the possibility of using economically self-sustaining sand 3D printing for application in resource stressed rural areas by eliminating the need for transportation and to solve poverty in the developing world.

Ahmed Khairy
MSc in Architecture and Environmental Studies
Arab Academy for Science & Technology and Maritime Transport Cairo, Egypt

I am truly excited about the E4D Summer School "Sand: an (in)finite resource?". Ever since I started Architecture, my biggest interest was sustainability and I am now preparing my Master's degree in architecture and environmental studies. I expect to gain extensive knowledge on the topics of study, particularly sand as an alternative to cement (bio-cementation). Also I look forward to discussing further issues regarding sustainability and the impact of similar applications on the environment with the other disciplines.

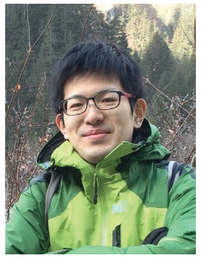
Moataz Mahrous
Algorithmic design
Private Consultant Office

I am an urban planner and GIS practitioner as well as an algorithmic design self-learner, and a technology enthusiast. I expect to get many insights in this programme that handles the topic from multiple perspectives in technology, material science, feasibility, and others as well. The building industry needs such "quest to innovation" to better address global challenges, by making use of the latest progress in technology and research, to produce applicable solutions. It should be a truly interdisciplinary and intercultural enriching experience.



Anna Mayberry
MSc in Architecture
ETH Zurich, Switzerland

Hi, my name is Anna and I am studying architecture at ETH Zurich. I completed my Bachelor's degree in Lausanne two years ago and started my Master's in Zurich last September. In the past few years, I have become increasingly aware of how important it is to address the issue of sustainability. Considering sand as a finite resource is a very relevant topic for architecture, especially seeing as it is one of the most used materials in the building industry. I am looking forward to meeting everyone and I hope that the interdisciplinary environment I will be in this summer will bring me exciting new outlooks.



Shumpei Mitsuyama
MSc Civil Engineering
Hokkaido University, Japan

I am a freshman in the MSc Civil Engineering Master at Hokkaido University, Japan. My current research is on soil improvement using Microbiologically Induced Calcite Precipitation (MICP). I was very delighted to find the opportunity to spend three weeks attending the E4D Summer School. I consider this programme a great chance to get in touch with European culture and educational system. I am very interested in different ways to study civil engineering at the foreign university. I hope to broaden my horizons and I look forward to working with all the other participants.

Menna Mohamed
MSc in Structural Geology
Cairo University, Egypt

Since I started studying Earth Sciences in 2008, I was taken by how Earth's simple constituents along with its dynamic processes had shaped this planet. This encouraged me to pursue post graduate studies in structural geology. Since then, my career has progressed by joining the American University in Cairo as a teaching assistant, where my resolve for research has strengthened. I am sure that the E4D Summer School will provide a positive environment that promotes inclusion, diversity and knowledge sharing. I look forward to meeting colleagues as well as experts with unique experiences about "sand", a real treasure which is considered a key element in many industries and an essential constituent in geoscience research.

Annina Moser
MSc Interdisciplinary Sciences, Physics and Material Sciences
ETH Zurich, Switzerland

In the final year of my Master's in Interdisciplinary Sciences at ETH Zurich, I am glad to have the chase to participate in generating innovative ideas for a more sustainable way of living. In my studies in physics and material science, I learn about the fabrication, processing and characterization of different types of solid materials. Sand, being cheap and abundant, is a frequent example.
In this summer school I hope to use this knowledge and learn much more from the participants and experts to be able to think outside the box.

Morteza Nikravan
PhD Environmental Engineering
Amirkabir University of Technology Tehran, Iran

I am glad to find this opportunity to attend the E4D Summer School 2016. I completed my BSc. and MSc in Civil Engineering and Environmental Engineering, respectively. Now, I am assistant director of the office of sustainability and continue my education. My specific areas of research are focused on sustainability, waste management, sustainable construction materials, Life-Cycle Assessment and environmental rating systems for building (LEED, BREEAM, etc.). I am excited to join this Summer School to get more familiar with current and future technologies on sand and building waste. In addition, the combination of academic lectures, excursions and symposia in a multicultural young group is very fascinating to me!

Vinh Pham
PhD Geoscience and Engineering
Delft University of Technology, the Netherlands

I am currently doing my thesis on biological cementation of the sand. I am very happy to work in this field of bio-mediation geo-technology, in which different biological processes are employed to improve the soil properties. To me this approach of cooperating with the nature instead of exploiting it is highly pertinent to a sustainable development. Therefore, I am very much looking forward to this E4D Summer School as it can help to broaden my vision of this field in both the scientific and industrial aspects of sustainability.

Lila Predouli
Geology, Environment & Biology Studies
University of Zurich, Switzerland

I have studied geology at the University of Athens and at ETH Zurich and I am currently studying biology at the University of Zurich. During my geology studies I have worked a lot with sediments; therefore sand is not an unknown word to me. I was a participant in the E4D Winter School last year and it was the most valuable experience of my academic life. So I have the greatest of expectations for this year›s school and I consider myself lucky to be selected to be part of it! I am looking forward to these three exciting weeks!

Karthikayen Raju
PhD Mechanical Engineering
National University of Singapore, Singapore

I am currently pursuing my doctorate in Mechanical Engineering researching damage in composite materials with variation of temperature, moisture and fatigue. So far, I have not worked with sand, and therefore I am looking forward to the Summer School to change that fact. I am also excited about attending the various lectures and workshops in a multidisciplinary environment. I will be waiting with enthusiasm what sharing knowledge with colleagues and experts about engineering projects and working in groups can provide us. I am looking forward to meeting you all.

Vaibhav Saxena
Bachelor in Architecture
Birla Institute of Technology, Mesra, Ranchi, India

I am a fourth year undergraduate student of architecture based in India. For the last four years, materials have become an integral part of my studies with my upcoming thesis also focussing on a material: salt. I am really excited about the workshops, in particular with 3D printing with sand. I really expect to spend most of my time on hands-on workshops and learning from the lecturers. The idea of a competition during the Summer School excites me. Finally, with an interdisciplinary environment, I intend to learn from each and every person.

Yonatan Mehari Tesfaye
MSc in Architecture
Ethiopian institute of Architecture Building construction and City development (EiABC), Ethiopia

I am a highly motivated and eager person who values every opportunity I get whether big or small. Interdisciplinary activities are one of the many things that I enjoy and constantly try to be part of. My relentless efforts are what I would call my best traits and I aspire to do more on this behavior. I am excited about the Summer School because I believe in exploring other construction techniques and mechanisms. Since I am more experienced in architectural visualizations and printing technology, I am enthusiastic about enhancing these skills further for my future career.

Daniel Alexander Türk
PhD Engineering Product Development
ETH Zurich, Switzerland

I am Daniel and I am a researcher at ETH Zurich. Originally from Vienna, I studied mechanical engineering in Munich. Then, I had the chance to pursue a Master's degree in design in Milan, Italy. Two years ago, the path led me into a PhD in Zurich. In my research I focus on additive manufacturing and carbon composites for high-end applications. I see the Summer School as a unique opportunity to apply engineering science to fields that have a broad impact to society. I expect to explore innovative approaches and lively discussions to understand the potentials of sand as a building material.

Demelash Wondimagegnehu
MSc in Hydraulic and Hydropower Engineering
Arba Minch University, Ethiopia

I come from Ethiopia and I am working as a senior lecturer and post graduate coordinator at Arba Minch University Institute of Technology. Apart from teaching and other departmental duties, I am participating in research activities specially related to water resources developments. I am very excited to participate in this Summer School. It is also a great opportunity to share culture and knowledge with people from all around the world. I am looking forward to learning from all the participants as well as the various speakers in the programme and to sharing the common interest in sand resources.

Dwica Wulandari
MSc in Environmental Engineering
Universitas Indonesia, Indonesia

I am an environmental engineer and involved in biotechnology projects, particularly in anaerobic digestion process and biogas research. The topic of this Summer School is very interesting for me because bio-cementation is a relatively new method and the research related to this process is still limited in my home country, Indonesia. Through this Summer School, I intend to acquire further understanding of bio-cementation and sustainable sand management and I hope to widen my acquaintance of this field by having contact directly with the experts. Moreover, I expect that the diverse academic circumstances will provide long-lasting links with many researchers from around the world.

Organization Team

Barbara Becker
Director for Global
Transformation Affairs
ETH Global

Barbara Becker is Director for Global Transformation Affairs and as such member of the Management Team of ETH Global. Formerly, she has been Managing Director of the North-South Centre of ETH Zurich, a competence centre dealing with research for development (R4D). Her professional background is tropical agro-ecology. Barbara Becker obtained her PhD at the University of Kassel, Germany. She gained international experience as UNEP field project officer, where she investigated the vegetation ecology of Andean land use systems in Peru. Her doctoral research focused on edible wild plants in Africa.
Her experience in research management is based on former positions with the German government and functions in various governance bodies related to international agricultural and research partnerships. Among others, Barbara Becker is Chair of the Programme Committee of the Board of Trustees of the Africa Rice Centre (former WARDA).

María Ubierna Aparicio
Project Manager
ETH Global

María Ubierna is the project manager of this E4D Winter School "Sand: an (in)finite resource?" organized by ETH Global. She also works as a research assistant for the Chair of Hydrology and Water Resources Management at ETH Zurich. Previously, she studied civil engineering in Spain and pursued her studies abroad with a Master of Advanced Studies in Sustainable Water Resources at ETH Zurich. Before moving to Switzerland, María worked for Accenture as a functional analyst and she was volunteer at Engineering Without Borders NGO where she was involved in the organization of conferences on education for development and appropriate technology for developing countries. Living on 4 different countries with people from over 40 different nationalities has fuelled her vocation to work in multicultural and transdisciplinary environments.

Artan Hajrullahu
Lecturer in Visual Anthropology and PhD student in Popular Culture
University of Zurich

After realizing the short film about the 2015 ETH Global Winter School, Artan is again responsible for the film documentation of this year›s program. In reference to his Master›s degree in Media Research and Film Studies, Artan is particularly interested in visualizing cultural dimensions and how the world is fashioned in the literature and media of everyday life. His motivation to again participate in this program is also to share his visions with students from different cultures.

Silica sand mine, Al Zafarana, Egypt by Aurel von Richthofen.

Aurel von Richthofen
Module Coordinator
Assistant Professorship of Architecture and Construction Dirk E. Hebel, Future Cities Laboratory Singapore

Aurel von Richthofen is Module Coordinator at the Assistant Professorship of Architecture and Construction Dirk E. Hebel at the Future Cities Laboratory, Singapore. Aurel is an architect trained in Switzerland and the USA. Prior to Singapore, Aurel was a visiting lecturer for two years at the Ohio State University and afterwards he spent four years as assistant professor at the German University of Technology in Oman. He was co-investigator on sustainable urbanisation patterns project sponsored by the Research Council Oman. At the Future Cities Laboratory in Singapore, he coordinates material research projects and implemented the "Sand Lab" that upcycles sand, ceramic, glass and concrete into alternative construction materials.

Felix Heisel
Researcher
Assistant Professorship of Architecture and Construction Dirk E. Hebel, ETH Zurich

Felix Heisel is a researcher in the Assistant Professorship of Architecture and Construction Dirk E. Hebel and the Future Cities Laboratory, Singapore. Prior, he taught and lectured at the EiABC in Addis Ababa, Ethiopia, the Berlage Institute in Rotterdam, the Netherlands and the University of the Arts Berlin, Germany. He has published Lessons of Informality: Architecture and Urban Planning for Emerging Territories (2016, Birkhäuser), Building from Waste: Recovered Materials in Architecture and Construction (2014, Birkhäuser), and contributed to The Economy of Sustainable Construction (2013, Ruby Press). In Zurich, Felix Heisel coordinates material research projects, especially targeting the resources bamboo and waste.

Leon van Paassen
Assistant Professor
Geo-Engineering
Delft University of Technology

Leon van Paassen is Assistant Professor at the Department of Geoscience & Engineering. After his MSc in Mining Engineering with a specialisation in Engineering Geology at TU Delft, he worked several years as a geotechnical consultant. In 2005, Leon co-authored a 2 million euro research proposal on Bio-mediated ground improvement, which resulted in several publications, patents, and national and international prizes. In his current position, he has lead research and industry funded projects in the field of Bio-based Geo & Civil Engineering. In 2017 he will take up the position as Associate Professor Bio-Geotechnics at Arizona State University and join the NSF Engineering Research Centre for Bio-mediated and Bio-inspired Geotechnics.

Yask Kulshreshtha
Research Assistant
Delft University of Technology

Yask Kulshreshtha completed his Bachelor study in Civil Engineering from India in year 2012 before moving to the Netherlands for his Master's degree. At Delft University of Technology (TU Delft), he developed CoRncrete as a part of his thesis and graduated with Masters of Sciences (Honours) degree in Civil Engineering with focus on Geo-Engineering and Materials in July 2015. He is currently a researcher in the GeoScience & Engineering department at TU Delft and extending his work on CoRncrete for ground improvement techniques. His research interests include bio-based construction materials, ground improvement using biopolymers and mechanical contraptions for application in water purification.

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Maps

TU Delft — Campus Map / Campusplattegrond

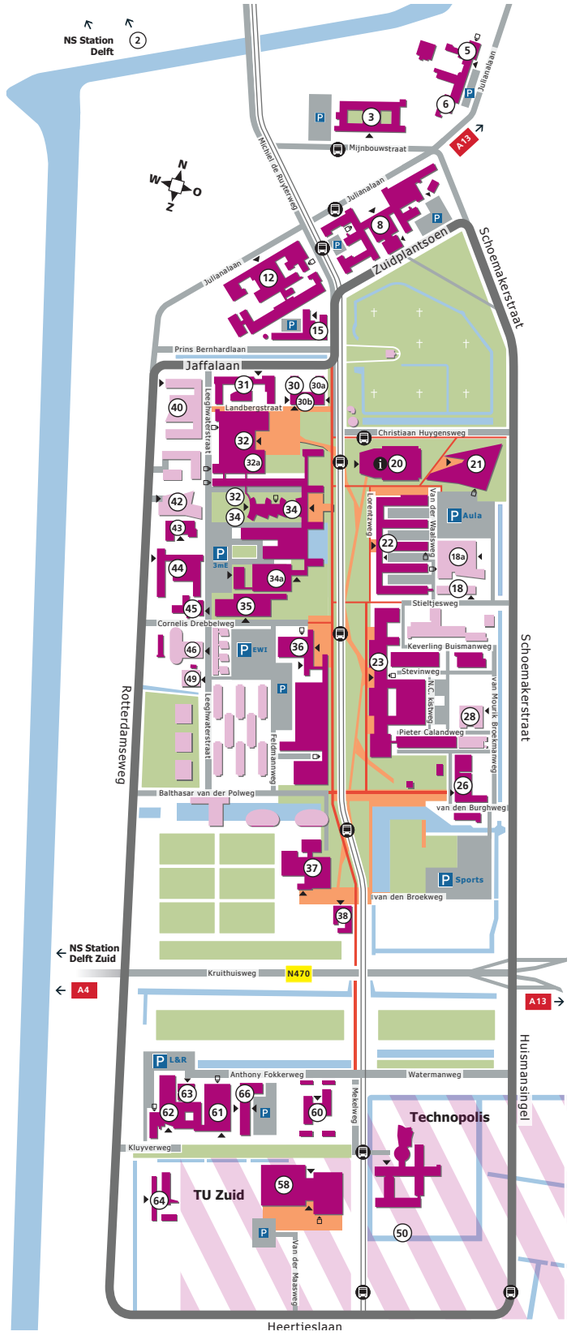
Legend / Legenda

- TU buildings / TU gebouwen
- Other buildings / prospective buildings / Overige gebouwen / gebouwen in aanbouw
- Building number / Gebouwnummer
- (Main) entrance building / (Hoofd)ingang gebouw
- Delivery entrance / Goedereningang
- TU roundway / TU ring
- Road / Autoweg
- Bus track / Busbaan
- Cycle path / Fietspad
- Pedestrian area / Voetgangersgebied
- Busstop / Bushalte
- Parking / Parkeerplaats
- Park / sports field / Park / sportveld
- Water
- Area under construction / Gebied in ontwikkeling
- Information Desk TU Delft / Tel: +31 (0)15 27 88022

See page 2 for building list and addresses
Zie pagina 2 voor gebouwenlijst en adressen

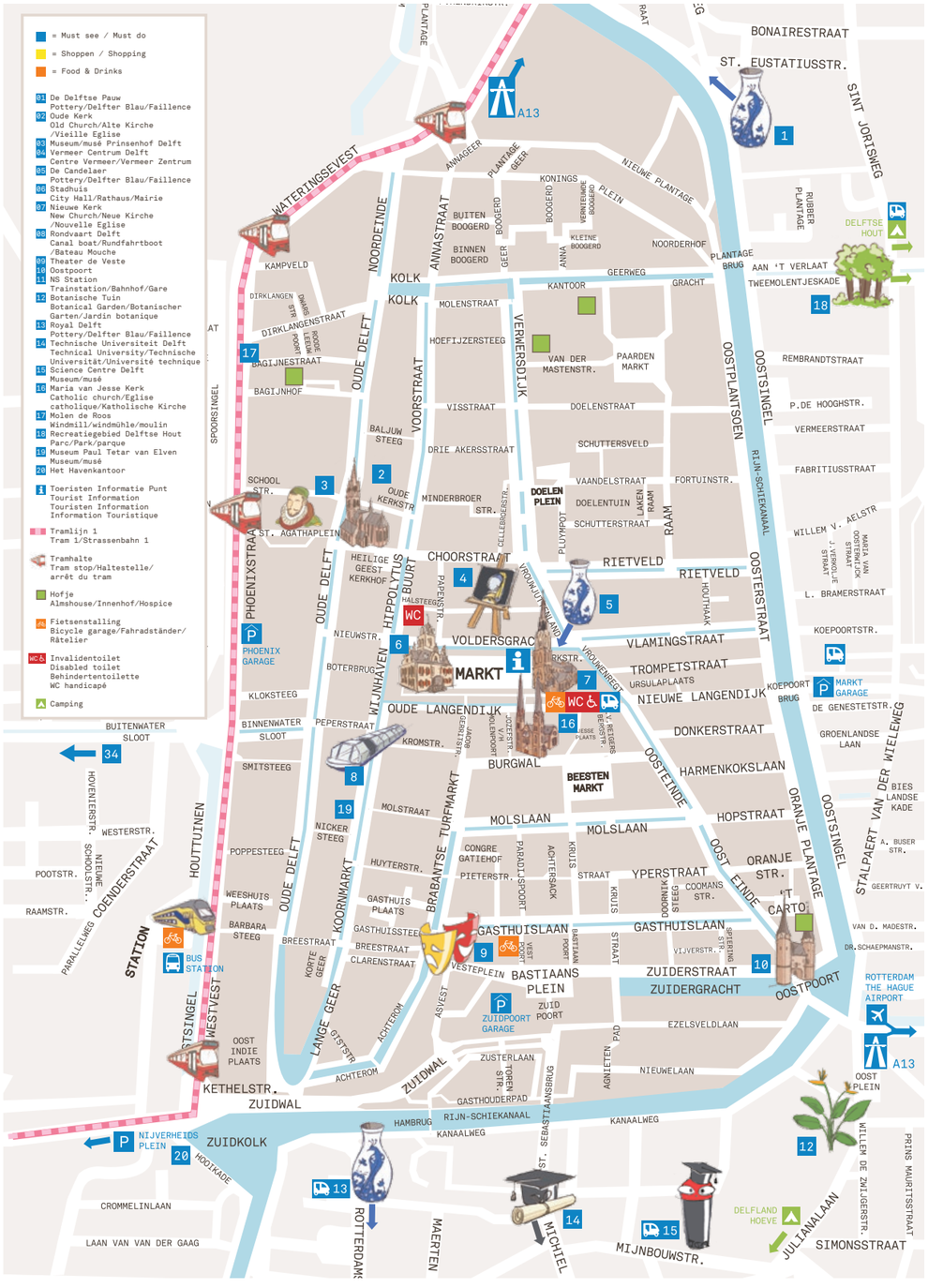
3 minuten

Mei 2016



TU Delft — Building list / Gebouwlijst

Nr	Name	Naam	Address / Adres
2	City centre (former Royal Dutch Army Museum)	Centrum (voormalig Legermuseum)	Korte Geer 1
3	Science Centre Delft	Science Centre Delft	Mijnbouwstraat 120
5	Biotechnology	Biotechnologie	Julianalaan 67
6	Botanical Garden	Botanische tuin	Poortlandplein 6
8	Architecture and the Built Environment (Arch)	Bouwkunde (BK)	Julianalaan 134
12	Chemical Engineering	Chemische Technologie	Julianalaan 136
15	TNW - Physical and Chemical Technology	TNW - Fysische en Chemische technologie	Prins Bernhardlaan 6
18	TNO	TNO	Stieltjesweg 1
18a	Van Leeuwenhoek Laboratory	Van Leeuwenhoek Laboratorium	Van der Waalsweg 16
20	Aula Conference Centre	Aula Conferentie Centrum	Mekelweg 5
21	TU Delft Library	TU Delft Library	Prometheusplein 1
21	Communication	Communication	Prometheusplein 1
22	Applied Physics	Technische Natuurkunde	Lorentzweg 1
23	Civil Engineering and Geosciences (CEG)	Civiele Techniek en Geowetenschappen (CiTG)	Stevinweg 1
23	University Corporate Office, departments: Finance, Human Resources and Legal Services	Universiteitsdienst, directies: Finance, Human Resources en Legal Services	Stevinweg 1
26	Multi-tenant building	Verzamelgebouw	Van der Burghweg 1
28	TNO	TNO	Van Mourik Broekmanweg 6
30	International School Delft	International School Delft	Jaffalaan 9
30	True Colors Delft	True Colors Delft	Jaffalaan 9
30a	Education & Student Affairs	Onderwijs & Studentzaken	Jaffalaan 9a
30b	Facility Management & Real Estate	Facilitair Management & Vastgoed	Landbergstraat 8
31	Technology, Policy and Management (TPM)	Techniek, Bestuur en Management (TBM)	Jaffalaan 5
32	Industrial Design Engineering (IDE)	Industrieel Ontwerpen (IO)	Landbergstraat 15
32	NewMedia Centre	NewMedia Centre	Landbergstraat 15
32	Shared Service Centre ICT	Shared Service Centre ICT	Landbergstraat 15
34	Mechanical, Maritime and Materials Engineering (3mE)	Werktuigbouwkunde, Maritieme Techniek, Technische Materiaalwetenschappen (3mE)	Mekelweg 2
34	Strategic Development	Strategic Development	Mekelweg 2
34a	Executive Board / Supervisory Board	College van Bestuur / Raad van Toezicht	Cornelis Drebbelweg 9
35	Education Building 35	Onderwijsgebouw 35	Jaffalaan 9
36	Electronic and Mechanical Support Division (EMSD)	Dienst Elektronische en Mechanische Ontwikkeling (DEMO)	Mekelweg 4
36	Electronic Engineering, Mathematics and Computer Sciences (EEMCS)	Elektrotechniek, Wiskunde en Informatica (EWI)	Mekelweg 4
36	Valorisation Centre	Valorisation Centre	Mekelweg 4
37	Unit Sports	Unit Sports	Mekelweg 8
38	Unit Culture	Unit Culture	Mekelweg 10
40	The Hague University of applied sciences	Haagse Hogeschool	Rotterdamseweg 137
42	Inholland University	Hogeschool Inholland	Rotterdamseweg 141
43	Combined Heat and Power Plant	Warmte Krachtcentrale	Leeghwaterstraat 36
44	Multi-tenant building	Verzamelgebouw	Rotterdamseweg 145
45	Composites laboratory / Inholland	Composietenlab./ Inholland	Leeghwaterstraat 42
45	Low Speed Windtunnel Laboratory	Lage snelheids Windtunnel Laboratorium	Leeghwaterstraat 42
46	TNO	TNO	Leeghwaterstraat 44
49	TNO	TNO	Leeghwaterstraat 46
50	Reactor Institute Delft	Reactor Instituut Delft	Mekelweg 15
58	Applied Sciences (South building)	Technische Natuurwetenschappen (TNW-Zuid)	Van der Maasweg 9
60	Logistics and Environment	Logistiek en Milieu	Anthony Fokkerweg 5
61	Delft Aerospace Structures & Materials Laboratory	Vliegtuighal	Kluyverweg 3
62	Aerospace Engineering (AE)	Lucht- en Ruimtevaarttechniek (LR)	Kluyverweg 1
63	SIMONA Research Flight Simulator	SIMONA Research Flight Simulator	Anthony Fokkerweg 1
64	Aerodynamics Laboratory, Windtunnels	Aerodynamica Laboratorium, Windtunnels	Kluyverweg 2
66	The Fellowship	The Fellowship	Kluyverweg 5



General numbers and addresses

City Office (Town Hall)

Phoenixstraat 16
2611 AL Delft
T 015 260 2222
Opening hours: weekdays 8.00 – 15.00
Friday evening: 18.00 – 20.00
→ **www.gemeentedelft.info**

Emergency number 112

112 is the European emergency number. This number is used in all member countries of the EU. In case of an emergency simply dial 112. The operator will ask you which service you need - the police, fire brigade or ambulance service. The number is free and can be called from any mobile, fixed telephone and public telephone box.

Hospital

Reinier de Graaf Hospital (RdGG)
Reinier de Graafweg 5
2625 AD Delft
T +31(0)15 260 30 60
→ **www.reinierdegraaf.nl**

Police department concerned with non-nationals

Stadhoudersplantsoen 24
2517 JL Den Haag
T +31(0)70 353 3000
Opening hours: weekdays 8.00 – 20.00
→ **www.politie.nl**

Schiphol National Airport

Evert v/d Beekstraat 202
1118 ZG Schiphol
T +31(0)20 79 40800
→ **www.schiphol.nl**

NS

Dutch Railways
T +31 900 202 1163
→ **www.ns.nl**

Tourist office Delft

Kerkstraat 3 (Markt)
2611 GX Delft
T +31(0)15 215 40 51
→ **www.delft.nl**

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ETH Zurich, June 2016