a façade research roadmap

Prof Dr.-Ing Ulrich Knaack
TU Delft / Chair Design of Construction – The Netherlands
TU Darmstadt / Chair Facadetechnology – Germany
Imagine envelope bv. – The Netherlands @ imagine group

http://facadeworld.com/
Influences


Massive Structure

-1000
1000

Use of Glass

1790 Ecole de Polytechnique
1850 Crystal Palace
1904 Ford
1920 Bauhaus
1973 Oil Cruises
1980 Digital Revolution
Influences

Kew Gardens
first generation structural glass
Influences
second generation structural glass
free form facades

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949</td>
<td>Glass House (Johnson)</td>
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<tr>
<td>1957</td>
<td>Centre Beaubourg (Paris)</td>
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<tr>
<td>1967</td>
<td>Habitat 67 (Canada)</td>
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<tr>
<td>1977</td>
<td>Centre Beaubourg (Reconstruction)</td>
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<tr>
<td>1985</td>
<td>Shanghai Bank (Hanse)</td>
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<tr>
<td>1992</td>
<td>British Pavilion, Seville (Spain)</td>
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<tr>
<td>1996</td>
<td>Educationum, Utrecht (OPA)</td>
</tr>
<tr>
<td>2000</td>
<td>National Stadium, Tokyo (Waseda)</td>
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</tbody>
</table>

by Daan Rietbergen
Influences

Stadttor Düsseldorf
Mick Davies / Polyvalente Wall for Lloyds of London: Understanding of the Facade as skin / organ of the building
Mick Davies / Polyvalente Wall for Lloyds of London
Box-window: Frankfurt Westhafen
Chimney facade: XX Hamburg
Corridor façade: Stadttor Düsseldorf
Chimney-box-window: ARAG Düsseldorf
Chimney-box-window: ARAG Düsseldorf
„alternating facade“. Debitel Stuttgart
double facades

boxed window facade

second skin facade

corridor facade

chimney boxed window facade

alternating facade

component facade
„Component facade“: integration of mechanical components: Posttower Bonn
Decentralized mechanical services in the floor slab

„Component facade“: integration of mechanical components: Posttower Bonn

Decentralized mechanical services in the floor slab
„Component facade“
Capricon Düsseldorf
Decentralized mechanical services in the facade panels
„Component facade“
Capricon Düsseldorf
Decentralized mechanical services in the facade panels
„Component facade“
Capricon Düsseldorf
Decentralized mechanical services in the facade panels
„Component facade“
T-Motion Facade from Wicona
Decentralized mechanical services in the facade panels
„Component facade“: E² facade by Schüco
„Component facade“: NEXT
component facades

Llodys of London  Posttower Bonn  T-motion facade  Capricon Düsseldorf  SmartBox  E² Fassade  NEXT Facade
Roadmap Facades

Capricon Düsseldorf
Roadmap Facades
massiv construction to layered construction
Roadmap Facades

Design School Essen
Claus en Kaan / Amsterdam (NL)
House Schlaich in Berlin (Ger) / Arge Bonne + Schlaich - Infra-Light Concrete
Deckenanschluss:
Zapfen in Auflagertaschen,
Elastomerlager
warmegetäusmt

Im Bad / WC:
Abgeh. Decke

Außenwandbau
- Leichtbeton 50cm Wandstärke
außen- und innenseitig Sichtbetonqualität
H-Schnitt
Seitlicher Anschluss Fassade
Design School Essen - SANAA / Tokyo
in collaboration with Mathias Schuller - Transsolar and Holger Techen - Bollinger und Grogmann
active insulation
massiv and performing construction
Roadmap Facades

Design School Essen
Roadmap Massiv
European facade research

Prof Dr.-Ing Ulrich Knaack
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http://facadeworld.com/
TU Delft / The Netherlands
Hochschule OWL / Germany
Hochschule Luzern / Swiss
Universidad del Pais Vasco - San Sebastian / Spain
University of Bath / United Kingdom
International Facade Master

Msc Façade Design
We bring façades to life!

International network

Facade Design Program

Facade Research Group

Link professional practice

International Facade Master

The programme is centred on the interaction of the disciplines of design, construction and management and aims to produce leaders in the field of façade design and construction. It is based on the premise that the design of façades is a complex task that requires a multidisciplinary approach. The programme is divided into two main parts: the theoretical and practical aspects of design and construction.

The theoretical part focuses on the development of skills in the design of façades, with emphasis on the following areas:

- Structural design
- Architectural design
- Thermal performance
- Acoustic performance
- Lighting design
- Sustainability
- Renewable energy
- Safety and security

The practical part is based on the application of the theoretical knowledge acquired in the design and construction of façades, with emphasis on the following areas:

- Façade materials
- Façade systems
- Façade installation
- Façade maintenance
- Façade management
- Façade testing
- Façade simulation

The programme includes a final project that involves the design and construction of a façade, with the aim of applying the knowledge acquired in the programme to a real-world project.

The programme is delivered by a team of experienced lecturers and professionals from the fields of design, construction, and management, with a strong emphasis on the integration of theoretical and practical knowledge.
facade2015
Nov. 27th // COMPUTATIONAL OPTIMISATION

In the last few decades, information technology has brought about lasting changes to design and production processes. At the same time, curators on design and building processes have increased the possibilities for intelligent, engineered, and performant buildings, buildings and environments.

The buzzwords like Big Data, Industry 4.0, and The Internet of Things already point towards the next Digital Revolution. Do what does this mean for building envelopes and their planning and building processes? Can we see an ever-increasing network of information contribute to a revolution in how we design, and construct?

These issues will be addressed at the conference facade2015 which will follow the same sequence, as the main phases of a design development: planning, construction and operation. The potential, chances and risks of progressive digitalisation and transparency in the field of building envelopes within the context of conference discussions.

8.30     Registration
9.00     Welcoming
Lizte Potgieter, Dean
9.15     Keynote #1: Planning
Marina Beues, Berlin-Leibnitz, Berlin
10.00    Technical Possibilities
Uli Körner, AIU Envelopes, London
10.30    Beyond the Skin
Anthony Cher, Gehry Technologies, Hospitaria
11.00    Coffee break
11.30    Keynote #2: Fabrication
Ansgard Paiz, designproduction, Stuttgart
12.15    File to Factory: Parametric Facades
Pino Griffo, Schüco International KG, Bielefeld
12.45    Research
Paul Rowen Derz, Fries Архитектурная компания GmbH, Berlin
13.15    Lunch break
14.15    Keynote #3: Operation
(Flo Foster, Wernigerode, Dessau)
15.00    Adaptive Building Envelopes
Suzanne Gerzony, Land University, Lund
15.20    Thinking Skins
Christian Meckling, RWTH Aachen University
16.00    Final Discussion

Registration: facade@stutt-ent.eu / facade@stutt-ent.eu
www.facetevent.org

Fees: 110 €
110 € members German chapter of architecture
25 € students / graduates of Hochschule OWL

Venue: Campus Fischlake, Ensemblesstr. 45, 37196, Detmold, Germany
www.facetevent.org / facade@stutt-ent.eu
European façade network MOBiL
work program „emerging envelopes“ 2013-2016
powered by Alcoa Foundation

A cooperation of
TU Delft – the Netherlands and
Hochschule OWL – Germany
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<tr>
<th>No.:</th>
<th>Poster title:</th>
<th>Associated researcher</th>
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<td>1</td>
<td>Active Thermoelectric Intelligent Apertures for high efficiency building facades</td>
<td>M. Santamouris, D. Kolokotsa</td>
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<td>Modeling of double-skin façade (DSF) performance: Flow conditions in DSF cavity</td>
<td>Olena Kalyanova Larsen</td>
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<td>2</td>
<td>Adaptive façades Systems: procedures and protocols for performance monitoring &amp; evaluation</td>
<td>Shady Attia</td>
<td>19</td>
<td>Multiplication of optical phenomena, Façade glare studies, Understanding perception of transparency in architecture</td>
<td>Marcin Brozicki</td>
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<td>3</td>
<td>Adaptive facades with energy collection and storage systems enabling zero energy operation of buildings, occupants comfort and health.</td>
<td>Philippe Lamarchand</td>
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<td>Novel façade technologies for the Mediterranean climate. Planning, design, retrofit</td>
<td>Luca Linin, Benedetta Mariani, Sandra Jordão, Luís Simões da Silva, Aldina Santiago</td>
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<td>4</td>
<td>Advance analysis of glazed connections for façades systems. Innovative solution for exterior elements connections of adaptive façade</td>
<td>Klára Machalická, Martina Elšíková</td>
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<td>Ongoing research on structural glass. Dep. of Civil Engineering University of Coimbra Portugal</td>
<td>Hana Yard, Filip Santor, Claudio Amadisio, Cornelius Czarnowski, Antoaneta Borodina</td>
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<td>5</td>
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<td>Passive and active control systems for adaptive glazing systems and envelopes</td>
<td>Chiara Bedin, Filipe Santos, Claudio Amadisio, Cornelius Czarnowski, Antoaneta Borodina</td>
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<td>Passive use of solar energy in double skin façades for reduction of cooling loads</td>
<td>Vlatka Rajić, Roko Žarić</td>
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<tr>
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<td>Poster list and location map</td>
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<td>24</td>
<td>Racking testing of the innovative hybrid load-bearing panel composed of laminated glass inserted in CLT frame</td>
<td>Giuseppe La Ferla</td>
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<tr>
<td>9</td>
<td>Architecture and building</td>
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<td>Consideration of the building envelope in terms of energy efficiency and impacts on humans.</td>
<td>Aleksandra Kurtic-Furundzic, Hana Yard, Filip Santor, Claudio Amadisio, Cornelius Czarnowski, Antoaneta Borodina</td>
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<td>10</td>
<td>Emporium Building Concept Zero-energy buildings with low-energy storage</td>
<td>Maxime Doya, Francis Allard</td>
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<td>Development of outdoor test-facility cells in order to evaluate the thermal performances of real-scale envelope components under oceanic climate</td>
<td>Renee Warszprak</td>
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<td>Energetic performance assessment of adaptive façades through experimental activity - TEBE (Politecnico di Torino)</td>
<td>Józef Hula, Roman Rabenseifl, Hanuš Peter, Peter Hartman, Paulina Susaňová</td>
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<td>29</td>
<td>Energy performance assessment of adaptive façades through experimental activity - TEBE (Politecnico di Torino)</td>
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Dear participant, if any information is wrong or missing, please contact: marcin.brzezicki@pwr.edu.pl
Poster map – façade function vs. research area

Mind map prepared based on the contents of the posters, COST TU 1403, WG 4

- create a durable construction
- allow responsible building materials
- provide a comfortable climate
- responsible handling in terms of sustainability
- support the use of the building

façade function:

- create a durable construction
- allow responsible building materials
- provide a comfortable climate
- responsible handling in terms of sustainability
- support the use of the building

research area:

- simulation, prototypes
- monitoring, assessment
- PV
- advanced materials
- façade glazing
- façade shading
- control systems

- the function list based on Klein T., Integral Façade Construction, 2013
- the link determines the activity in more research areas

Dear participant, if any information is wrong or missing, please contact: marcin.brzezicki@pwr.edu.pl

COST is supported by the EU Framework Programme Horizon 2020
TU Darmstadt
Institute for Structural Mechanic and Design

Research Information

Profile
The Institute for Structural Mechanics and Design combines research and education in the fields of structural analysis, structural dynamics, materials, facade and structural engineering, in order to achieve consistent, integrative basic knowledge for resource-efficient design and construction. With this vision in mind the institute promotes fundamental theoretical work on mathematical and design methods, material testing and modelling, numerical simulations, safety theory, construction processes as well as applied research and design of structures from the component down to the material level. All this pursuit also energy questions are taken in consideration from an integrative point of view of structural design and materials.

Research
The Institute for Structural Mechanics and Design engages in fundamentals of theory and applied research and development in the research groups Methods, Materials, Technologies, and Energy. Here it is cooperating with partners from science and research, industry and administration.

Fundamental research, applied research and development are synergistically linked in approximately equal proportions.

Research activities are in line with the comprehensive approach on material and structure distinctive of the institute, and are not only limited to construction, components and materials, but can rather be found throughout all applications of the field of engineering. They include in the field of Structural Mechanics and Dynamics the modeling of structures to record their static and dynamic behavior, the mechanical modeling and simulation of deformation, damage and failure of materials, components and load-bearing structures, the development of new materials and their application in the construction industry and/or consideration of safety issues, environmental aspects in the construction, design-related energy issues, simulation and experiment of shock, explosion and contact accidents, simulation and measurement of the vibration behavior of structures and structural glass and polymeric mechanics.

Research in the field of the building envelope deals with questions of development and evolution, from biomimicry to structures to measure constructions, and their feedback into the overall design and energetic performance. Current topics can be found in the field of integration between smart home technology and building enveopes, evaluation of constructions on the background of grey energy considerations and the consequent redesign of structures and joints, as well as material and design development exemplified through additive manufacturing (AM) technologies.

Thanks to a horizontal connection between scientific fields, the research groups operate across disciplines and react to evolving research questions and connections. Through cooperation with other institutions and private investors, the Institute of Structural Mechanics and Design has access to many experimental facilities and has a wide range of tools to perform tests and measurements on site.

Involved persons: Prof. Dr. Ing. Jens Schneider
Prof. Dr. Ing. Ulrich Knaack

Time span: continuous

Contact data:
Jens Schneider: jens.schneider(at)tu-darmstadt.de
Ulrich Knaack: ulrich.knaack(at)mail.tu-darmstadt.de

Associated Publications:
1. J. Schneider, Cyclic fatigue of annealed and tempered soda-lime glass, PhD TU Darmstadt, 2012
5. J. Schneider, J. Kollup, J. Kondic, S. Mencner, Tensile properties of different polymer composites under high strain rates, Polymers, 5 (2013), pp. 1739-1749
15. J. Schneider, J. Kollup, J. Kondic, S. Mencner, Tensile properties of different polymer composites under high strain rates, Polymers, 5 (2013), pp. 1739-1749
17. J. Schneider, J. Kollup, J. Kondic, S. Mencner, Tensile properties of different polymer composites under high strain rates, Polymers, 5 (2013), pp. 1739-1749
FAÇADE RESEARCH GROUP

Strategy and development of research in the field of the building envelope

The goal of the Façade Research Group is to improve the performance of the building envelope as part of the entire building and to enhance the possibilities for architectural design by exploring new strategies and design tools as well as construction and production technologies. The group consists of national and international located PhD students under the leadership of Dr. Tillman Klein and Prof. Dr. Ulrich Knaack.

The Façade Research Group organizes itself via 4 themes: Design Tools and Strategies, Production and Assembly, Construction, Product and Material, Climate, Comfort and Energy, since 2006 five PhD’s finished within the group, 13 PhD’s are currently active (status 7/13). Regular peer review sessions are executed twice per year – to meet, interact and secure success of the research. Future research areas are identified and targeted in relation to the 4 themes.

The activity is linked to education via the in the Building Technology master embedded track ‘International Façade Master in Delft’ and the International façade master of Design and Construction in Rotterdam. Valorisation is done via the book series “The Future Envelope”, which will merge with a new established Journal of Façade Design and Construction at IOS Press, the “Principles” series with Birkhäuser publisher and the imagine series with O’Jai publisher. Next to this the two conference series ‘The Future Envelope – Delft/Bath as well as “Façadesxx” – Delft / Luzern is organized.
Delft University of Technology

Eindhoven University of Technology

University of Twente

3TU.Bouw

center of excellence for the built environment
The DoubleFace project aimed at developing a new product that positively improves thermal comfort of indoor and semi-indoor spaces by means of lightweight materials for facade heat storage, while simultaneously allowing daylight to pass through as much as possible. Specifically, the project aimed at designing and prototyping an adjustable translucent modular system featuring thermal insulation and thermal absorption in a controllable manner, which is adjustable according to different heat loads during summer and winter.

The output consists of a proof of concept, a series of performance simulations and measurement and a prototype of an adjustable thermal mass system based on lightweight and translucent materials: phase-changing materials (PCMs) for latent heat storage and transparent aerogel particles for thermal insulation.

The adjustable Trombe wall system leads to an energy reduction of roughly 40%.

Thermal benefits and translucency

The system is based on an innovative approach to thermal principles of Trombe walls. As compared to traditional Trombe walls, the system is about five times lighter than traditional Trombe walls. In order to avoid structural load from buildings, it is adjusted in order to balance heat gains and losses, and in order to validate the thermal effects, lightness and translucency are achieved by means of the applied materials. Instead of heavy and opaque materials like concrete, a novel application of PCM and aerogel is proposed. Several prototypes and technical systems are currently available on the market for adapting PCM by integrating them into walls, containers, or ventilation systems or in facades. Double Face proposes a system based on interior design elements, having advantages of the dynamic behavior of PCM as well as its accessibility. As such, the system can be integrated into different materials and building structures such as new buildings as well as renovated or existing buildings. Additionally, the system is adaptive in order to enhance the thermal benefits. Preparing thermal masses in sumer, under radiant heat (positive heat gain) and protecting them from the summer sun, they are stored for later use. In winter, the PCM could be used to store the interior and thereby change temperature of the building over time, thereby changing the interior. Preparing the heat is stored in the PCM, which is released when the interior temperature needs to be increased. During the summer, the PCM could be stored in the PCM, which is released when the interior temperature needs to be increased.

Ajustable Trombewall

The research process started with a wide inventory of existing PCM, an analysis of their properties, and a subsequent short list of selected materials. For each of the selected PCMs, digital simulations were conducted to analyze the thermal behavior. They were simulated for single layers, for layers of PCM in various thicknesses, and for combinations of layers, one of PCM in various thicknesses and one of translucent insulation, also in various thicknesses. The transparent insulation was simulated as a layer of aerogel and as a layer of a combination of aerogel and a transparent insulating material. These simulations were performed in the laboratory for Building Physics at Delft University of Technology for their thermal properties and at Delft University of Technology for their light transmittance. The simulations allowed for testing the dimension as well as the ranking weekly the lot of selected materials. As a result, PCM thicknesses were reduced to 5-6 mm. Furthermore, using the measured properties as input, simulations of the thermal behavior of a standard window equipped with this Trombe wall were performed. In the simulations, all thicknesses were studied to assess several variations including PCM layer thickness, insulation layer thickness, extra costs and percentage of boost in the wall. These simulations showed that we can achieve an increase of roughly 20%.

Exposed technical systems

The research process started with a wide inventory of existing PCMs, an analysis of their properties, and a subsequent short list of selected materials. For each of the selected PCMs, digital simulations were conducted to analyze the thermal behavior. They were simulated for single layers, for layers of PCM in various thicknesses, and for combinations of layers, one of PCM in various thicknesses and one of translucent insulation, also in various thicknesses. The transparent insulation was simulated as a layer of aerogel and as a layer of a combination of aerogel and a transparent insulating material. These simulations were performed in the laboratory for Building Physics at Delft University of Technology for their thermal properties and at Delft University of Technology for their light transmittance. The simulations allowed for testing the dimension as well as the ranking weekly the lot of selected materials. As a result, PCM thicknesses were reduced to 5-6 mm. Furthermore, using the measured properties as input, simulations of the thermal behavior of a standard window equipped with this Trombe wall were performed. In the simulations, all thicknesses were studied to assess several variations including PCM layer thickness, insulation layer thickness, extra costs and percentage of boost in the wall. These simulations showed that we can achieve an increase of roughly 20%.

Contingent conditions

The thermal behavior of the prototypes is now being measured using heat flow sensors and thermocouples at Delft University of Technology. Additionally, further performance simulations are being run in order to validate the behavior of the modular and adaptive system under different climatic conditions and in various room environments. Current simulations include the rotation of the simulation of the elements in order to extend the simulation according to current conditions (e.g., air temperature). The measurements of the team include tuning the prototype and exploring other design alternatives, both thermal and adaptive. This will allow for on-going development and testing of the prototype. A number of companies have been interested in the project and its architectural applications.

Double Face

Delft University of Technology
M.A., Michaela Tuntura
M.A., Marko Jeglic
M.A., Paul de Ruyter
M.A., Willem Meijer
M.A., Wouter van der Stok
M.A., Carlos Arrieta

Delft University of Technology
M.A., Patrick Holtslag
M.A., Fabrice Trefil
M.A., Steven Vossen
M.A., Peter van Baarle
Developing a flexible mould will encourage industrial companies to manufacture complex geometries in a cost efficient way.

The Kine-Mould is a development that makes it easier to manufacture building elements with complex geometry. Since June 2014 the team has been working on a range of solutions and prototypes. Various building materials have been investigated such as concrete and glass. The following prototype is designed and built.

Prototype for concrete

Before the start of the STU LightHouse project, a smaller scale prototype model of the flexible mould was used for concrete, using a grid of flexible strips as an interlocking surface. This prototype showed very promising results, but the team was aware of some potential issues and decided to develop a more detailed model and test its performance.

The forming of moulds is challenging as it is prone to failure. It is therefore important to have a wide range of materials and solutions for forming and releasing the material.
Questions for the national science agenda 2015

DE TOEKOMST WORDT GEBOUWD
Façade projects
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TU Darmstadt / Chair Facadetechnolgy – Germany
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http://facadeword.com/
Heizkraftwerk Aachen
Client: BLB Bau- und Liegenschaftsbetrieb Aachen
Architect: IP Arch
Completion: 2010
Sparkasse Ludwigshafen
Client: Sparkasse Vorderpfalz
General Planner: Evers Ingenieurgesellschaft
HVAC: Balck und Partner
Completion: 2009
Refurbishment concept

Upgrading of windows
Cleaning, painting substructure
Final design
Second skin protects inner facade
Clean insulation layer
Decentralized climate units
New local air ducts
New automated sun shading
Fire protection and sprinkler system
Solarlux Nijverda
Client: Solarlux NL
Completion: 2011
Hoogeschool InHolland / Delft

Client: InHolland
Architect: Rietfeld Architects New York
Contractor: Octatube
Completion: 2010
Roadmap / European facade research / facades projects

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