ne—xt *facades*

COST ACTION TU1403
ADAPTIVE FACADES NETWORK
MID-TERM CONFERENCE

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ne-xt facades

Adaptive Facade Network

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Philipp Lionel Molter, Moritz Mungenast, Matej Banozic, Oliver Englhardt, Tillmann Klein,
TU Delft for the COST Action 1403 adaptive facade network

ne-xt facades – Adaptive Facade Network

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Editors
Philipp Lionel Molter, Moritz Mungenast, Matej Banozic, Oliver Englhardt, Tillmann Klein

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Preface – Science meets Practice

The ne-xt facades conference is the official International Mid-term Conference of the European COST Action TU1403 ‘Adaptive Facade Network’, an international scientific cooperation with the aim to harmonise, share and disseminate technological knowledge on adaptive facades on a European level.

During the mid-term conference first results are presented to stakeholders from industry and design and to the public. The goal is to share knowledge and discuss novel facade concepts, effective evaluation tools and design methods for adaptive facades.
We thank our industry sponsors for their commitment and their trust in our work. Not only are they fundamental in making this event happen, they are also taking part in the important debate about the relevance of our research results for the practice field. The conference is supported by the EU Framework Programme Horizon 2020.

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An optimized interior comfort and savings in operational energy is one of the main drivers for adaptivity in building envelopes. The session looks at new means of achieving and evaluating the desired performance. One important aspect is how that is done technically: By using high-tech versus low-tech solutions.

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The implementation of new adaptive materials, components and facades always falls in the context of architectural design. But how are design and technology geared towards holistic newly built applications? What is the role of the different stakeholders and how can the process of creating new innovative adaptive facades be organised?

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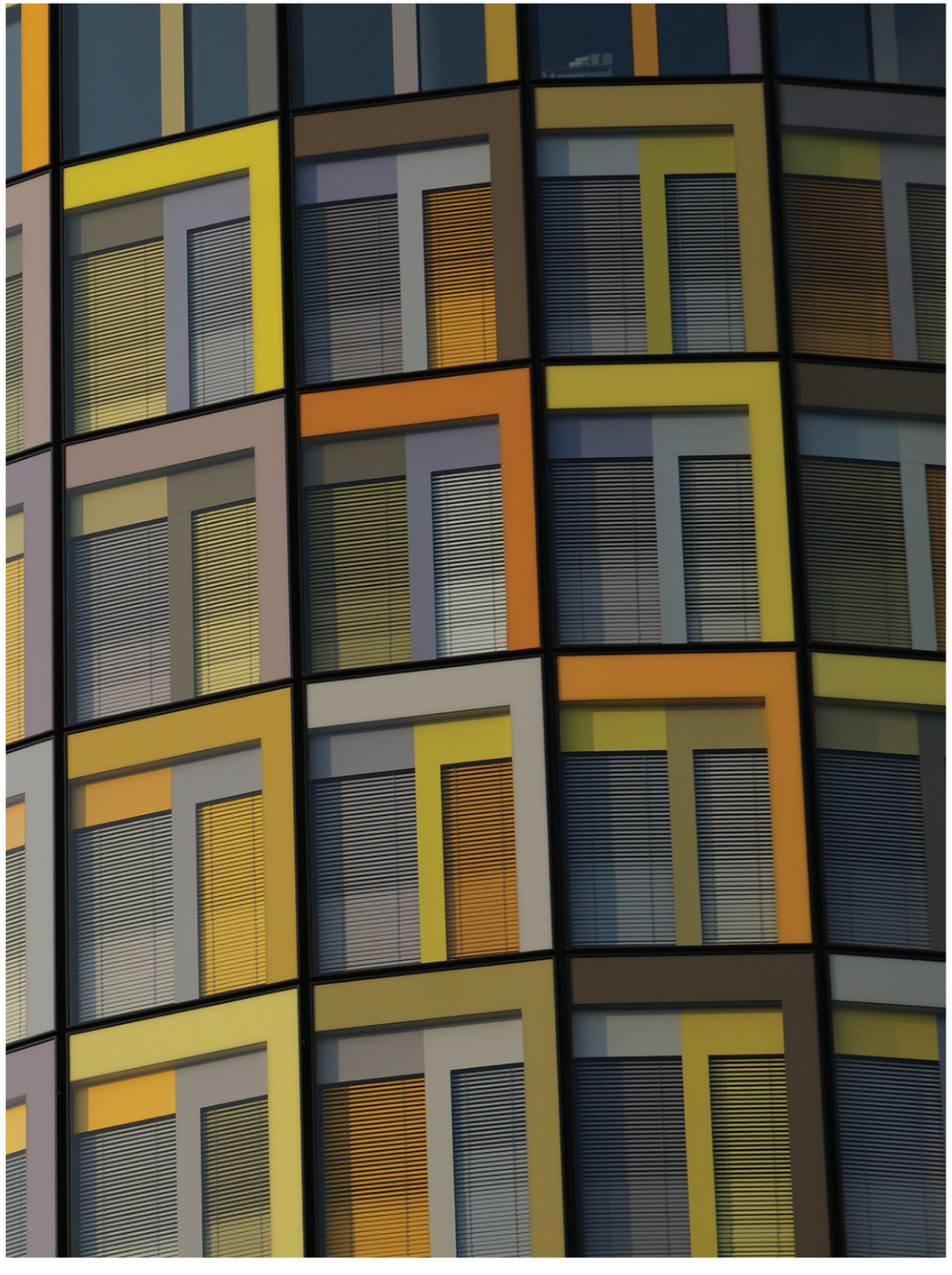

General introduction

Today’s facades are mostly passive systems and are largely exhausted from an energetic point of view. They can neither adapt to changing environmental conditions related to daily and annual cycles nor to changing user requirements. Multifunctional, adaptive and dynamic facades can be considered the next big milestone in facade technology. Adaptive building envelopes are able to interact with the environment and the user by reacting to external influences and adapting their behaviour and functionality accordingly: the building envelope insulates only when necessary, it produces energy when possible, it shades or ventilates when the indoor comfort so demands.
In spite of numerous already realised projects the development and realisation of adaptive building envelopes are still in the initial stage. In addition to new technologies that enable adaptive behaviour, simulation tools and suitable testing methods must be developed; existing norms and regulations must be adapted, and holistic concepts to integrate such facades in the overall building system must be developed.
Researchers as well as planners and professionals in the facade industry are all involved in developing concepts and technologies to increase interior comfort and reduce the energy consumption of buildings. An integrated effort is needed to provide successful and holistic concepts in the development, design and construction of adaptive building envelopes.
During the conference multinational participants from all over Europe discuss new developments and technologies for the design and manufacturing of high-performance adaptive building envelopes: Architects, structural and mechanical engineers, facade engineers, specialists in building physics and energy design, material developers, researchers and manufacturers.
The program is organised in four sessions, each comprising a mix of scientific contributions as well as invited speakers from practice. Debating the results of contributions with the audience is a fundamental component of the event.

Collection of abstracts

Previous to the event a call for abstract was launched. The abstracts were subjected to have undergone a strict review process and the selection for oral presentation was subjected to the following criteria: Scientific quality, match with one of the four conference topics, potential contribution to the debate during the conference. Since only a limited number of presentations were feasible not all abstracts of high quality could be selected for oral presentation. The full list of abstracts we can be found on the following pages under the four conference topics.

Abstracts

Session 1 – New Functionalities

Increase in adaptivity of facades leads to new facade functionalities such as shape changing or adapting material properties, function enlargement by integrating HVAC systems or photovoltaics. Session 1 aims at analysing the state of the art of adaptive facades and cast a view ahead of future possibilities.

Session 2 – Digital Environments

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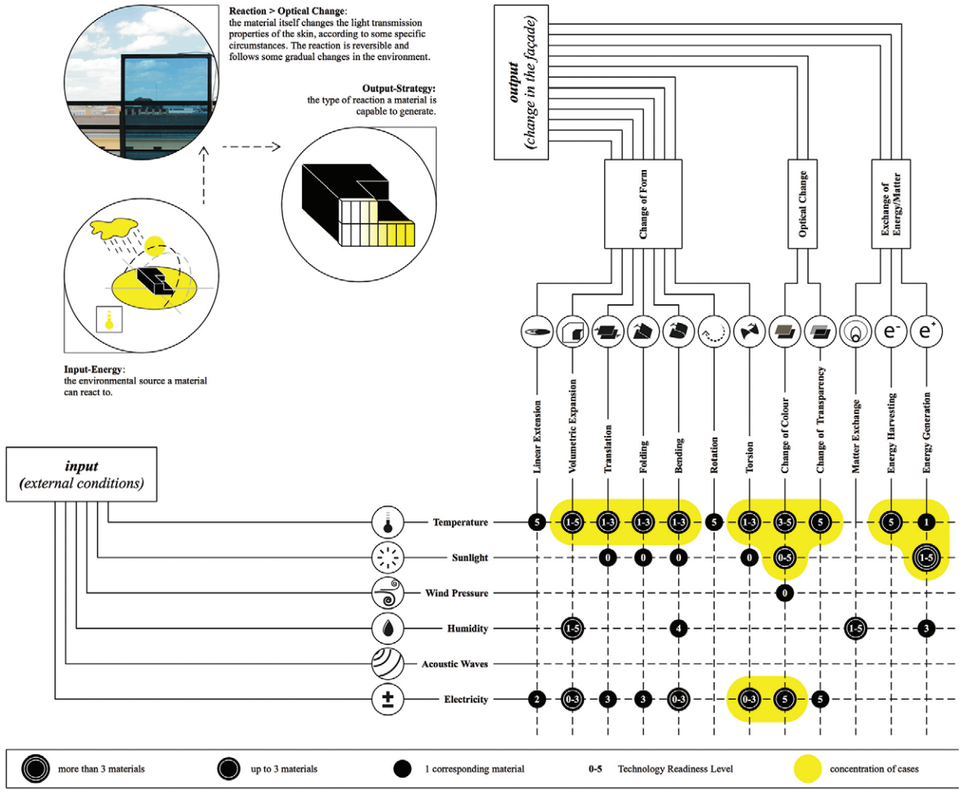

Auto-reactive strategies
A catalogue of materials for innovative facade components

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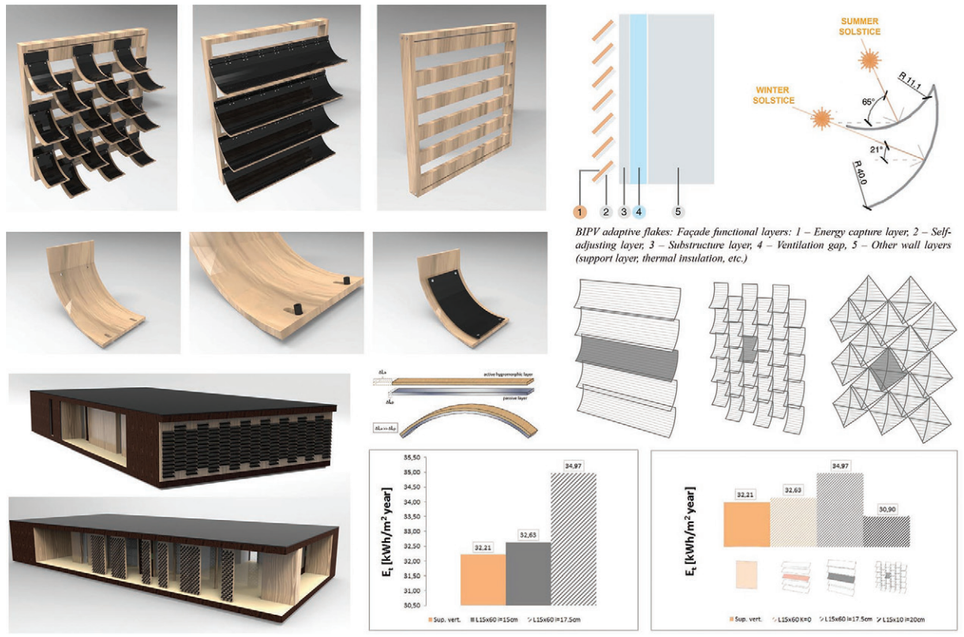
Associate Professorship of Architectural Design and Building Envelope,
Department of Architecture, Technical University of Munich, Germany
conference #3544

Not only does the envelope act as a barrier, but it is the spatial device that links the building interior to the outside. As soon as it effectively mediates between the specific customer needs (inside) and the climatic circumstances of local context (outside), the envelope can provide solutions to many problems of climate control.
Although various strategies rely on this interaction between inside and outside, their outcome mostly concerns facade components that process inputs by using an external controlled intelligence. Within architecture the search for more dynamic and responsive technology generally seems to have increased solutions dependency on technology (and energy) rather than its independence, failing to simplify facades systems.
Yet this study aims to challenge the need of external sources, developing auto-reactive strategies. The term ‘auto reactive’ - also defined passive in the recent literature - has been applied and misapplied to describe many different concepts. In this research it is intended as the capability to transform resources from the environment into other types of energy, needing no processors or external power supply to work. Above all, it involves that the device is energetically autonomous and self-sufficient.
Lacking of prior purely architectural background studies on which to rely on, this research approaches different case studies from closely related disciplines - such as medicine, biology, chemistry, automotive and aerospace industry. In order to develop a potential application into buildings, the various reactions - that are due to the alteration of climatic conditions – have been grouped in three macro-categories: the dynamic change, the optical change and the exchanges of energy or matter with the environment.
Rather than being just a report of material reactions, this work includes a catalogue of passive systems, which illustrates the most relevant properties of materials (e.g.: operating temperature range, reaction time, behaviour, availability on the market, recycling) in fifty data-sheets. All components are categorized according to their physical principle and two main parameters of classification - input-Energy and output-Strategy. While the input-Energy corresponds to the environmental source - that triggers a chemical-physical reactive process - the output-Strategy indicates the reaction generated by the material in response to a specific stimulus.
Moreover the analysis and the catalogue are implemented and complemented by a survey of case studies, allowing a major understanding of the application of auto-reactive strategies - and auto-reactive materials - in contemporaneous architectural projects.

key words: adaptive, passive, auto-reactive systems, input-output, catalogue



BIPV adaptive flakes: Façade functional layers: 1 – Energy capture layer, 2 – Self-adjusting layer, 3 – Substructure layer, 4 – Ventilation gap, 5 – Other wall layers (support layer, thermal insulation, etc.)

Study of a BIPV adaptive system combining timber and photovoltaic technologies

Enrico Sergio Mazzucchelli[1], Luisa Doniacovo[1] and Mark Alston[2]
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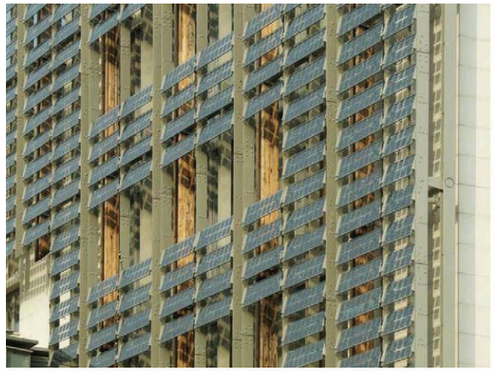
[2] School of the Built Environment, University of Salford, Manchester, UK
conference #3548

The reduction in building energy consumption and CO2 emissions is one of the main goals in the nearly Zero Energy Buildings (nZEB) framework. In this regard, adaptive technologies and materials represent a constantly developing sector and source of innovation. Moreover, these systems are often aimed at collect and convert renewable energy (mainly solar) in order to cover as much as possible the building energy consumption.
In this context, the research goal has been the design of a BIPV (Building Integrated PhotoVoltaic) facade system able to change its curvature in relation to the external environmental conditions, orientating itself in order to optimize the energy production without the aid of any mechanical and electrical system. The following aspects have been considered: passive dynamism, lightness, weather resistance, easy maintenance, applicability on a large scale, easy integration in the building envelope, Life Cycle sustainability.
The adaptive layer consists of two wooden sheets, one active and one passive, joined together. The response of a hydromorphic material is a function of ΔMC' (effective moisture content change), that is, the difference in the moisture content in the wood, which in turn depends on the air temperature and Relative Humidity (RH) and it varies in relation to the wood species. Moreover, this response is a function of the dimensional variations of the two wooden layers used to produce the composite self-adjusting flake. The variation in outdoor air RH activates the movement of the wooden flakes, that can therefore change their curvature thanks to the different expansion coefficients of the two wooden slats.
To evaluate the performance of the component, three shape configurations for the adaptive flakes have been assumed. For each hypothesis, the flakes have been modelled using the Rhinoceros 5 Software, according to the curvatures taken during the different months of the year. The Rhino models have been imported into Autodesk Ecotect Analysis to calculate the incident solar radiation and to study the self-shadowing effect in the various configurations (considering the climatic conditions of the city of Milano).

key words: wood, hydromorphic materials, building, facades, BIPV technology, adaptive system



Istituto Atesino di Sviluppo in Trento, Italy (arch. Renzo Piano Building Workshop, 2012)

BIPV adaptive flakes: Façade functional layers: 1 – Energy capture layer, 2 – Self-adjusting layer, 3 – Substructure layer, 4 – Ventilation gap, 5 – Other wall layers (support layer, thermal insulation, etc.)

Adaptive Solar Facade photographed at Glasstec 2016

Desired morphology in energy capture and storage advanced facades

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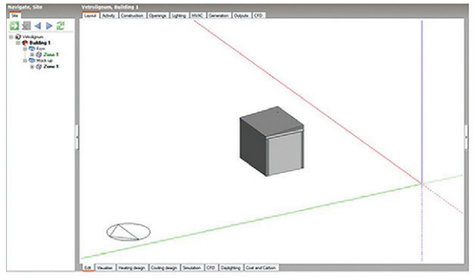
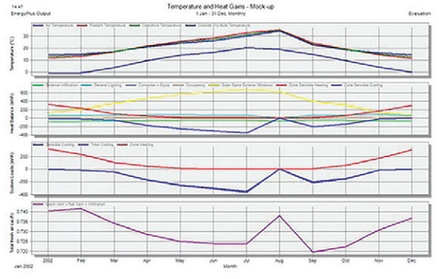
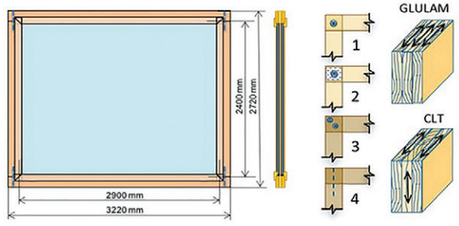
conference #3559

Current strategies for facades envelopes are determined by a static response defined by a single prescriptive value. This code requirement diminishes the ability of a facade to interact with the environment by constant readjustment of functional performance. This is the knowledge gap between present code compliant facades, based on measures in the reduction of thermal conduction to what could be.
The research proposes methods to demonstrate principle functions to capture and storage energy in facades that is derived by natural systems. It demonstrates nature's characterization of materials by methods to control material assembly and functionality by hierarchical strategies that can be applied to envelope functionality. Nature generates materials with defined parameters to move neighbouring atoms within and between materials at a micrometer or nanometer levels. This interface reaction between different materials is driven by chemical composition and temperature with unprecedented levels of complexity and prevision. This is a thermal measurement system of precise modulation response as a dynamic reaction diffusion system. The question is, why is this characterization of function not emulated in envelope design?
The aim of the research is therefore to demonstrate how utilizing bio-inspired engineering aims would progress the knowledge gap in understanding, to advance energy capture and storage materials and to determine hierarchical rule based measures defined by steady state theory, in the control of solar heat load. The application to observe and quantify heat flow targeting theory will progress our understanding to derive proof of principle results. To embed natures approach to advanced materials of energy capture and storage will ultimately lead to desired morphology in functional facades. This through a case studies approach.
Embarking on the biological solutions, the requirement of the maximizing the solar energy capture can be fulfilled by following the present and previously recognized natural strategies of heliotropism (following the sun, which could be observed e.g. in the sunflowers). The plans use a phytochrome, a photoreceptor pigment to detect light. Light-detection mechanism is utilized in long and short-range behaviour regulation. It regulates the circadian rhythm as well as the seasonal rhythms like time of flowering and seeding. Leaf position is modified in the mechanism of stem elongation that is called phototropism: a chemical compound called auxin causes the plant cells to have an elongated shape on the further side form the light (this makes the stem bend towards the light).

key words: capture, storage, energy, nature, bio-inspired, optimization







Holistic investigation and IEQ assessment of building integrated hybrid facade element

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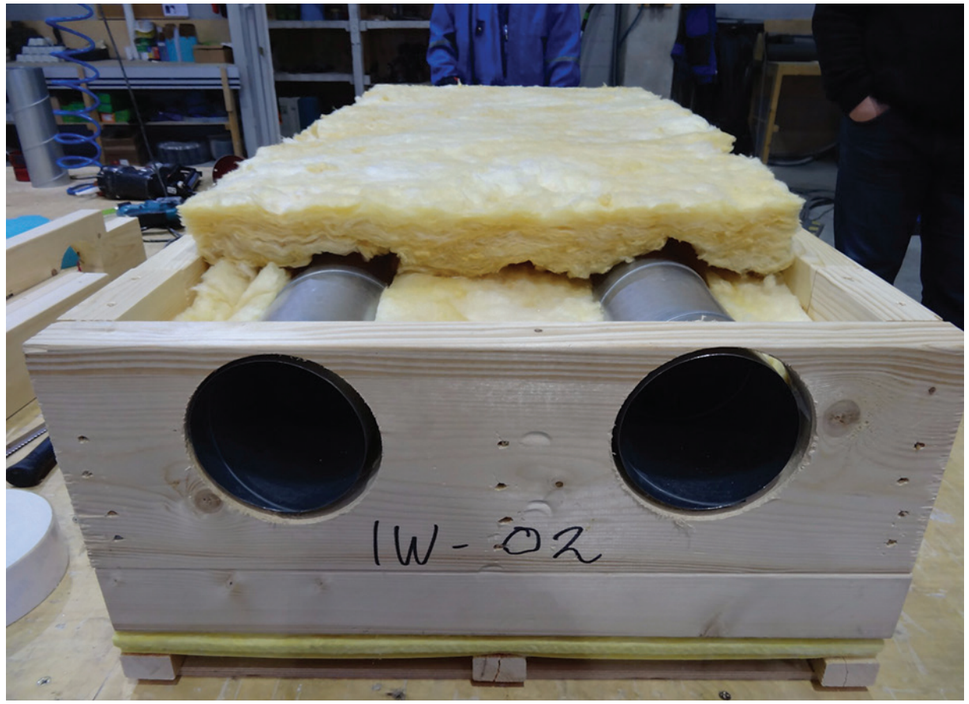
conference #3570

The number contemporary facades are based on glass panels that are designed either as non-structural curtain walls or recent decade emerging glass structural facade elements. The main obstacle to wider use of structural glass elements is lack of internationally accepted codes to support their design. This paper presents a starting point and an overview of holistic investigation and indoor environmental quality assessment of building integrated hybrid facade elements. The first part of this study is preliminary design of the Mock-up building and parametric simulations of selected panels.
On the other side, the future experimental research will be realized by integration of two ongoing projects: VETROLINGUM (mock-up building, University of Zagreb) and SENSO (Intelligent indoor environmental quality data logging system, University of Novi Sad). The SENSO is low-cost indoor environmental quality monitoring platform, consisting of inexpensive measuring units for all of the necessary parameters and cloud based software that aggregates and visualizes environmental data in user friendly browser environment for all gadget platforms. The physical properties that can be measured are: thermal comfort (air and radiant temperatures, air speed, humidity), air quality (CO2, CO, Volatile Organic Compounds, Formaldehyde, and Particulate Matter), acoustics, lighting, geo-location, local weather and other related outdoor environmental parameters.
Energy characteristics of these hybrid (structural glass – timber) elements will be tested trough the full size mock-up building, an onsite laboratory posted in Zagreb. Additionally, series of measurement with SENSO logging system will check accuracy of standard sensors set at the Mock-up and provide wider analysis in sense of additional indoor environmental quality measurements.

key words: hybrid facade element; mock-up building; data logging system; building performance simulation; indoor environmental quality

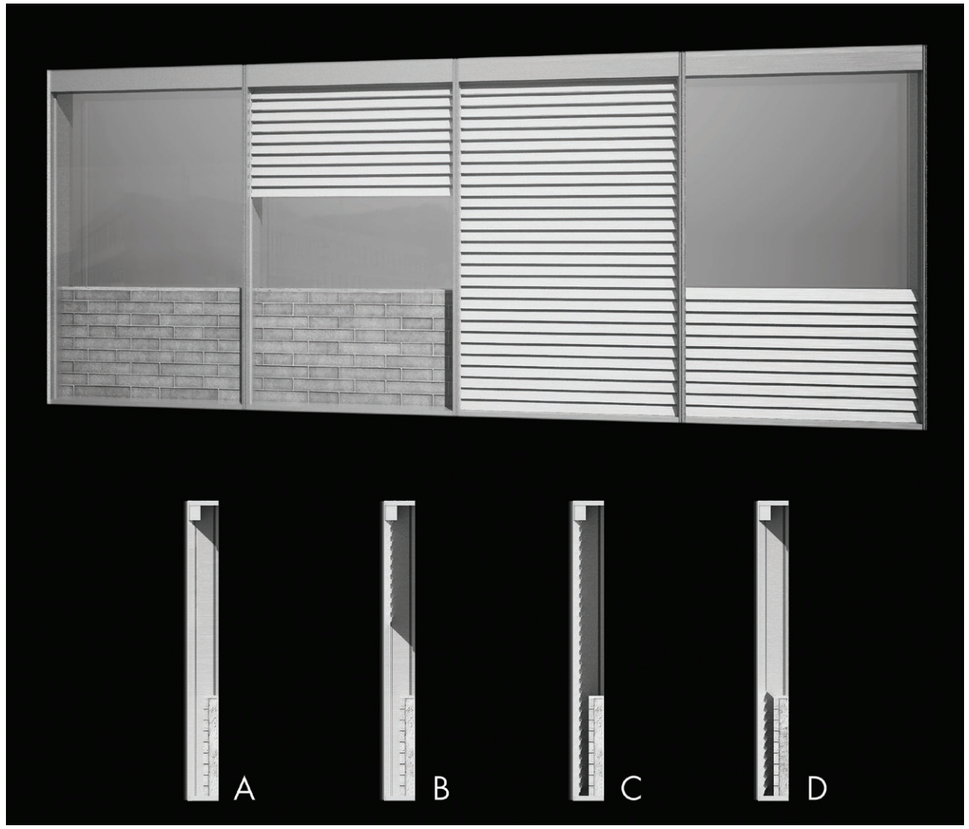


Modular element facade renovation with integrated duct design

Jurgis Zemitis, Anatolijs Borodinecs
Heat, Gas and Water Technology Institute, Riga Technical University, Latvia
conference #3576

The ongoing intensive renovation process of existing apartment buildings in many countries provide a good opportunity to apply innovative strategies regarding ventilation system integration in the external facade. The renovated buildings have a need for reliable ventilation system with heat recovery to reduce energy consumption, and only fully mechanical system with centralized AHU can provide that. However, in many cases it is difficult to place the ventilation ducts inside the existing shafts due to their size or location.
One of the potential solutions for such cases would be to integrate the ventilation ducts inside modular retrofitting elements as this type of external facade insulation approaches have become increasingly popular both in cases of renovation and new buildings. Such installation type ensures high quality, fast assembly process and accuracy. However, the duct size is limited to the thickness of insulation and can reduce the U-value of the construction, but as the air flowing through the ducts is preheated the theoretical heat loses through building envelope at this place are non-existent as there is no temperature gradient between inside and outside.
This approach of ventilation duct installation has been recently tested and applied to several buildings in Estonia and Latvia in scope of MORE-CONNECT project. The results of this project are presented in several papers (1; 2; 3). The knowledge gained from these case studies have shown that such type of approach is highly recommendable as it provides possibility to ensure good IAQ for renovation projects and modular elements with insulation thickness of 200 mm are enough to place the ducts.

key words: Ventilation, ducts, integration, renovation, modular elements



Solar Energy Balanced Facade

Thomas Wüest, Andreas Luible
Department of Engineering and Architecture, Lucerne University of Applied Sciences and Arts, Switzerland
conference #3584

Historically, buildings were developed and built for specific, regional climate conditions. As a result, buildings were built to match their surroundings with the intent to create a comfortable indoor environment. Developments in modern times lead to the construction of buildings which are less site-specific and therefore strongly depend on technical systems in order to maintain comfortable climate within the building. In Switzerland / Europe 31.5% of the total energy consumption is used for heating, ventilation and air conditioning (HVAC) of buildings (SFOE, 2015). The quality of the building envelope (or facade) is an important component which greatly contributes to the amount of energy used and therefore plays a significant part in the level of comfort which can be achieved in a building. Two important goals in a sustainable building industry are the reduction of building energy consumption and the reduction of carbon dioxide emissions (European Commission, 2011). Proper facade construction as a main element of building energy management is essential to meet these standards.

The review of existing facade systems and ongoing research show that transparent and opaque facades are considered as two separate entities. This study on the other hand presents a novel hybrid facade system, combining transparent and opaque solar double-skin-facades (DSF): The solar-energy balanced facade (SEBF) system. It incorporates seasonal adaptive daily solar-gain management to achieve an improved energy balance. By combining active controls, passive strategies and high quality materials this innovative facade system allows to efficiently profit from solar energy.

The main idea of the SEBF is to reduce the amount of transparent facade elements and instead use more opaque elements which function as a thermal storage. This results in the capability to smooth out daily energy flux variations. The system is equipped with two shading systems: one to manage transparent solar gains and the other one to manage the thermal storages energy level. To ensure a reliable shading system it is necessary to protect them with a second-skin type structure. The SEBF has two primary function modes; summer and winter. In the summer mode the main goal is to keep the solar energy outside and allow night-cooling. This is realized by closing both shades during daytime (Mode C or D) and open them at nighttime (Mode A). By closing all shades and pre cooling the storage, the overheating effect of DSF’s is reduced. In winter mode as much solar energy as possible should be gathered. Therefore the maximum amount of possible daylight getting in contact with the facade is desired (Mode A or B). For this scenario the thermal storage will also receive all the available solar energy. At nighttime, the closed shading will improve the thermal losses and therefore effectively reduce overall energy losses from the facade (Mode C).

key words: Passive facade, low-tec energy efficiency, adaptive facade, hybrid facade

Behavior of load-bearing timber-glass-composites facade in case of fire | fire protection concepts

Alireza Fadai[1], Wolfgang Winter[1], Matthias Rinnhofer[1], Andreas Schleicher[2], Frank Peter[2]
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[2] brandRat ZT Ltd., Vienna, Austria
conference #3585

Facades are very multifaceted systems, which serve many different claims; it is more and more in the interest to use them also for static functions considering resource efficient constructions. The objective of several research projects of the Department of Structural
Design and Timber Engineering (ITI) at the Vienna University of Technology (TU Wien) was to develop stiffening timber-glass fronts, which replace expensive frameworks and/or wind bracings in mid-rise buildings. The solutions for multi-story bracing facades were developed. The timber-glass-composites (TGC) facades enable a more efficient functionality of structural glass by allowing the use of approved timber joining techniques. The results provide a marketable component system for buildings, which could optimally use timber and glass. Currently thanks to these research projects and implementations, the requirements are well known. Critical issues such as flammability of TGC facades, flashover and the failure of static effective TGC facade elements were investigated within the joint research project “Timber- Glass-Composites facades | Behaviour in case of fire | Fire protection concepts” in cooperation with brandRat ZT Ltd.
The research project aimed at developing of fire resistant TGC facades including specific fire resistant details. Different types of TGC facades were compared with each other. Through knowledge gained by fire tests on prototypes, innovative fire protection concepts are developed. They allow the adherence to high safety standards to large-volume buildings in urban areas for the population of Vienna. The discussion of the safety factor should proceed to enable the engineers to calculate TGC facades in a reasonable way, based on a normative background.
The research project includes design concepts, feasibility studies and performance assessments of the components in order to improve the overall performance. The fire protection concepts elaborated in this research project shows that the application of timber-glass composite facades for multi-story buildings comply with the current state-of-the-art of fire-protection. Concerning the tested fire protection concepts and the underlying reference buildings, the focus was placed on office buildings, which have a great potential for the use of TGC facades. This is on the one hand due to the transparent construction of this facade technology, since room-high glazed curtain walls or double facades are often implemented in office buildings. On the other hand, several fire-protection requirements have been facilitated, especially in residential buildings, due to the amendment of the OIB-guideline 2 (Österreisches Institut für Bautechnik, 2015).

key words: multifunctional facade system, fire protection, fire safety regulations

Cell boxes M05 and M06 situated in the Plataforma de Automatización de Arquitectura Sostenible (PAAS) in Madrid, Montegancedo Campus of UPM

Thermal and comfort performance of adaptive radiant glass facade for commercial buildings

Giuseppe La Ferla
Escuela Técnica Superior de Arquitectura, Polytechnic University of Madrid, Spain
conference #3587

Currently, most commercial buildings, especially office buildings, are designed with full glazed facades. Since the early 20th century this type of skin has become a sign of identity in architecture as an expression of modernity, with recognized examples of projects by illustrious architects.
After 70s' energy crisis this sector started to thinking about the problems linked to the energy consumption and how archiving human comfort (especial thermal) with mechanical building services.
Now a day the main focus in building envelopes are on the new generation of facade, consisting of multifunctional and adaptive systems, where different physicals domains play a significant role in the change of some property or behaviour to adapt its performance to specific requirements or boundary conditions.
Relevant studies have been carried out regarding this physics domain, analyzing the impact on the visual and thermal comfort of occupants and focusing on internal beam solar gain in summer, thermal loads and radiant asymmetry between facade and internal environment in winter.
Office buildings are the most widespread commercial edifices designed with full glazed facades. In these types of buildings, discomfort caused by thermal asymmetry could be addressed using a standard glass curtain wall equipped with radiant glass technology, where this type of adaptive facade can control its behaviour changing functions according to y depending on the interior and exterior boundary conditions.
It can archive indoor thermal comfort by implementing a responsive function like radiant long wave heat flux with intrinsic operational, in a short response time, acting on the whole facade building or on a single module with an acceptable gradual free of adaptability.
This work presents the results of an experimental campaign of adaptive Radiant Glass Facade (RGF) performance in real cell box test, to assess the thermal and comfort performances at different seasonal exterior conditions (Figure 1).
The RGF technology is made up of a low-e double glazed window commonly used in commercial insulating curtain wall facade, also it knowns as coated Transparent Conductive Oxide (TCO), with good optical transparency and electrical conductivity property.

key words: adaptive glass facade, radiant glass, electrically heated glass, thermal comfort, commercial building facade

Conceptual Rendering of ATSF

A dynamic thermo-optical ETFE facade system

Daekwon Park[1], Jungmin Han[2]
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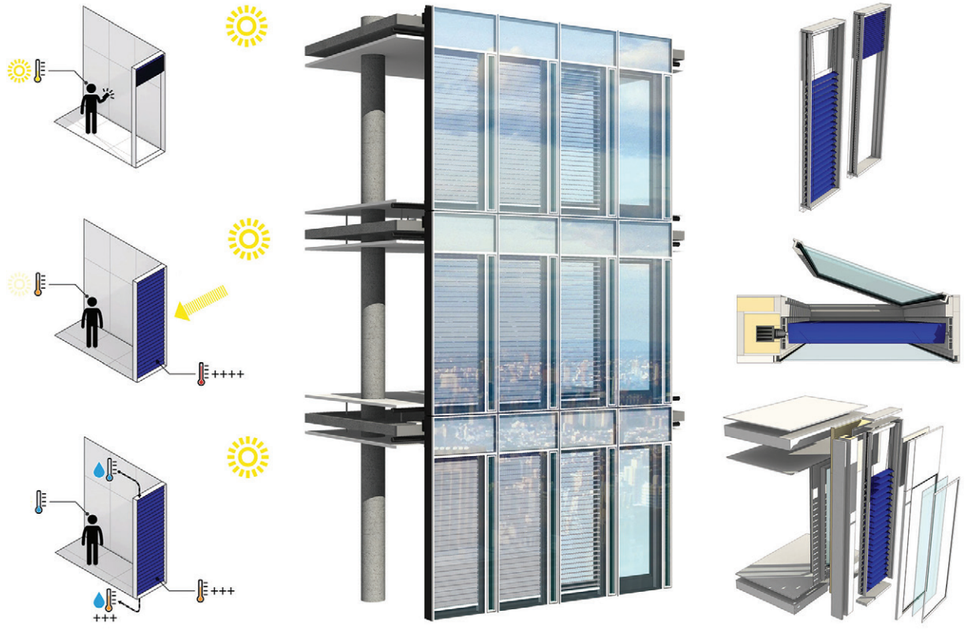
conference # 3588

The proposed Adaptive Topo-Skin Facade (ATSF) investigates the ideal range of adaptive thermo-optical properties of ETFE facades system with seasonal outdoor temperature variations. The ATSF system is a hybrid frame-and-skin high-rise envelope system consisting of a rigid bracing system enclosed in a soft and transparent membrane skin. Compared to traditional aluminum and glass cladding system, this approach not only drastically reduce the volume and weight but also contributes to the resiliency of facade assembly.
ATSF implements topology optimization in designing and sizing the lateral bracing system. This method ensures that the volume and weight of the steel framing are minimized without a compromise in structural performance. The multi-layered ETFE pillows that encase the lateral bracing system are transparent, durable, and lightweight. By dynamically adjusting the level of inflation, it is possible to vary its U-value based on seasonal changes, building orientation, and daily temperature fluctuation.
At full inflation, the U-value is minimum due to the low conductivity of still air contained within the layers. The six layers (thin and tall air cavity spaces) ensure that the convection heat transfer via air circulation is suppressed. The radiation heat transfer can also be minimized using the low-emissivity coating on the interstitial layers. At full deflation, the air layers are collapsed into a single membrane significantly increasing the U-value. This fosters the heat exchange between the interior and the exterior thermal environment. The functionality of low- emissivity coating is also eliminated since it is in contact with the adjacent membrane layers.
The design and optimization of the ETFE layers utilize the analytical models developed by Adrian Bejan and Kimber et al. A prototype of the skin is fabricated based on these prediction models and physically tested using heat flux sensors and thermocouples. The dynamic U-value predictions derived from the analytical model and the physical testing show strong correlations. This result enables the correlations to be utilized parametrically in implementing the ATSF for a broad range of building configurations and environmental conditions.
Finally, a series of building thermal performance simulation (EnergyPlus) was conducted to compare the annual Energy Use Intensity (EUI) between the ATSF and best practice large office buildings in New York City (i.e., EUI between 93 and 120).

key words: topology optimization, dynamic insulation, adaptive building envelope, membrane structure, hybrid frame-and-skin facade



Solar thermal Venetian blinds – transparency, user comfort and solar energy in one!

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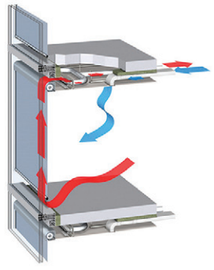
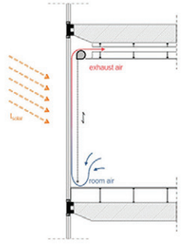
conference #3611

Building-integrated solar thermal (BIST) collectors have saved 40% in the past in comparison to building-attached collectors installed after the initial construction or retrofitting. But with modern architecture thriving for highly transparent facades space for opaque BIST is limited.
Solar thermal Venetian blinds (STVB) offer the opportunity to include the functionality of a solar thermal collector into Venetian blinds and thus into the glazed areas of facades. Especially in high-rise buildings, Venetian blinds are often used in between an outer and inner glazing and can reach high temperatures due to solar irradiation. Here lies another potential of STVB not only to harvest thermal energy but also to improve the thermal comfort within the building by lowering temperatures of the glass panes facing the interior.
The solar thermal Venetian blinds being developed by Facade-Lab and Fraunhofer ISE in the R&D project ArKol aim to combine the advantages of Venetian blinds and solar thermal collectors and even enhancing it using symbiotic effects. At first they have the clear advantages of collecting solar energy for domestic hot water, heating and solar cooling. Additionally the STVB can actively reduce the heat flux to the building interior decreasing the cooling load and improving the thermal comfort thanks to lower surface temperatures.
Heat pipes are used to extract the absorbed solar energy from the Venetian blind slats which are fully tiltable and retractable. The heat pipes are connected to vertical header tubes by a dry connection which leads to only two hydraulic connections per facade element. The STVB is designed to provide all functionalities known from regular Venetian blinds and offering the same user comfort. A control strategy can be implemented to optimize thermal comfort, energy harvesting and user comfort.
First mechanical prototypes have been built and a 1:1 facade Mock-Up is currently in the planning to be measured at Fraunhofer ISE test facilities. Based on these findings further optimization and facade integration of this technology will be developed.

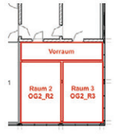
key words: multifunctional Venetian blind, building-integrated solar thermal (BIST), energy harvesting building envelope, thermal comfort, energy-efficient transparent facade

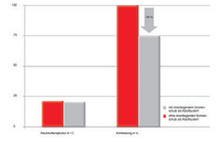
Concept

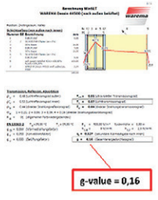


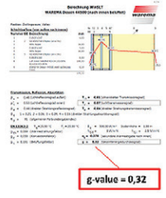


Measuring









Construction projects

Fully glazed again – Exhaust air facade enables energy efficient glass facades!

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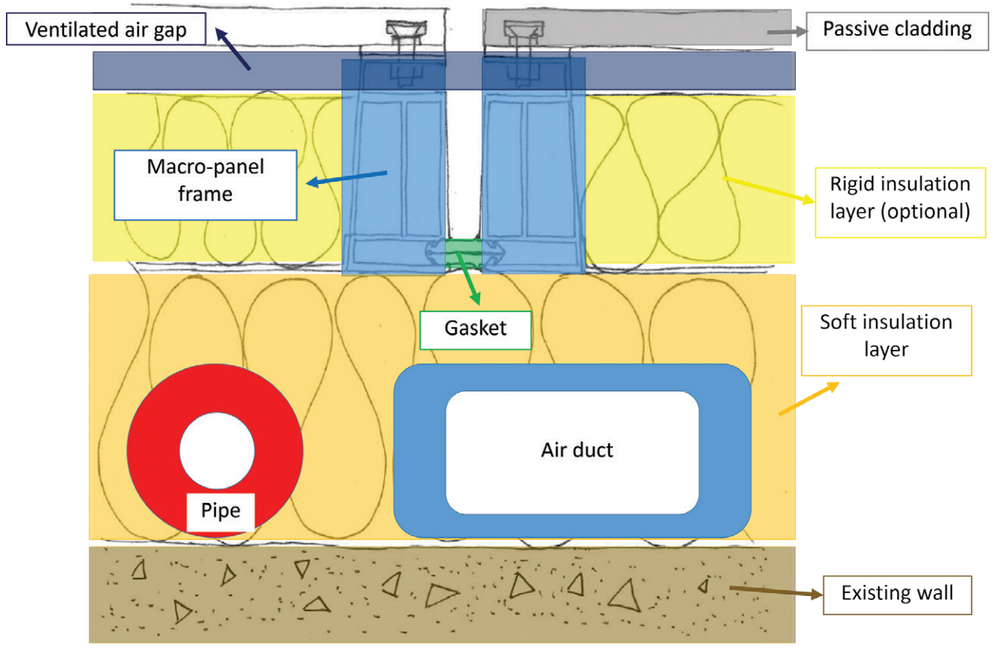
conference #3613

In contemporary office buildings cooling accounts for the majority of the energy consumption because of internal heat sources and high solar income during summer or at low winter sun. Based on the classical air-exhaust facade of an insulated glazing plus an internally ventilated glazing a new concept of an active blind was developed to act as adequate sun shading. The mandatory inner blind for anti-glare operates as separation layer to generate an air-exhaust corridor between blind and external glazing. Enabling an internal sun-shading by generating a buffer zone to exhaust heat from solar radiation without any external influences like wind etc.
Solar radiation is captured within the given corridor between blind and glazing. On the surface of the blind the solar radiation is absorbed and transformed into long-wave heat radiation. The exhaust air from the office is than sucked into and through this interspace extracting the generated heat. Thus preventing heating-up of the interior. In addition the surface of the blind facing the inside is cooled. These lower surface temperatures enable a higher comfort preventing radiation asymmetry within the building. As a result less cooling energy is needed and a higher user comfort can be ensured. The system can be operated individually creating a dynamically g-value regardless of weather conditions.
To verify the efficiency of EAF simulations and testing have been executed.
At Fraunhofer Institute on Building Physics' in-situ testing facility set-ups had been analysed. Testing the EAF to develop and evaluate construction, material properties and exhaust-air volume and velocity. Showcasing that a majority of the solar radiation can be exhausted before entering the room. During October with high direct solar radiation towards the facade from a global radiation of 800 W up to 380 W were extracted by the exhausted air not yet including the reflection by the external glazing.
In addition a parallel measuring at the Fraunhofer IBP Twin-Rooms was done. Giving a direct comparison between a ventilated inner blind, as Exhaust Air Facade, and a non-ventilated inner blind behind the glazing. The EAF needs up to 25% less energy for cooling than the compared standard solution.
Also simulations confirm the effect of the EAF as sun-shading. Resulting into a g-value of 0,16 whereas the same set-up as standard system without the air exhaust only has a g-value of 0,32.
The undertaken measuring and simulation show that the Exhaust Air Facade ensures high values of comfort and energy efficiency and at the same time can be executed cost and especially space-efficient enabling usage of the space till the external glazing.

key words: fully glazed facade, single layer facade, exhaust air facade, user comfort



Design of a multifunctional facade system for the residential buildings retrofit

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conference #3614

Within the construction sector, the retrofit of existing building is one key measure for the reduction of the energy consumption. One of the main barriers in this field is the lack of systemic approach in designing the retrofit action decoupling the envelope from the HVAC system. Hence, flexible facade solutions capable of being easily implemented in different cases and hosting energy system services can be a way tackling these barriers. Further design drivers are the drastic reduction of the buildings heat needs, controlling the risk of overheating, the facilitation of the integration of passive and solar active components as well as the energy distribution systems, a faster construction processes with high quality standards and being low intrusive for the inhabitants. Hence, an innovative facade solution for the retrofit of multifamily houses is under development within the European project BuildHEAT.

The BuildHEAT project

BuildHeat drives change in the construction sector, brings information and coherence onto the market, facilitating the decision making and planning processes through: (1) efficient, reliable, non-intrusive and cost-effective technologies for the building envelope and energy system; (2) functional, systemic and easy-to-implement solutions, enhancing energy standards, comfort and healthiness; (3) innovative business models designed to mobilize large investments from the public and private sectors. During the project, the demonstration of the effectiveness of its solutions is foreseen in residential blocks in Rome (Italy), Zaragoza (Spain) and Salford (UK), covering more than 120 individual dwellings.

Facade concept

The facade concept has been designed based on technologies next to the market and with the necessary attributes of standardisation, flexibility, easy installation and cost effectiveness. The facade is flexible meaning that is capable of hosting passive and solar active cladding as well as because of the possibility to adapt to the exiting walls' uneven geometry. The facade concept is a preassembled ventilated facade and comprises the following components. (i) Preassembled metal substructure with a set of anchoring systems capable of hosting passive and solar active elements. (ii) A first thermal insulation layer adherent to the existing wall and a second optional one fixed at the metal structure. (iii) Passive cladding panels made of polymer concrete coated with a reflective painting and/or solar thermal or photovoltaic panel. (iv)

key words: Envelope retrofit, Multifunctional facade, systemic approach, design flexibility, low intrusive solution

Building guidelines to provide as-designed solutions for Energy-efficient envelopes

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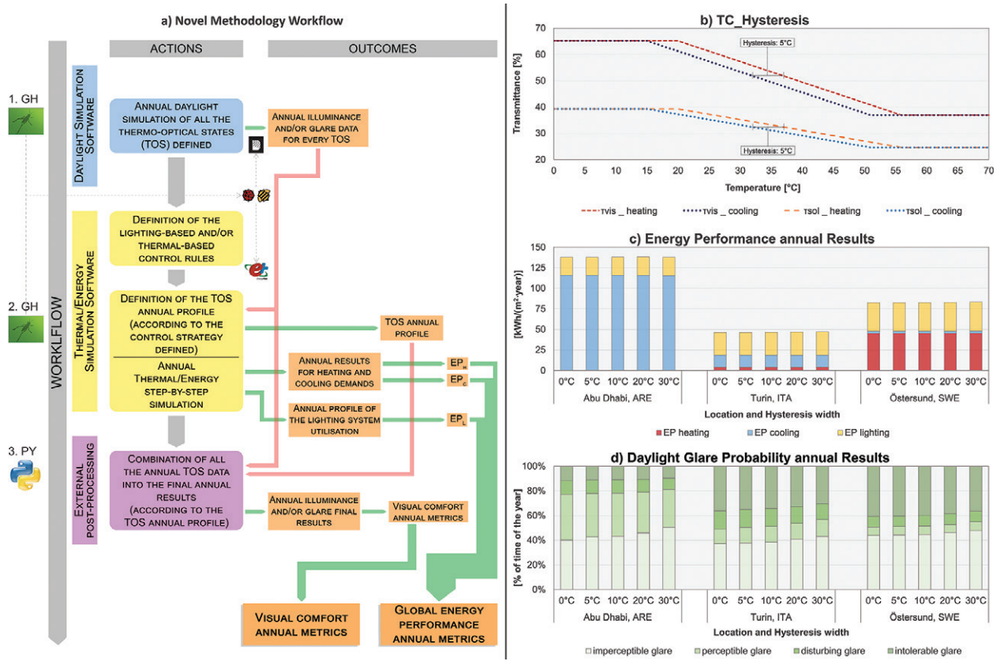
conference #3620

The construction sector is responsible for almost 40% of energy consumption and 36% of CO2 emissions in the EU (European Union, 2012) and, in the last few years, the European Authorities has set stringent standards to reduce energy consumption in the building stock. Therefore, the benefits of new and refurbishment solutions for critical building components, in new and existing facilities, can have a significant impact.
Nowadays, one of the main issue is that the as-design solutions for energy efficient buildings (EeBs) are often not properly implemented on site. The procedures of inspection and/or installation are mainly based on worker's experience and do not usually follow detailed protocols to avoid energy low performances and, above all, are not integrated in a comprehensive platform that can be used by different stakeholders. As a result, the quality control processes are often at risk and the energy performances of the building may not achieved the required levels. In addition, in 2016 the European Commission proposed an update to the Energy Performance of Buildings Directive, in order to promote the use of smart technology in the construction process.
The Insiter project, under the Horizon 2020 research program, aims at identifying and preventing quality and performance gaps between the design and the realization of buildings during on-site realization. This goal will be achieved by developing self-instruction and self-inspection procedures, supported by BIM-based software tools, Augmented Reality applications, and measurement tools, that shall be integrated in a software-based platform.
The guidelines, presented in this paper, are the bridge to bring research knowledge into practical implementation and will not disrupt on-site working processes by additional effort. The aim is to propose simple and user-friendly devices that can be used by blue-collar efficient and accurate. workers, inspector, architects and engineers,tosavetime and costs bymaking the processes efficient and accurate.

key words: self-inspection, guidelines, building envelope, BIM, augmented reality



New Functionalities

An advanced integrated simulation procedure to evaluate 1 the performance of adaptive glazings

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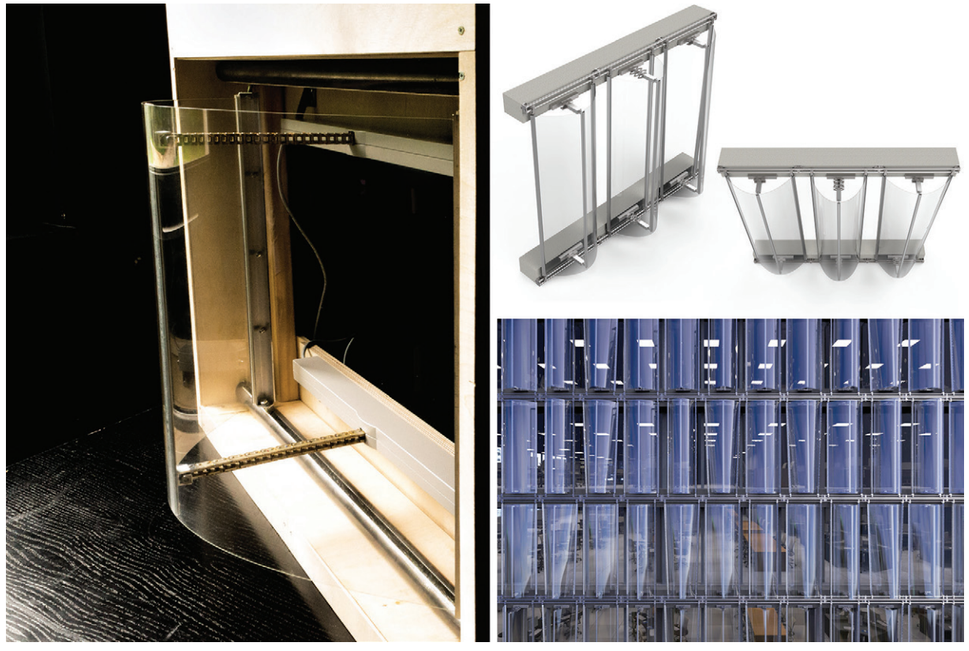
conference #3624

The use of thermochromic glazings (TCG) can significantly improve the energy performance of a building compared to traditional static glazings, due to their capability of varying their thermo-optical properties in response to the material temperature variation. To evaluate their potential in an accurate and comprehensive manner and to verify the performance of a design solution it is essential to have numerical models and simulation tools which correctly reproduce the behaviour of such components at the building level. Current Building Performance Simulation (BPS) tools have limited capability in evaluating the performance of adaptive building envelope technologies [1], such as the TCG, due to their inability to: (a) dynamically change the thermo-optical properties of adaptive materials; (b) accurately evaluate the mutual effects of transparent adaptive technologies on energy use and on indoor environmental quality (mainly thermal and visual). For the case of TCG, most studies focused on the energy aspects only, without considering the mutual influence between energy and daylighting [2]. Moreover, most of the studies adopted the TCG models currently available in BPS tools [3], which do not consider a) the hysteresis effect between heating and cooling of a TC material, b) the wave-length dependent optical properties of a thermochromic layer [4]. The authors hereby present a novel simulation procedure which enables to appropriately assess the following for an adaptive transparent facade component:
- the thermal/energy and daylight performances in synergy;
- the mutual influence, in the building environment, of thermal and daylight physical domains due to the adaptiveness of the component;
- In the case of the TCG, its hysteretic behaviour and the influence of this one on visual comfort and energy performance of the analysed spaces.
The methodology here presented is meant to be general and applicable to any kind of adaptive facade. It can be used to investigate the effect of the variation of different design parameters on the adaptive facade performance both in thermal and daylight related aspects at a time.

key words: Adaptive glazing; thermochromic glazing; integrated simulation procedure; hysteresis; integrated thermal/daylighting performance



Flexible Transparency - a study on adaptive thin glass facade panels

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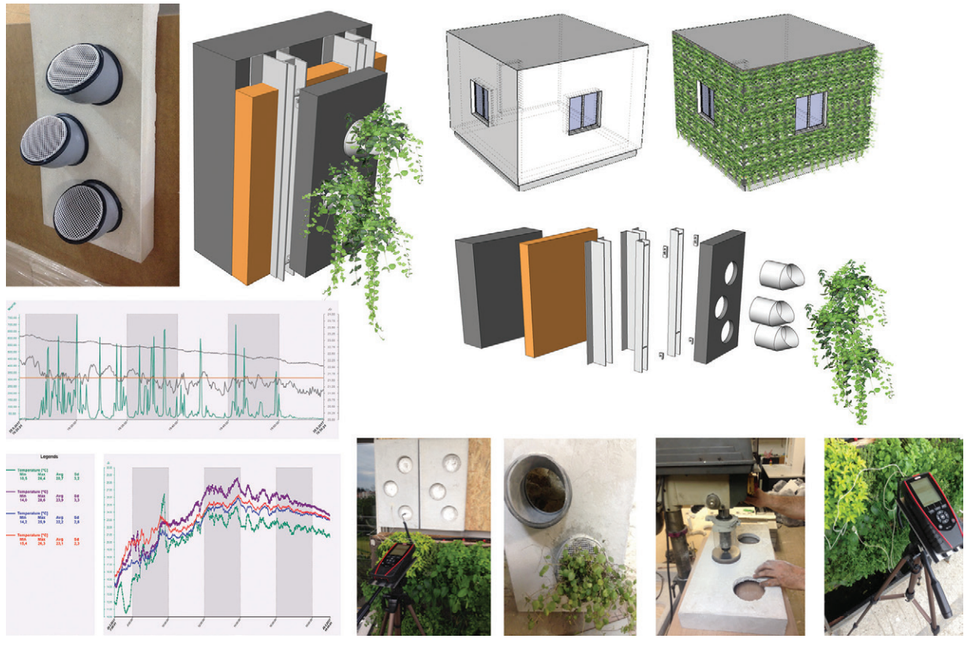
conference #3626

Chemically strengthened thin glass (t<2mm) is a material that is stronger and, due to its thickness, more flexible than conventional window glass.
In the context of facades, this material offers the possibility of lightweight and adaptive glass facades. The concept was developed in an MSc study on the use of thin glass in adaptive facade panels.
The behaviour of thin glass in this context depends on different factors; its thickness and strength define its bending limits, while the desired geometry and movement affect its overall stiffness and visual outcome.
To integrate these factors, different configurations of panels were analyzed in numerical models. These analyses proved important to understand the desired movement and geometry to correctly define the supports and degrees of freedom of the panel, avoiding stress concentration (mainly on the edges) and allowing for an unobstructed movement of the panel.
The development of these analyses resulted in the conception of a design example of an adaptive facade panel, taking into consideration the design guidelines developed in the research. To test the theoretical assumptions of this study, a mock-up of 80 by 60 cm was developed.
Before thin glass can be safely applied in real facades, more research is still necessary. Nevertheless, this research showed that thin glass offers a high potential for dead load reduction, a positive environmental effect due to material savings, and possibilities for new architectural designs.

key words: Thin glass, adaptive panels, lightweight facade, kinetic facade



Contribution of green wall to reduction of building overheating

Budimir Sudimac, Aleksandra Krstic-Furundzic, Andjela Dubljevic
University of Belgrade, Faculty of Architecture, Serbia
conference #3627

Green walls are one of the concepts in the design of sustainable building envelopes which affect energy performance of facades and their visual characteristics. Since green walls change their appearance during the seasons they can be considered as adaptive building envelope. This fact is based on the original scale buildings with vegetation walls that represent a significant factor in the process of improving the thermal characteristics and design performance of the buildings.
This paper shows the potential of a particular technology of constructing a green wall with a goal to reduce the temperature peaks of external surfaces of buildings envelope in summer. The use of vegetation walls in architecture has opened up new planning possibilities and created planning conditions for reducing the energy necessary for cooling buildings. This research shows design and construction of the concrete prefabricated, modular model of green wall which contains plants that correspond to the selected technology and specific climatic conditions. The paper's methodology is presented by analysing climatic characteristics, experimental measures of the built modular model, software simulation analysis of the existing heat gains in office buildings during the summer, possibility of integrating vegetation wall into an office building envelope, and by analysing the reduction of heat gains in a building after the application of vegetation wall.
Unlike conventional facade materials, vegetation walls do not absorb the received solar radiation. Solar radiation descending on the leaf area of vegetation walls is partly reflected, part is used for photosynthesis, part is used in the process of evapotranspiration and a smaller part reaches the load bearing part of the facade covering. This was concluded from the practical research which was done on an experimental modular model of vegetation wall, which was used to measure contact.
The model considers coupled heat and mass transfer phenomena through the green module.
The leaf canopy is characterized by the coverage ratio, the leaf area index and semitransparent radiative properties. The model equations establish the heat balances on the leaf canopy and on the substrate surface.
The distribution of temperature values, seen on the thermograms of practical models, is also read on the simulation of the hypothetical model. The reduction of contract area temperatures leads to the reduction of overall energy necessary for cooling the air inside the building. The wall's vegetable structure protects the load bearing surface of the wall from excessive UV radiation and atmospheric precipitation.

key words: thermal comfort, green wall, building envelope, energy performance, reduction of overheating

3D prints of the investigated variants, Photo: EBB

Prefabricated window with integrated technology for refurbishments “Window Machine”

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conference #3631

Exterior wall and thermal glazing constructions have today reached sophisticated levels of energy efficiency and quality. The weak point of a facade with many individual windows is the connection of the window frame and the wall, where design, constructional, structural, functional and organizational problems are concentrated in one place. Complaints in this area are one of the most common grounds for legal disputes in the construction industry (STI, 2009).

Overview & objectives

“Prefabricated window with integrated technology for refurbishments”, a research project from TUM’s Chair of Building Construction and Material Science, which was supported with funding from the Research initiative Future Building, seeks to discover how as many requirements as possible can be incorporated into a functionally expanded prefabricated window element for use in energy-saving renovation works. The majority of such renovation needs in Germany are presented in buildings of the 1950s to 1970s. The unadorned, ‘standardized‘ facades of this era are predestined for the application of industrial prefabricated solutions. This research project focuses on buildings typical of their generation in which no energy-saving improvements (BMWi, 2014) have yet been carried out.

Focus of the project

The installation of conventional window replacements is complicated by the involvement of many trades and numerous interfaces at geometrically and structurally challenging places. Through the integration of sun, glare and insect protection in an elegant prefabricated quality element – the “window machine” – the user will profit from a less intrusive construction process, lower costs as well as higher construction quality. Alongside typical window functionality, the inclusion of building services such as ventilation / heat exchanger, electrification / building automation will be studied as additional components in the window element. Thus, additional otherwise laborious renovation measures can be carried out as part of the window replacement with minimal intrusion into the building fabric.

key words: multifunctional, window element, prefabrication, integrated technology, energy renovation

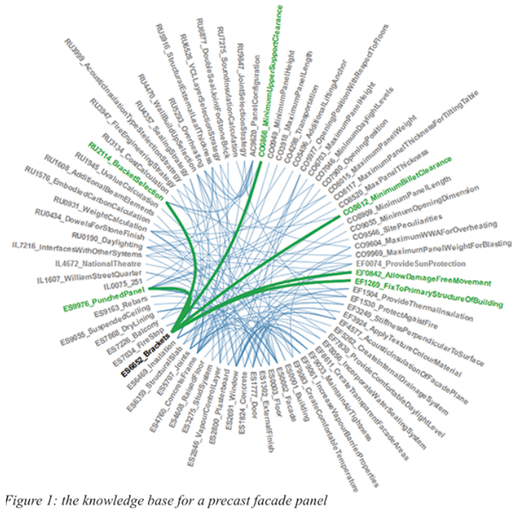

Figure 1: the knowledge base for a precast facade panel

Watch the video of the knowledge base in action:

or go to **http://tiny.cc/jm_web_interactive**

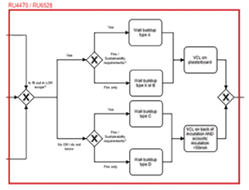

Figure 2: extract of a process maps built from the knowledge base

Figure 3: digital tool development from the knowledge base

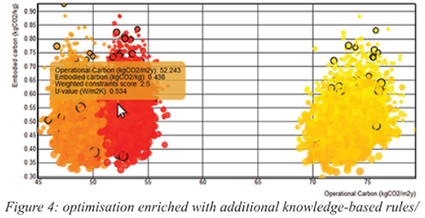

Figure 4: optimisation enriched with additional knowledge-based rules/ constraints (shown in HTML via D3.js)

Interactive knowledge-bases to support facade design: knowledge management meets data visualisation

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conference #3554

Today's major challenge in facade design is to devise a solution that satisfies the intended architectural expression, while guaranteeing ease of installation and production, and the specified performance during the service life (Montali, Overend, Pelken, & Sauchelli, 2017a). The knowledge of these aspects is very often held by parties (aka actors) either those intervening later in the process, e.g. facade contractor, or the external parties analysing the compliance to specific standards, e.g. structural / facade engineers.

The present research proposes an approach for building interactive knowledge-bases that make knowledge available to design teams, for more informed decisions. The proposed tool (Figure 1) uses HTML-based MOKA forms (Stokes, 2001) to store the knowledge and the JavaScript library D3.js (Bostock, Ogievetsky, & Heer, 2011) to visually represent the interrelations between forms. The user can interactively navigate through the knowledge and address specific design issues. The integration of multiple design criteria from different disciplines in a unique platform shows the governing interrelationships between the various aspects of facade design.

The use of knowledge bases is here demonstrated for three possible applications:

Design process maps: by exploring the knowledge base and the connections between different design criteria, it is possible to develop specific design process maps. Figure 2 shows an extract of a map (in BPMN notation) that is aimed at choosing the best build-up of the concrete panel. Different design criteria, such as fire, sustainability and level of involvement of the contractor in the installation of the panel are considered.

Digital tool development: a knowledge base can also be used to develop digital tools that automatically apply different rules/constraints. Figure 3 shows a Rhinoceros / Grasshopper tool developed for precast panels (Montali, Overend, Pelken, & Sauchelli, 2017b): as the user modifies parameters governing the design of the panel (such as build-up – A), some performance indicators (B-D), as well as compliance to specific constraints by querying the knowledge base (C) are shown.

Optimisation: Traditional optimisation algorithms can be enriched with additional knowledge. Figure 4 shows the optimisation of a precast concrete panel (under specific environmental conditions) in terms of embodied vs operational carbon. The diagram adds information to the choice of the optimal solution through the radius of each point: the larger the radius, the more visible the solution, the lower the number of broken design constraints. The colour of each circle represents the U-value of the solution.

key words: facade design process, data visualisation, knowledge-base, design automation, knowledge management

New engineered parametric nodes

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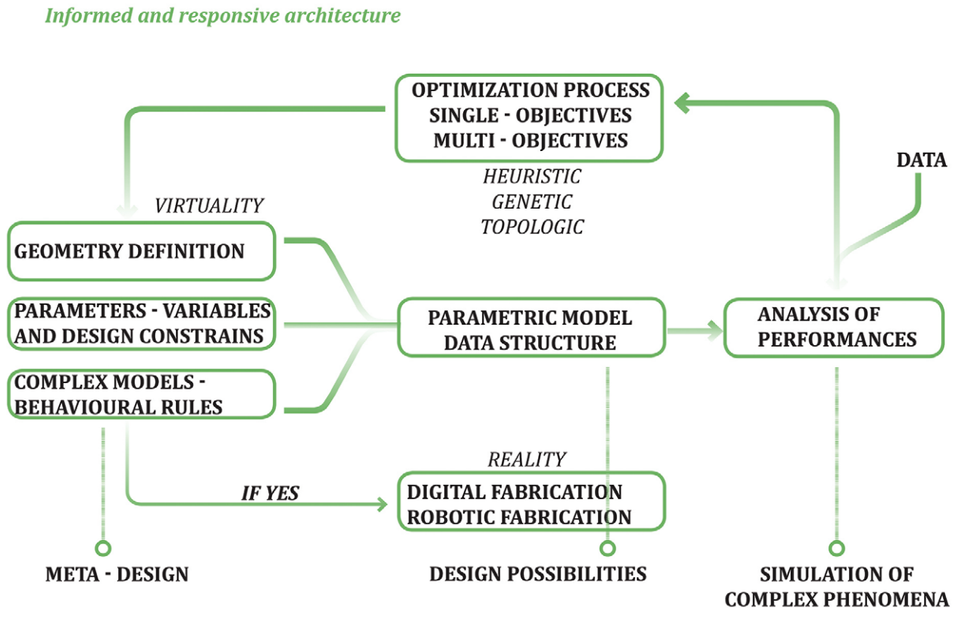
conference #3568

The radical change in architectural design transcends the individuality of design towards multi-various individuation. The immersion of parametric diagrams in the representation of architectural objects leads towards a process, which could be grasped and manipulated with a high degree of efficiency. Computational advanced design techniques are becoming inevitable, and new methods need to be implemented to work on retooling the traditional ways of manufacturing elements.
To formulate the problem; Architects, facade engineers and manufacturers need a speculated new solutions and be their liaison for collaboration.
Intricate designs driven out of parametric potentials are characterized by the different angles and inclinations that form the mullions/sub-construction, which forms the desirable design. Accordingly having a flexible connection that can provide a full range of proper angles is requisite.
Additive manufacturing is known as 3D printing is based on the theory that any object could be synthesized by breaking it down into multilayers, which needed to be laid at the top of each other to form the final object. Metal-Based additive manufacturing has significant growth in the last couple of years, based on the advantages that AM offers, which is producing complex 3D objects directed from CAD data without the need for that careful and detailed analysis required by the other manufacturing processes.
A unique collaboration between architects, facade engineers and manufacturers could be achieved by following a whole new aspect, which is how to move from Design to Production.
The merger of the revolution in design and manufacturing will lead towards building a new role for the utilization of these advanced computational technologies and additive manufacturing. The move from design to fabrication will result towards a whole new era of planning new construction, which eliminates several constraints, which affecting the process dramatically and holding off all parties from getting the job done.

key words: parametric, nodes, free-form, additive manufacturing, adaptive solutions

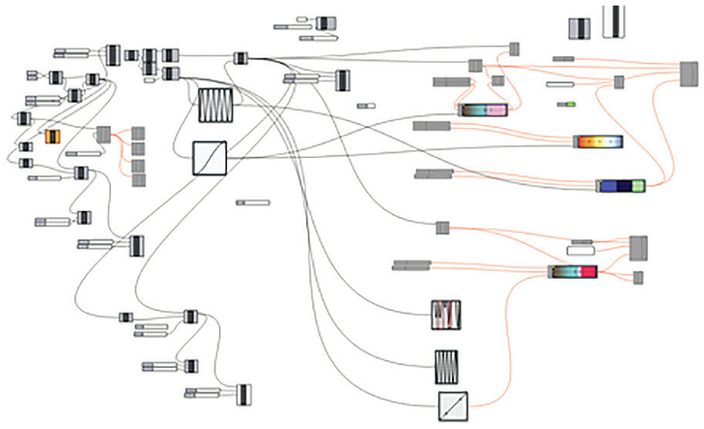


Informed envelopes. Parametric design and digital fabrication techniques for a new concept of responsiveness

Angelo Figliola
PDTA Planning, Design and Technology, "La Sapienza" University of Rome, Italy
conference #3575

The concept of performance in architecture is related on his ability to create a dynamic relation with the users, function and with the environment in which architecture is placed. The dynamic relation can be explained through a series of design operations that are able to exploit the potentialities offered by technological innovation of the contemporary era: responsive devices able to respond to external stimuli with mechanical systems or with material properties are possible interpretation of the dynamic relation between architecture and external environment. If the benefits derived from the use of the dynamic systems are well known in contemporary architectural practice, equally obvious are the critical issues as the scalability of the processes, the economic and the formal aspects. Within this scenario, generative design and digital computing play a key role in the efficient exploration of design solutions, as well as for the ability to focus on a single workflow, formal generation, simulation of dynamic phenomena and manufacturing (img.). Process analysis, besides defining the limits and potentials of the design approach, opens the debate on the role of technological experimentation in the post-digital era defined as post-industrial robotics. The anthropomorphic robots, used in the automotive field since the 80 ' to perform specific tasks, is reprogrammed and used to transfer digital models in the real world, creating a possible infinite combinations making it possible the realization of optimized and responsive geometries. The introduction of robots and the final affirmation of 3D printing technologies opens up a post-industrial era that has its roots in the combination of computational design and digital fabrication. In the post-industrial era, the aspects related to sustainability and creativity are the central points of the projects rather than the automation and the economy of the processes. The direct connection between the generative processes and the fabrication procedures does not mean to follow a formal evolution without logical relationships but rather to use the machine as an agent through which realize optimized and informed geometries. The material and the fabrication technique used are not parameters to consider at the end of the design process but as input through which the designers can construct the space of design possibilities. This approach opens up new scenarios related to the parametric process and data-driven strategy, the use of new materials and the exploration of new fabrication techniques for traditional materials as well as the introduction of new design paradigms for informed envelopes.

key words: computational design, performance-based architecture, digital materiality, optimization, digital fabrication



Integrating sustainable goals for design of an adaptive facade for office building

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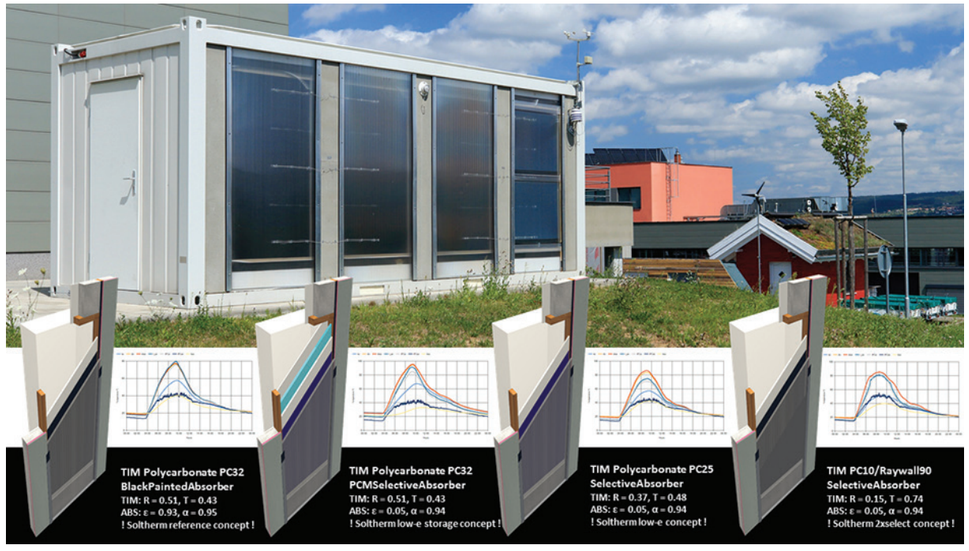
conference #3594

The buildings are identified as one of the main contributors to the degradation of the environment due to the intense resource consumption and waste creation as well as the lack of design quality. The sustainable design in architecture intends to improve the buildings performance by integrating the environmental, social and economic aspects into buildings design, thus forming complex interrelations among them. Due to this complexity and multitude of design objectives, the designers are faced with difficulties when choosing the optimal sustainable design solution.
The aim of this research is to evaluate and integrate several design objectives for an office building facade. Governed by the idea of integrative design, the approach is based on inclusiveness where the opinions of the designers, users and construction companies are assessed in order to rank the relevant design objectives for a facade design.
For assigning appropriate weight factors to the objectives a structured decision making tool is utilized known as the Analytic Hierarchy Process (AHP). Based on a pair-wise comparison it enables objectively to quantify the relevance of the design goals. This would enable the project team to make more informed design decisions for the facade design and to set the focus on the relevant goals during the design process in the schematic design phase.

key words: sustainable design, parametric modelling, analytic hierarchy process



Research on climatically active solar facades with the integration of the advanced material solutions

Miroslav Čekon, Richard Slávik, Karel Struhala, Jakub Čurpek
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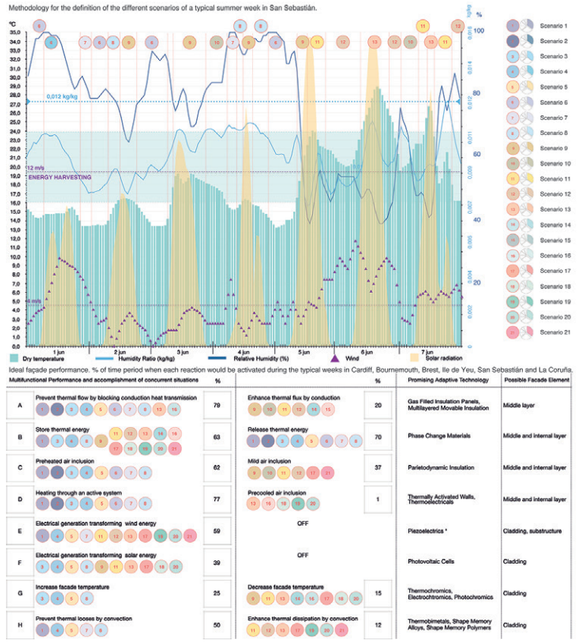
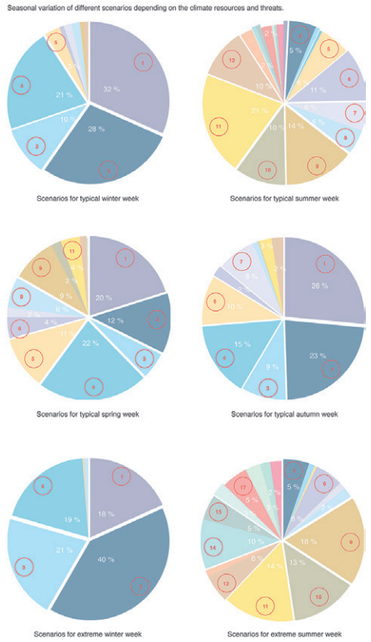
conference #3542

Recent research and development in the facade engineering field highlights the need of comprehensive system solutions and advanced materials. The real performance of these materials and facade systems is very relevant issue as they can contribute towards the European energy and environment policies: e.g. the implementation of nearly-Zero Energy Buildings (nZEB) required by the Energy Performance of Buildings Directive (EPBD).
The development and implementation of novel facade concepts needs to be accompanied by applying of appropriate simulation and experimental methods. These methods are involved in performance prediction of the facade concepts.
Presented research focuses on verification of thermal, energy and life cycle performance of advanced materials implemented in modular solar facade concept. The concept is based on sensible use of (renewable) solar energy to reduce the heating and cooling demand of buildings. The concept investigates integration of transparent insulation materials (TIMs) in opaque building facades in a way similar to more common “Trombe wall” systems. For this purpose the TIMs are combined with spectrally selective layers (non-selective absorber nSA and selective absorber SA types), enhanced with optical raster and heat accumulation layers based on latent thermal energy storage (basically PCMs).
The proposed concept was tested at laboratory materials´ level, then full scale both in a climate chamber and real climate conditions. Currently there are two ongoing full scale outdoor tests in Brno (Czechia; see Figure) and Bratislava (Slovakia). Several variants of facade structures incorporating TIMs are tested there in real climate. The tested variants include different types of TIMs (with cavities parallel or perpendicular to the surface) as well as varying composition of the structure (see Figure). Especially the influence of various polycarbonate-based TIMs (with different thermal and optical parameters representing different number of chambers and geometry) on the overall performance of the facade is studied in detail. In general, polycarbonate systems are similar in thermal performance to standard glazing systems. However, recent technological advances in polycarbonate production may have opened ways for new integrations. In these aspects, the presented research pursues utilization of solar transmittance of the material in multi-layer facade concepts.

key words: Transparent Insulation Materials (TIMs), Phase Change Materials (PCMs), optical and thermal performance, building energy simulation, full-scale testing





Characterization of adaptive opaque facades

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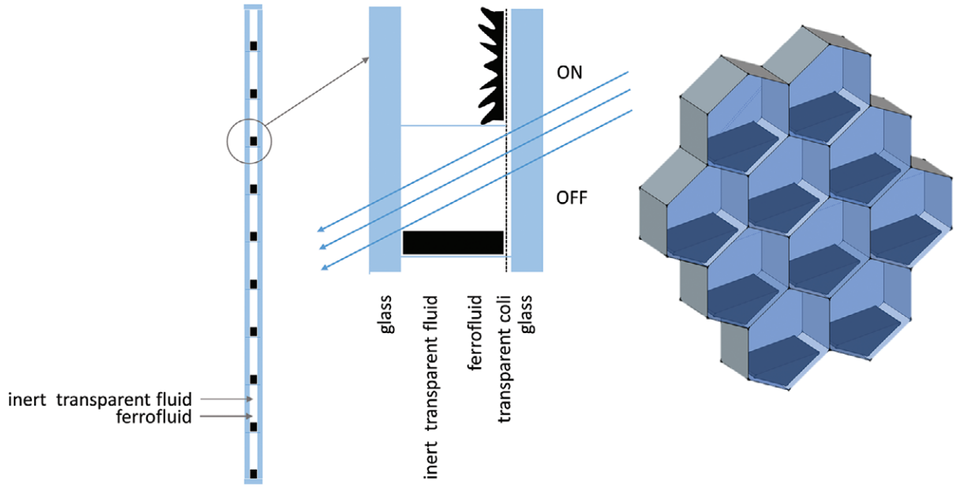
conference #3549

The development of adaptive building shells, as well as the “selective” approach design strategy, is considered a promising breakthrough for the achievement of a Zero Energy Building Target. The building envelope is considered a modulator between indoor and outdoor environments and reacts to changes while accomplishing Comfort Standards. Along this, substantial progress is being made in glazed facade technologies, which are mostly aimed at office buildings. Nevertheless, European environmental objectives for 2020 and 2050 include all building typologies and around two thirds of buildings´ consumption come from dwellings. In the Atlantic Zone, most of the primary energy is consumed in the heating system, followed by hot water production and appliances. Even if energy efficiency trends in households show a strong reduction in most of the countries, the utilization of environmental resources for it is still undeveloped. Industry development for adaptive building envelopes in residential buildings and in particular for opaque facade systems, has not been reached yet and neither has a case study been built in a temperate climate coastal area. All this requires establishing preliminary concepts that will allow the optimal development of new advanced opaque facade systems. This proposal consists of an initial design characterization for adaptive opaque facades in Atlantic Climates and shows their potential in dwellings. For this purpose, six seaside locations of different European countries are studied for each season. The Range of environmental agents’ variation and needed reactions are indicated. Environmental resources and their opportunities are highlighted and threats are evaluated. Non-static hourly scenarios analysis plot concurrent situations and different combinations of simultaneous envelope functions are described. According to this, the most demanded facade responses are linked with promising technologies, which will help to scope future research and design strategies.

key words: adaptive opaque facade, zero energy building, dwelling, temperate climate, environmental resources



Potentials for the use of ferrofluids in instantly-reacting solar shading

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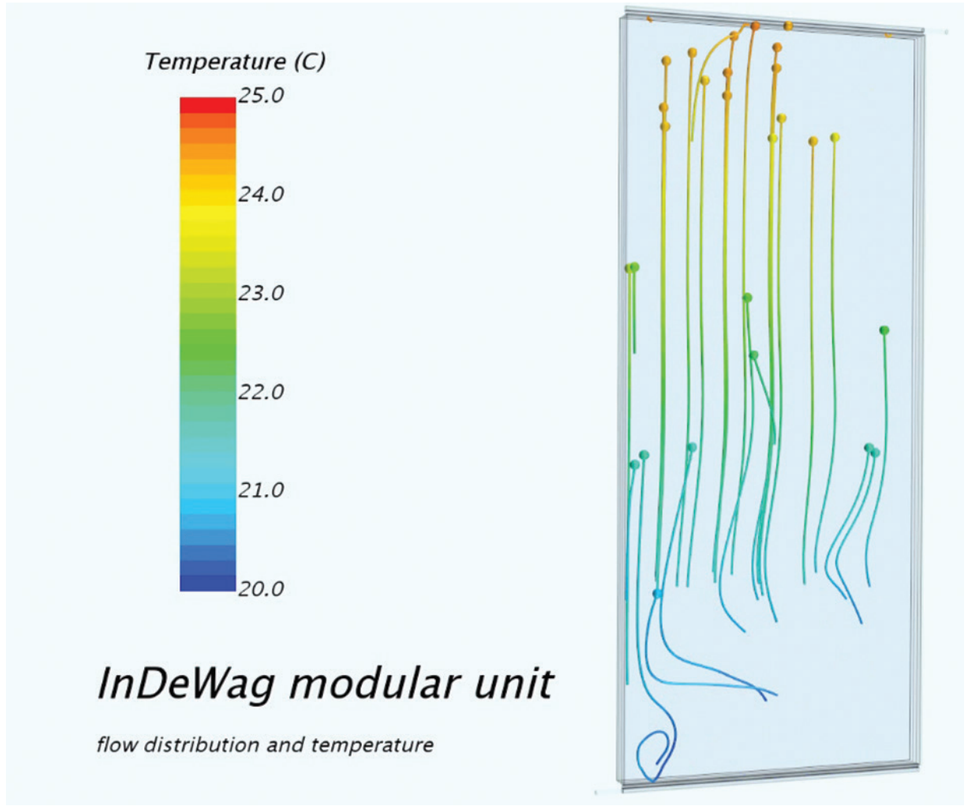
conference #3565

Ferrofluids are colloidal liquids made of nanoscale ferromagnetic, or ferrimagnetic, particles (usually 10 nm particles of metallic elements) which are suspended in a carrier fluid (usually an organic solvent or water). The solution becomes strongly magnetized in a magnetic field. Ferrofluids are the focus of research carried out in a variety of fields (e.g. electronics, medicine), including projects such as adaptive shape-shifting magnetic mirrors.
The potential for the application of ferrofluids in facade shading design lies in two specific features of these substances. The first is the dark colour of the fluid (e.g. black in the case of iron nanoparticles), which makes it fully opaque, thus allowing it to function as a shading device. The second feature is the possibility to freely modify the ferrofluid shape in a magnetic field density ranging from 100 to 500 mT (mili Tesla) in a matter of milliseconds.
Ferrofluids “can be precisely positioned and controlled by an external magnetic field” (Magnetic Liquid Technology, 2015). This opens a wide range of possibilities for the application of opaque ferrofluids in facade design. Another important feature of ferrofluids is that they “respond immediately to the changes in the applied magnetic field” (Magnetic Liquid Technology, 2015) and can therefore be used to design light valves that react instantly.
The research on the manipulation of micro- and nano-sized droplets of ferrofluid is developing dynamically. The potential for various technical applications of ferrofluid has been proved e.g. in valves without mechanical parts or in light-directing optical devices (Torres-Díaz et al, 2014). The discipline of transparent conductive layers also has been growing rapidly mainly in response to the push from the market of flat TV and cellphone displays. So far transparent electrode coils have been created to test wireless power transfer using coatings made of multilayered IZTO/Ag/IZTO, and have proved to be efficient in charging e.g. medical devices. Planar loops and spiral coils were placed on the top and bottom of an acrylic substrate (Lee et al, 2016). A typical fridge magnet with a magnetic field density of approx. 5 mT (militesla) is not powerful enough to manipulate the ferrofluid, but this can be done successfully by means of neodymium magnets with a magnetic flux density of approx. 1.2 – 1.5 Tesla. Similar density can also be achieved by a loudspeaker coil (1-1.5 Tesla).

key words: ferrofluid, shading, optical effects, daylight processing



Graphical represantation of computational fluid dynamics (CFD) results of the water flow glazing unit.

Water flow glazing - building envelope for the future of daylight and energy efficiency?

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conference #3573

Building industry is still chasing the dream of fully transparent glass facades. Currently available technologies are in clear contradiction to the main purpose of a fully glazed facade: The clear and unobstructed view from the inside into the outside environment. The main reason is the inevitable requirement of solar protection to avoid solar heat gains and consequently high cooling loads in buildings. Solar coatings, tinted glass, switchable windows and classic interior and exterior sun shading devices all have the same general effect: The quality of the views to the outside is reduced. Within the framework of the European research program HORIZON 2020 the project InDeWaG (Industrial Development of Water Flow Glazing Systems) has been funded by the European Union. During the funded period of three and a half years an international consortium incorporating research institutes, industry and designers is developing a new insulation glass unit. In the cavity of this unit a water-glycol mixture is circulating. Due to the spectral properties of water it captures most of the infrared solar radiation: it is transparent to visible wavelengths of the sunlight but opaque to NIR wavelengths. Consequently water flow glazing has the same natural light transmission as conventional glazing whilst reducing the heat transfer towards the interior space. Furthermore, the water circulation allows to use, store or dissipate the energy captured by absorption of the water filled cavity.
InDeWaG technology is a passive radiant surface technology, adoptable to the building envelope as well as to interior walls. Maximum daylight use with appealing glass facades while meeting nearly zero energy building performance at minimum HVAC expense is the main objective of the InDeWaG approach. The contribution gives an overview of the current state of the project and enlightens the future potential of the technology.

key words: daylight, energy efficiency, water flow glazing

Main view on the electrochromic facade, Swiss International School in Dubai (WME Consultants, UAE)

Evaluation of adaptive facades: A case study with electrochromic glazing

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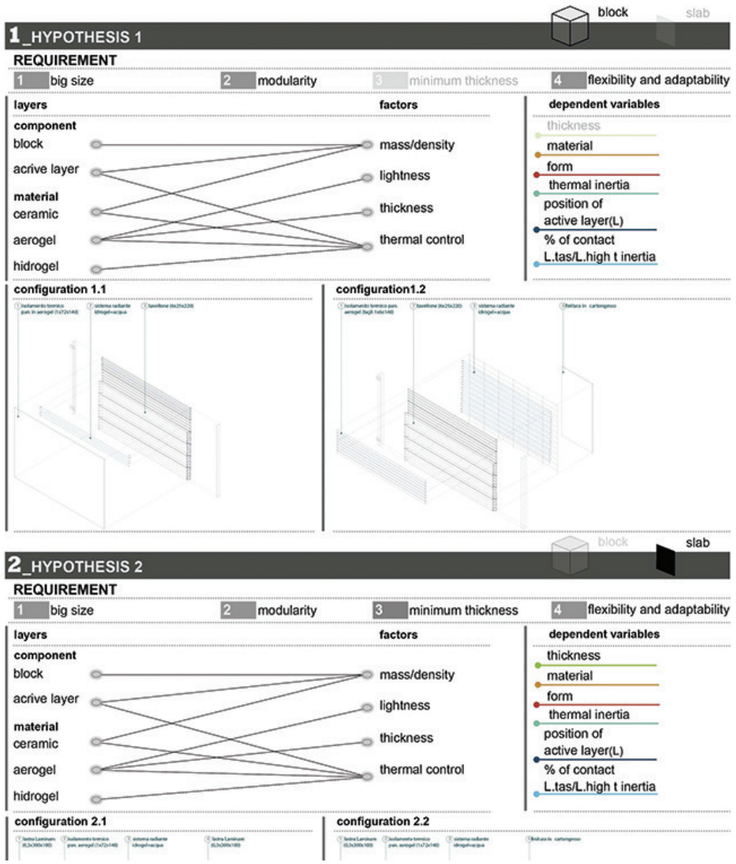
conference #3586

Adaptive facades are performance based envelopes that are able to respond dynamically to climatic conditions. One of the recognized adaptive facade technologies is electrochromic glazing. However, very few studies evaluated the performance of electrochromic glazing on the building level. Therefore, we selected a case study of a certified educational building with a nearly zero energy building performance that includes an electrochromic facade. The overall aim of the research is to understand the performance requirements of electrochromic glazing and its overall contribution to energy saving s and thermal and visual comfort improvement. The performance of the Swiss International School in Dubai was analyzed based on interviews with the design and build team, monitored data and post occupancy evaluation. A systematic process mapping took place to review the performance indicators, simulation tools and team responsibilities during the design, construction and operation stages of the building. The paper identifies the key performance criteria of electrochromic glazing in relation to energy and comfort. Finally, we assess the significance of using electrochromic glazing from a technical point of view and share the learned lessons for architects and facade engineers.

key words: electrochromic glazing, facade assessment, monitoring



Architectural enveloping as a thermal-active System

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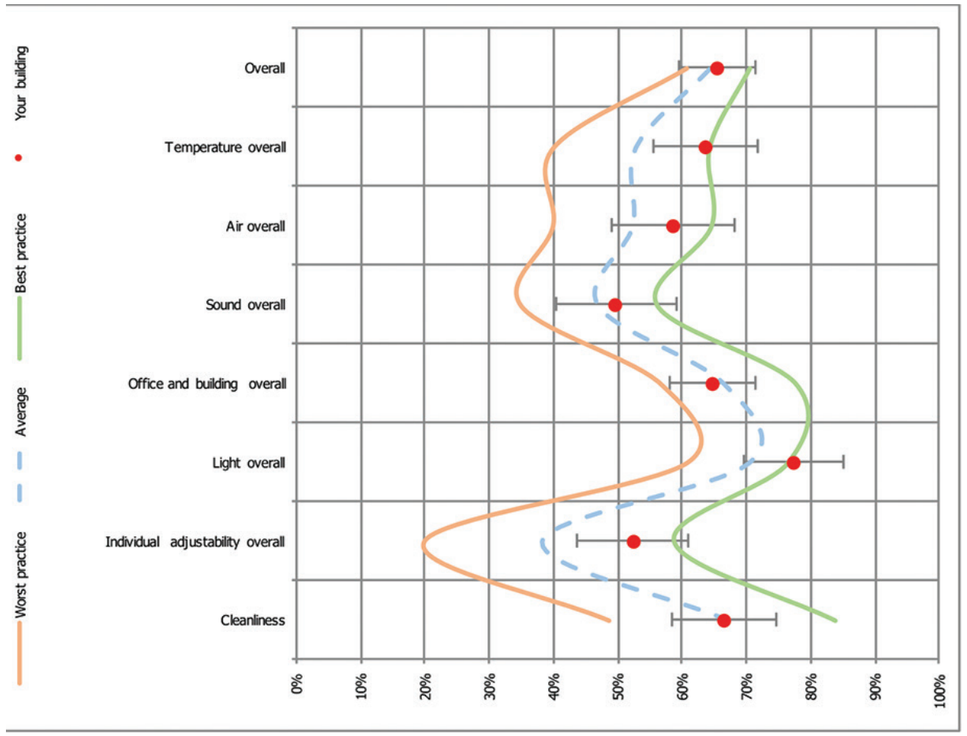
University of Rome La Sapienza, Italy
conference #3591

Proposed contribution focuses on thermal-active systems in architecture and places itself in the environmental technology design known as Active House: an approach promoting the building enclosure to a central role for its purposes which releases a number of technological design possibilities for both the new construction and regeneration; this approach looks at aspects such as: the quality of construction, management, the durability and the satisfaction of the inhabitants. Research on these components has been evolving over the last decades by testing elements able to change the results according to external micro-climate conditions in order to maintain stability in terms of energy consumption also in relation to the building structure as a whole and as a function of the amount of people occupying it. Unlike other components, benefits of thermal-active systems are not just about energy saving and thermal comfort, but concern the concept of innovative design of building which are cost-effective and psychologically convenient. This approach represents a new model for sustainability, based on the assumption that component responses are not rigid, but modulated to different possibilities.

The text explores the different fields of application, conceptual and technological design line of both opaque and transparent thermo-active systems, ranging from the study and development of accumulation and thermodynamic systems to the elements designed for cooling which try to benefit from evaporative processes.

The most important lines of interest for the development of TABS systems related to the main geographical applications and the main cooling and heating strategies for which those are chosen and highlighted that can also be implemented in the Mediterranean Area, which are the basis for the research through the creation of prototypes and experiments on the Mediterranean climate and our local situations developed in our Department and in particular for the Egle Ministeri PhD thesis.



Post-occupancy evaluation strategy of an office building in Athens, Greece

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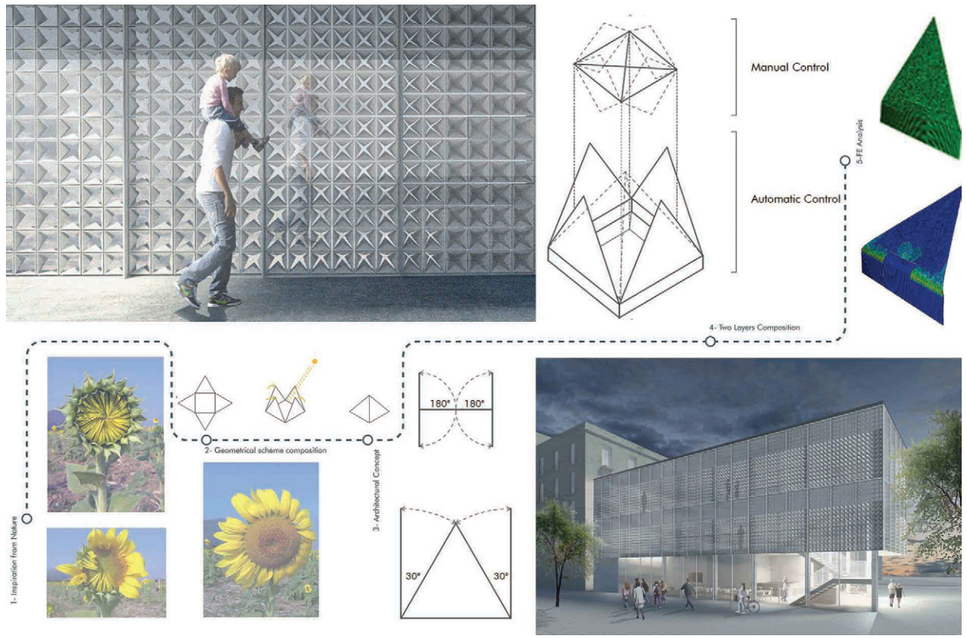
conference #3600

The quality of indoor work environment is proved to have a direct effect on the employee's productivity, job satisfaction and health. However, the issue of indoor environmental quality in not often considered due to various reasons resulting in inappropriate working conditions. The aim of the present study is to provide a simple, yet efficient solution for the evaluation of buildings performance, considering the complexity of the indoor environment. To this end, an assessment tool, called "Comfortmeter" has been developed in order to identify critical situations and to provide a set of suggested improvements. The tool focuses on 6 main comfort aspects: lighting, acoustics, thermal comfort, office environment, air quality and individual control. The assessment has been performed for an office building in Athens/Greece with the following procedure: An online survey has been administrated among the employees and the responses were statistically analysed guaranteed all confidentiality issues. The outcome is an analysis, a) presenting the current comfort conditions of the building, b) indicating issues of attention, c) suggesting measures of improvement d) providing financial indicators of productivity advantage and productivity improvement potential in €/year.
The study has been performed in the framework of QUANTUM project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 680529. It presents a part of an assessment conducted in 20 buildings in Greece and over 50 all over Europe.
The case study is a 3 storey office building in Athens/Greece hosting a technical and environmental consultancy company. It is located in the north suburbs of Athens built in 2000. The windows are double glazed with aluminium frames and there are internal blinds for shading. For heating and cooling VRV units are utilized and the building is equipped with mechanical ventilation, while the system has thermostat for individual control in the offices. The building is equipped with 3cm insulation both in walls and the roof.
After the collection of data from the completed questionnaires and the analysis of the raw data, a "Productivity advantage" and "Productivity improvement potential" in €/year can be calculated. The initial analysis provides information about the fields that need improvement in order to increase productivity in the working environment. Each different building is compared with the already formed database of investigated buildings that are used as reference, stating the best and worst practice in each field.

key words: indoor performance evaluation; thermal comfort; indoor air quality; indoor environmental quality



Exploitation of shape memory materials in sun adaptive user-controllable building facades

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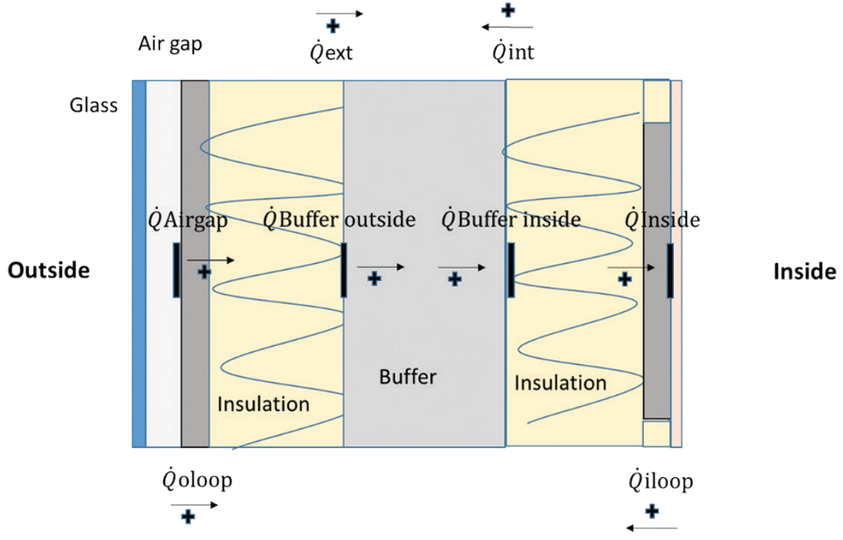
conference #3606

Smart morphing materials are increasingly studied and are also expected to soon become economically available for architects and engineers, being potentially suitable for a great number of applications. In particular, shape memory materials possess the unique feature of memorizing shapes that can be continuously recovered through the application of external stimuli. This research proves the potentialities of an adaptive shading module actuated by smart materials, which enable the facade shape to change in response to the incoming solar radiation. The final goal is to design a building skin that is attuned to climatic changes and which creates occupants' awareness of environmental variation. In particular, the exploitation of the physical properties of shape memory materials would guarantee the internal daylight comfort with (almost) zero-energy actuation and reduced system complexity; this would be in contrast with kinetic envelopes which, in order to preserve interior conditions in response to external variations, rely on sensors, motors, and computational feedback loops.
Inspired by nature and mimicking petals' movement dynamics, the proposed facade module has been designed starting from a geometrical schematization of flower's shape: four triangular petals on a square basis dynamically adapt their degree of openness based on the incoming solar radiation. The petal-like wings, actuated by strips of a two-way shape memory polymer, allow a completely autonomous passive control of building interiors' conditions and zero-energy actuation. The actuator is located on each petal side directly exposed to solar irradiation, triggering the shape transition: activation is started by solar absorption, which increases the polymer film temperature until the transition condition in attained. Moreover, the integration and addition of a matched internal opaque layer, actuated by a set of (electrically controlled) antagonistic shape memory alloy torsion springs, grants the possible implementation of the resulting structure in real buildings, conciliating comfort, well-being and user controllability of living and working environments.
Dynamic daylight simulations have been carried out to assess the effects of the resulting shading system on a medium size office room oriented towards South-East, during the most illustrative days of the year. The movement of the external autonomous shading layer has been discretized into four different positions, from a completely open to a fully closed one. The daylight quality was assessed by computing two different performance indices: the work plane illuminance and the degree of glare probability (Dubois, 2016).

key words: smart dynamic facade, sun responsive architecture, zero energy actuation, user controllability, shape memory materials



Performance indicators for adaptive facades. The case study of Adaptiwall

Pascal Vullo[1], Timea Bejat[2], Lorenza Bianco[2], Stefano Avesani[1], D. Rogier Donkervoort[3]

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conference #3609

Adaptiwall is an adaptive facade concept for building renovation. Adaptiwall aims at collecting, storing and transmitting heat to or from the room minimizing the energy demand and maximizing thermal comfort. The management of the heat fluxes between indoors and outdoors enables Adaptiwall to adapt to different climate conditions.

An approach to define performance indicators

How can we assess the performance of such an adaptive facade where traditional steady state values are not adequate to describe the system's characteristics?

The focus of the work is to present a methodological approach to define performance metrics to evaluate and compare the dynamic performance of different prototypes of Adaptiwall.

Functioning of Adaptiwall

Adaptiwall has a structural core of lightweight concrete with embedded phase change material to serve as a thermal buffer and is equipped with a solar thermal collector on the outside to allow heat transmission via casted water loops to the inside (cooling mode works on the reversible way during hot season).

Experimental campaign

Four lab-scale prototypes were tested under real outdoor conditions, aiming at characterizing solar heat collection, heat storage and heat transfer to the room for the different design variants.

Challenge

The challenge is to investigate such dynamic functionalities of adaptive systems under real outdoor conditions, and define simple performance indicators that enable for easy comparison among facade variants.

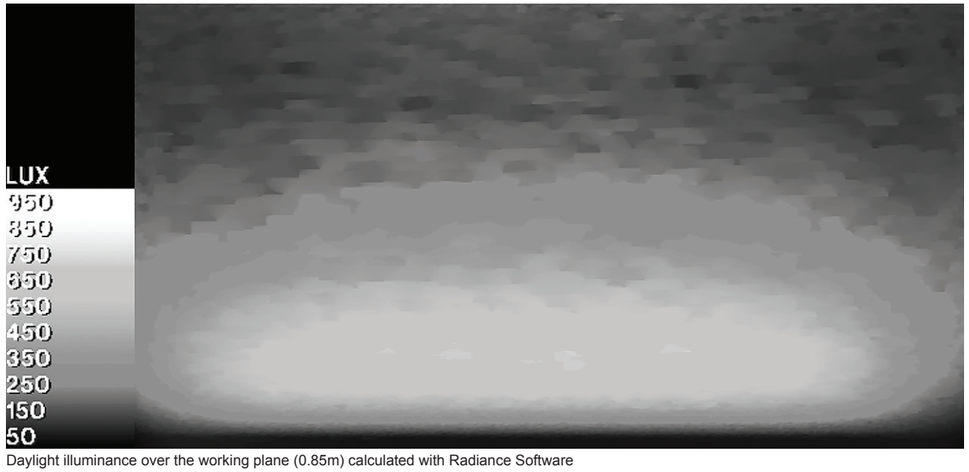
Performance indicators

Starting from the work of Favoino et al. [1] on an adaptive facade named "Actress" (integrating ventilation and PCMs), performance indicators to assess the energy performance of Adaptiwall were calculated using as input monitored data.

Outlook: performance indicators on adaptivity

While the standard performance metrics asses the system (or subsystems) for steady state conditions, within a one-day time frame or with a unique value for an entire year, adaptivity in many cases needs longer or shorter time frames from hours to several days, weeks or seasons. The work also discusses this aspect of adaptivity needed for future performance metrics.

key words: adaptive facades, Adaptiwall, outdoor lab scale testing, dynamic performance indicators, adaptivity



Daylight illuminance over the working plane (0.85m) calculated with Radiance Software

Optimization of glazing ratio based on primary energy for air-conditioning and lighting in office buildings in 5 climate zones

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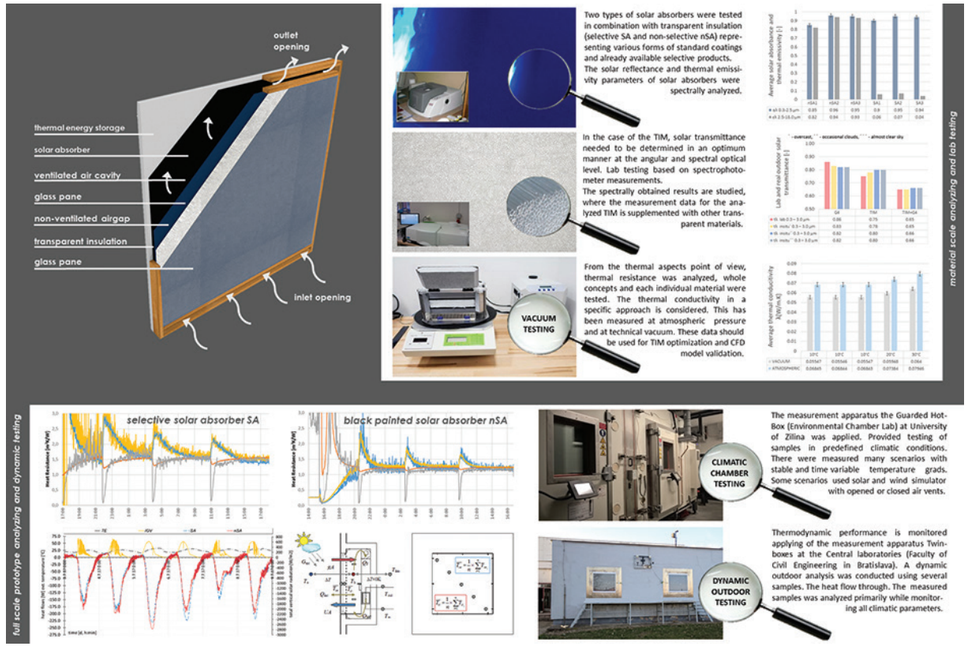
conference #3610

Reducing operating energy is a recurring theme and primary objective in world energy policy. In recent years technological innovation, joined with a greater sensitivity about the issue, have led to a decrease in operating energy demand associated to newly built buildings. Facade system, as element that separates the interior space from the outside, is a fundamental variable in evaluation of energy loads for cooling, heating and lighting. Technological development has increased the wide range of typologies of facade which ensure high performances. The building envelope, in sustainable design, must perform two main functions: to insulate from external stresses and to take an advantage of free solar gains.
The growing use, in contemporary architecture, of large glazing surface in office buildings increases the importance of the facade glazing ratio, defined as WWR (Window to Wall Ratio), to assess global primary energy.
The WWR plays an important role in energy savings and daylight use. In particular in office buildings, the use of working space during daytime requires greater attention on solar gain and daylight control. Moreover, the lighting comfort has a significant impact on the productivity of occupants.
The scope of the paper is to outline guidelines for designers to optimize the value of glazing ratio in different climate zones, in order to minimize air-conditioning and lighting energy demand. Furthermore, the research focuses also on indoor lighting comfort, according to daylight availability. The WWR is a key factor globally affecting the comfort in the inner spaces of buildings. The paper will address the visual comfort issue related to the increase of transparent surfaces (i.e. glare and overheating) and the energy demand issue related to the increase of opaque surfaces (i.e. additional artificial lighting loads), defining the optimal condition.
The research, through dynamic energy simulation (by means of IES Virtual Environment software), analyses the performance of different facade layout, characterized by various value of WWR, for a case study, in different climate zones in 5 different sites: Copenaghen (Denmark), Munchen (Germany), Athene (Greece), New York (USA), Moscow (Russia).

key words: operating energy, office, daylight, air-conditioning, glazing ratio.



Experimental thermal and energy performance study of a solar facade prototype using honeycomb transparent insulation and selective absorber

Richard Slávik[1], Miroslav Čekon[1], Karel Struhala[1], Jakub Čurpek[1, 2], Peter Juráš[3]

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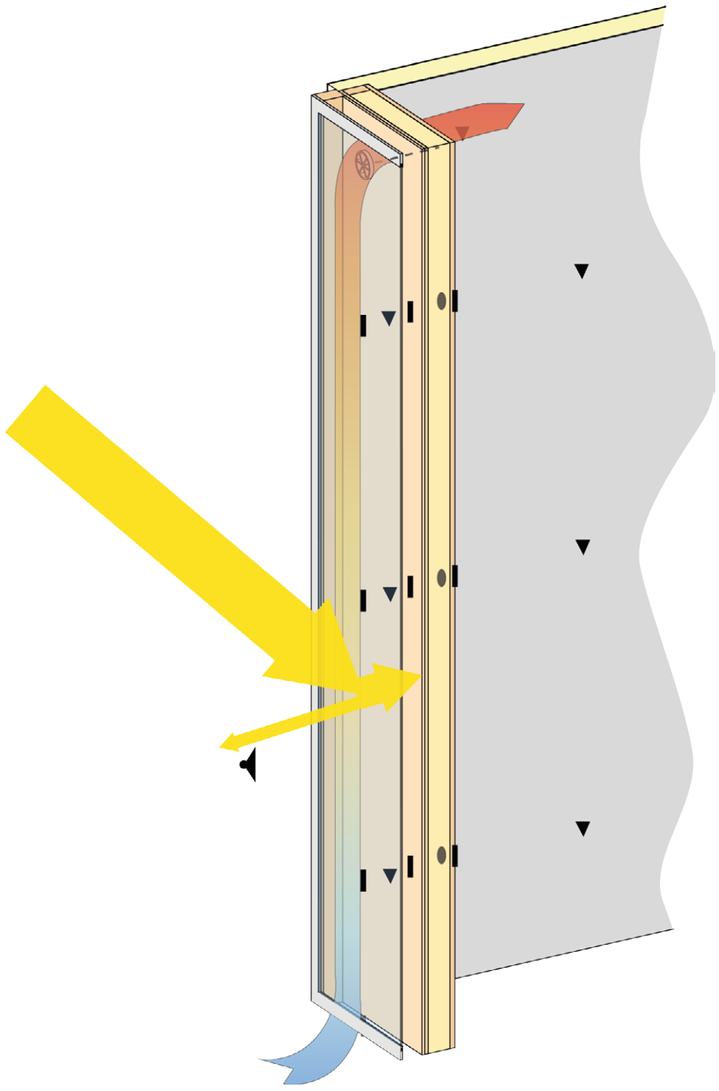
conference #3612

Application of advanced materials in building facades could bring relevant energy savings. Successful development of new and innovative (solar) facade concepts as well as their practical implementation relies on both theoretical and experimental activities. For example preliminary designs could be supported by computer modelling and simulations. Such simulations save significant amount of time and resources during development of the general concept, assembly details or construction processes. However the simulations should be always verified by experiments, because the performance of building components is influenced in many random variables that are hard to predict or model.
Presented study describes initial results of modelling and testing of prototypes of solar facade concept inbuilt into an opaque building envelope. The concept combines transparent insulations with spectrally selective layers and latent thermal energy storage. The original concept was conceived using wide range of computer simulations: from simple one-dimensional energy transfer modelling to advanced CFD simulations of the heat convection and radiation in air gaps within the structure of the facade concept.
The simulations were followed by testing of several prototypes. Several different laboratory and in situ experiments have been performed so far to verify the accuracy of the simulations. Climate chamber testing investigates mainly the thermal and optical properties of the developed prototypes in controlled environment. Both steady-state and transient boundary conditions were applied during the climate chamber testing. The tests included guarded hot plate and heat flux methods used to measure heat transfer coefficients of the tested materials. Thermal conductivity of the transparent insulation was measured at both atmospheric pressure and at technical vacuum.
In situ testing of the prototypes supports the climate chamber testing, as it provides data about performance in unstable and unpredictable weather conditions. Two full scale in situ tests were launched to provide real life data from different locations. Both utilize the twin box method: multiple prototypes are tested in pairs. Each prototype in any pair can serve as a stand-alone testing platform or they can be used in pairs for comparison of test results.

key words: solar thermal system, transparent insulation, selective absorber, experimental testing, climate chamber:



Experimental and numerical analysis of a fan-assisted double-skin component for buildings energy retrofit

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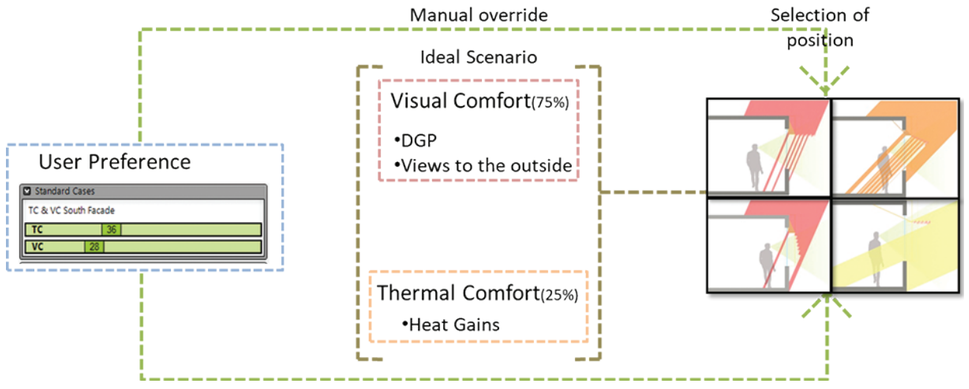
conference #3615

The development of dynamic envelope components is of key importance to improve the building energy efficiency, thus reducing greenhouse gas emissions. The possibility to exploit these new technologies for refurbishment purposes is even more important, since the vast majority of the existing building stock was built when energy regulations were not present or very limited.
In this paper, an experimental activity through outdoor test cells was aimed at characterizing an innovative double-skin building envelope component. This system can be easily applied to existing opaque building envelopes and has the potential to significantly increase the building energy efficiency. This technology consists of a fan-assisted double-skin facade in which a glass layer constitutes the exterior skin, while the interior layer is composed by a specifically shaped absorber panel applied to an opaque wall. This system is designed to reduce the heating and ventilation demands by supplying air to the indoor environment using a fan-assisted ventilation.
As a first step, an experimental campaign on a full scale facade module was carried out in Turin during the heating season: surface temperature at the different interfaces were measured, as well as air temperatures, vertical solar irradiance and heat fluxes through the envelope. As a next step, a simulation model was built using the software EnergyPlusTM, which was then validated using the experimental data. Finally, the validated simulation model was used to assess the behaviour of different technological configurations, considering both the opaque and the glazed part.
This research activity shows the potential of the above described building envelope component. In facts, the seasonal average efficiency of the different configurations is promising, since it never goes below 28%, and it reaches 40% in the best scenario cases. Moreover, in the last cases, a useful supply of warm air (from 20 to 35°C) was found to occur for the 37% of the time.

key words: double-skin facade; building envelope; facade refurbishment; solar heating wall; passive heating



Adaptive solar shading

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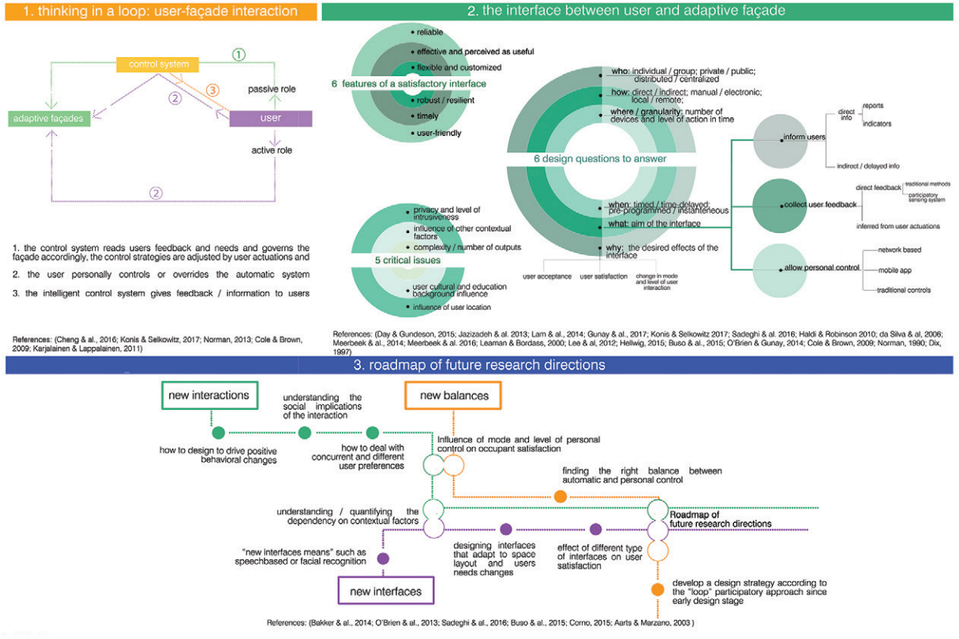
conference #3622

This paper deals with the development of a parametric algorithm for design of kinetic shading systems and demonstrates its efficiency for two case examples in India and Germany. The parametric algorithm is developed to optimize daylight availability, accessible views, heating and cooling energy consumption, and Building integrated photovoltaic (BIPV) energy generation.
A modular Kinetic Shading System is designed to facilitate the physical implementation of the algorithm. This is virtually modelled in Rhino software program. The algorithm is implemented in Grasshopper tool, which associates with EnergyPlus, and Radiance simulation tools for dynamic analysis. The application of the algorithm as a parametric optimization tool for shading design as well as a feedback model which assists the design process through a set of case-studies modelled in Rhino software tool is demonstrated and the potential for energy savings as well as building integrated renewable energy generation by using this tool at various iterations of the system can be calculated.
The paper demonstrates the optimisation of the system for two locations; Delhi and Munich, where the tool suggests the position of the kinetic shading system. It was observed that Delhi requires shading during Winter for glare reduction and in Summer to cut down heat gains. Whereas, Munich requires a system that cuts down glare but maximises natural heat gain. It is observed that the proposed system is 34.4% more efficient when compared to a non-shaded facade in Delhi and 37.8% more efficient in Munich.
The system defaults to a position which is most efficient in terms of thermal and visual comfort. However, it adapts to the user's preference of comfort and choice. The study is an attempt to develop a multi-parametric optimization and feedback model for generative building facades. Further scope in this area includes consideration of other objective parameters like material type, installation, maintenance and durability and subjective parameters like aesthetics of the facade for which a questionnaire based assessment is being carried out.

key words: climate responsive, adaptive, sustainability, solar responsive, BIPV



Climate Response

A roadmap for capturing user-adaptive facade interaction

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conference #3637

Adaptive façades are building envelopes that interact with users and vary their performance or properties (controlling thermal or solar energy, air flow and/or daylight) in response to changing external conditions and indoor needs. However, effective adaptive façade solutions that provide an optimal balance between user comfort, satisfaction and energy efficiency cannot be achieved without a comprehensive knowledge of the user-façade interaction. A systematic literature review was conducted to highlight the implications of occupants environmental control in interactive systems and provide up-to-date research suggestions to address the complexity of user – adaptive façade interaction.
The main objective of this poster is to facilitate discussion on two of the multidisciplinary features of a satisfactory user - adaptive facade interaction: (1) the interface between users and facades and (2) the acknowledgment of the interaction strategy as a "loop", in which users' feedback enhances automatic control strategies. Lastly, a map of research gaps and future research directions / objectives is presented.

key words: occupants satisfaction, user interaction, interface, adaptive facade, control strategy

Design principles of biological and living building: What can we learn from plant cell walls to design future building envelopes

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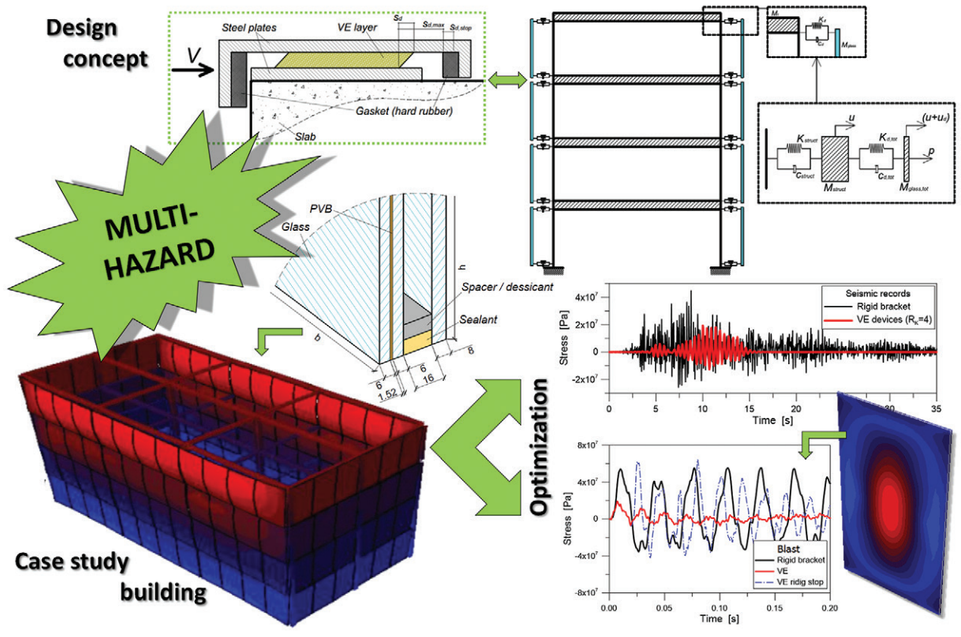
conference #3547

The building envelope has been a significant element of human settlements since the rise of civilisation. It plays a dominant role in the exchange of heat and fresh air, provides views and daylight, and protects the indoor environment and occupants against extremes of temperature, solar radiation, water and wind. A number of innovations in building envelope technologies have been implemented recently, for example to improve insulation and air tightness to reduce energy consumption. However, growing concern over the embodied energy and carbon as well as resource depletion, is beginning to impact on the design and implementation of existing and novel building envelope technologies. Biomimicry is proposed as one approach to create buildings which are resilient to a changing climate, embedded in wider ecological systems, energy efficient and waste free. However, the diversity of form and function in biological organisms and therefore potential applications for biomimicry, requires a holistic approach spanning biology, materials science and architecture. In this research, plant cell walls are compared to building envelopes. Key features of cell walls with the potential to inform the development of design principles of biological and living building envelopes are identified and discussed.

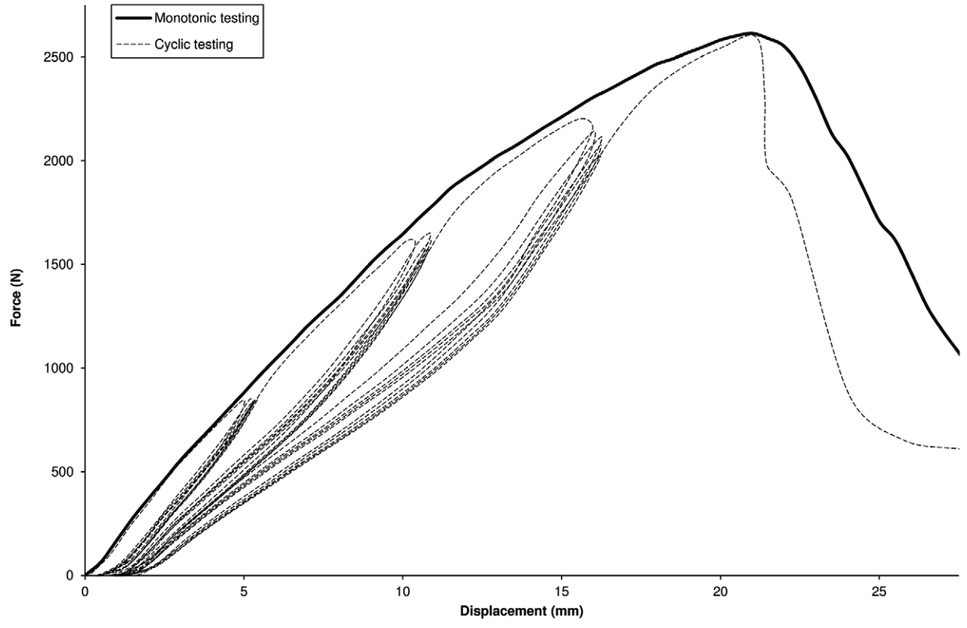


Passive curtain walls - Enhancing the multi-hazard performance of buildings

Chiara Bedon, Claudio Amadio
Department of Engineering and Architecture, University of Trieste, Italy
conference #3564

Glass facades are widely used in buildings, due to a multitude of aspects. In most of the cases, wide transparent surfaces are realized in commercial, residential and strategic buildings, including airports, museums, offices, etc., often susceptible to crowd. From a structural point of view, however, under the action of exceptional loads such as human induced / accidental / natural hazards, these facades represent a critical component for buildings, due to the typical brittle behaviour and limited tensile resistance of glass, as well as to the high vulnerability of structural details, etc., hence requiring specific safety levels.
In this regard, the prediction of the dynamic behaviour of facades under exceptional loads (including the interaction between a given envelope and the building), or the implementation and optimization of advanced retrofitting tools, represent open topics still requiring extended investigations.
Taking advantage of earlier studies, the current research aims to assess the feasibility and potential of special vibration control systems (VCSs) at the interface between a multi-storey building and the enclosing facade, under extreme loading scenarios. Careful consideration is paid for the mitigation of major effects due to seismic and blast events. A key role is assigned to the optimal design of stiffness / damping features of VCSs. The final result of such a design concept consists in an assembled structural system in which the glazing facade works as a passive control system for the primary structure, in the form of a distributed Tuned-Mass Damper, with marked local / global benefits. Parametric analyses are carried out in ABAQUS on a reference building, under (a) seismic records (PGA= 0.35g) or (b) blast pressures (low / medium / high level). Major benefits are hence emphasized, including comparisons of (i) traditional, rigid brackets for the facade modules and (ii) variations in the VCSs mechanical properties.

key words: passive control systems, multi-hazard protection, safe design, structural dynamics



Force-displacement diagram for monotonic and cyclic testing

Structural performance of continuous adhesive glass-steel connections under cyclic loading

Bert Van Lancker, Wouter De Corte, Jan Belis
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conference #3577

The origin of continuous adhesive connections between glass and metals can be found in nineteenth century railway stations, greenhouses and galleries. Slender metal primary structures were braced by glass panes using a watertight putty to connect them. This concept of metal frames onto which glass panes are continuously bonded using adhesives revived in the mid-1960s in the form of structural sealant glazing systems for facades. The design of continuous adhesive glass-metal connections used in such systems, however, is still, even after fifty years of experience very conservative as very high safety factors are considered to determine maximum allowable stresses in the adhesive. Therefore, to enable an optimisation of the design of such connections and to enable the development of new and innovative concepts of adhesive connections in the building construction industry, fundamental research on the structural performance of adhesive glass-metal connections is inevitable. This research focuses on the mechanical behaviour of continuous adhesive glass-steel connections under cyclic loading, to which these elements are subjected on a daily basis, e.g. wind, or possibly subjected during their lifetime, e.g. earthquakes. The aim of the study was to compare the structural response of a continuous adhesive connection between a monolithic annealed float glass panel and a rectangular cold-formed stainless steel section, using the conventional two-component structural silicone Sikasil® SG-500, under cyclic loading with the mechanical behaviour under monotonic loading. Experimental tests (cfr. Figure 1), utilising a so-called Peköz-setup (Van Lancker et al., 2014; 2016a; 2016b), were therefore performed in triplicate for both monotonic loading and cyclic loading, for which each cycle was repeated five times. The data obtained from the tests allows the derivation of the relationship between the applied force on and the vertical displacement of the free flange of the cold-formed stainless steel section. The comparison between the load-displacement diagrams for monotonic testing and for cyclic testing reveals the presence of progressive cyclic softening in the continuous adhesive glass-cold-formed stainless steel connections (cfr. Figure 2). This material softening can be attributed to the appreciable change in mechanical properties of the structural silicone resulting from the maximum strain value prior to cyclic loading, i.e. the so-called Mullins effect (Diani et al., 2009). Furthermore, most of the softening, characterised by a lower resulting stress for the same applied strain, appears after the first load (cfr. Figure 2). After a few cycles, the material responses coincide during the following cycles, aside from fatigue effects (cfr. Figure 3).

key words: glass, steel, structural sealant, continuous connection, cyclic loading

Towards the applications of adaptive glazing systems

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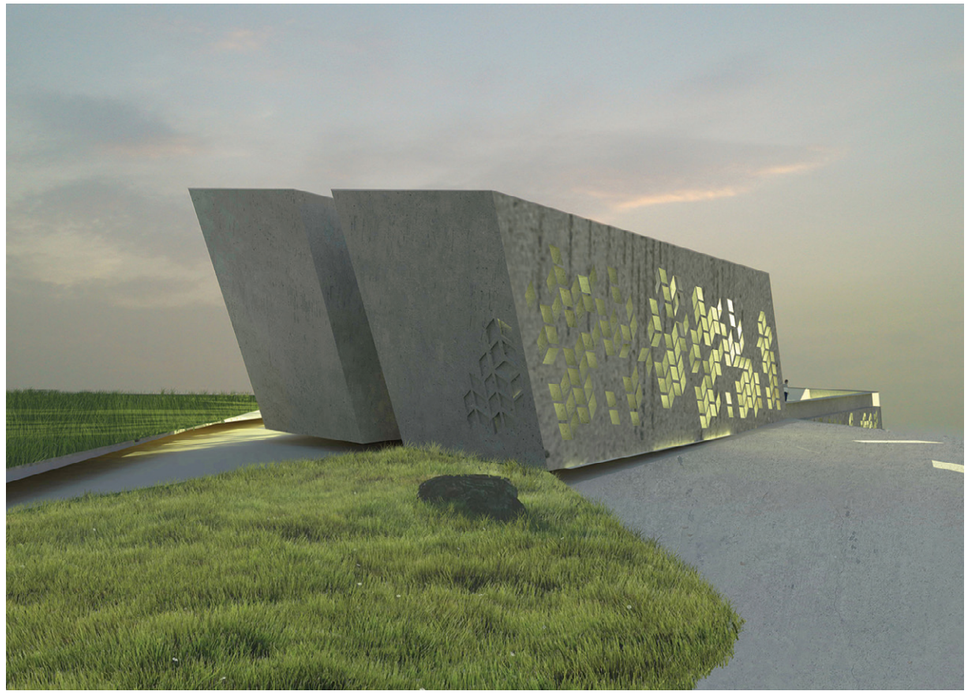
conference #3595

The facade, as an interface between the interior and the exterior environment, performs multiple tasks. On one hand it has to ensure the highest possible comfort for building occupants, on the other hand it should contribute to minimizing the energy demand of the building. The detailed requirements on a facade depend on its orientation, local climatic conditions and the building use. Since surrounding conditions vary, an invariant facade system cannot react properly to this variability. This calls for concepts for adaptive facades with adjustable light and energy transmission properties. Various commercially available adaptive technologies including thermochromic, electrochromic and angle-dependent glazing systems were investigated within a recent research project at the Institute for Lightweight Structures and Conceptual Design (ILEK). The adaptive systems were characterised, studied in a facade test facility and simulated numerically.
The facade test facility is a two-storey timber building in Stuttgart which is provided with measurement equipment for recording the outdoor and indoor conditions. The building includes four test rooms with dimensions of 2.00 m x 4.20 m x 2.70 m. Each of these rooms can be considered an independent office space. The south facade of the building is designed for incorporation of different glazing units. The adaptive glazing systems were mounted in the facade of different test rooms and monitored during the project duration.
The numerical transient energy and lighting performance simulations of the glazing systems took into account four different climatic conditions and three different building typologies (a cellular office in light timber construction, a classroom and an open plan office with solid construction, south facades fully glazed). For the switchable glazing systems, four different control strategies were developed and evaluated numerically. These efforts aimed at identifying the most appropriate application scenarios for the different adaptive facades. Proposals for optimised control strategies for the adjustable systems were formulated and the potentials of adaptive glazing systems revealed.

key words: adaptive facade, switchable glazing, energy performance, thermal comfort, daylighting

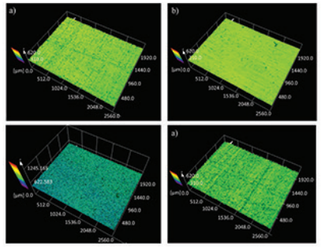


Climate-reactive architecture

Andreas Hammer
Architecture, University o.A.S. Mainz, Germany
conference #3599

Four peculiar architecture designs from the Frankfurt and Mainz Universities will be discussed within this paper and their future potential for adaptable and solar- pv implemented facades will be shown acting and reacting on climate/solar changes of the specific sites. The different aspects, as well as limitations with regard to costs, technical and functional restrictions, will be named. The design process for three different architecture design-courses containing a “high-rise apartment building refurbishment” a “bikers lodge” and a “house of People[s]” will be critically outlined, displaying how the designs were developed step by step by an international studentship towards an overall energy strategy that firstly had to push the design to a plus-energy building and secondly had to incorporate bionic aspects into the building skins design.
Both main parameters needed to be reviewed and refined during the whole design process. Various basic bionic approaches had been given [e.g. solar ivy TM [2], flectofin TM [1] or hygroskin TM [3]], which were to experiment with, regarding the use of bendable photovoltaic elements being parts of a hybrid, kinetic facade system.
Unique designs will be shown with an appropriate answer to the functional needs and the technical necessities. Energetic calculations of these systems in comparison to conventional building shells will be displayed and specific solutions for a sustainable and efficient mode of operation of these future buildings will be proposed for discussion.
The essential question for the future is how we architects can add to overcome the problem of an increasing waste of energy in a fast-rising world population. One challenging and promising aspect that has already been started in the academic field and in between a minority of architects, would be the goal to develop, in a time range of approximately 50 years, buildings, that never again use up and waste energy and other resources but instead become themselves a mean of generating the necessary output for themselves and for other intentions as well, the so called plus-energy buildings. The strategy would be to concentrate on the development of the inherent principles regarding the most proposing element of the buildings for reaching this goal – the building envelope.
As we need to collect energy in future buildings, to shift those manmade artificial objects towards plus-energy-buildings, the complete building envelope has to work like the human skin, adapting at the right time [of the day, of the season, to the weather and the climate] to the right functional need, with the minimum amount of energy-input or physical power. Low-Tec- systems will therefore have a lot of benefits on maintenance costs. As we find these concepts already hidden in natural systems [flowers close at night and open up at day], it is our task to highlight them and to transport these brilliant ideas, that evolved during centuries, into our building concepts.

key words: energy-strategy, BIPV, bionic and bioclimatic design, plus-energy-buildings, climate adaptive building shells [CABS]



	Zn-electroplated steel - smooth	Zn-electroplated steel - roughened	Anodized aluminium	Aluminium - smooth	Aluminium - roughened
Ra [μm]	3.4	10.6	5.8	3.5	6.0
Rz [μm]	121.5	157.8	183.3	113.0	113.4

Experimental analysis of adhesively bonded joints for facade application exposed to accelerated aging

Klára Machalická[1], Miroslav Vokáč[1], Martina Eliášová[2]
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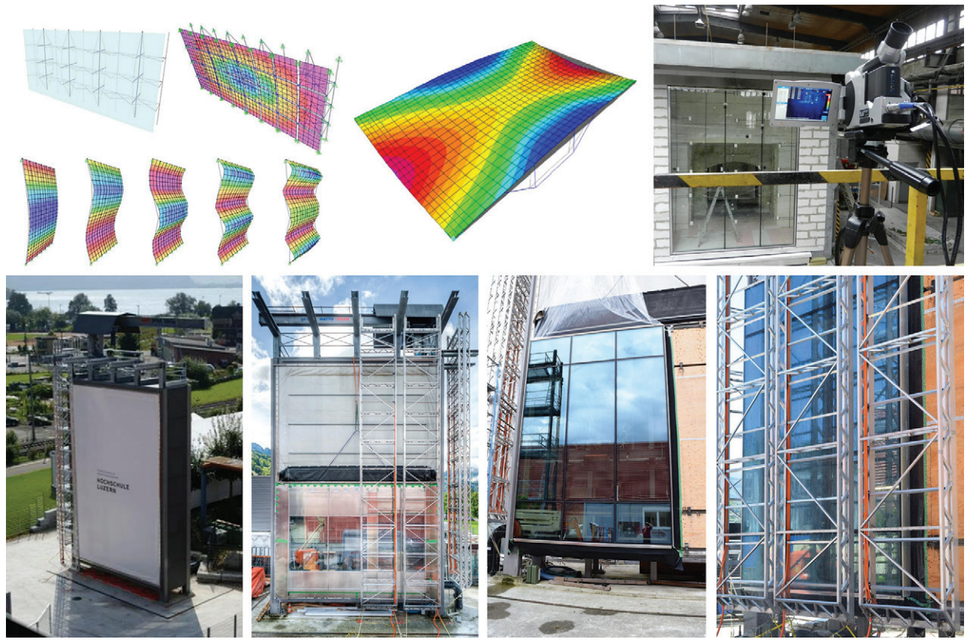
conference #3601

In contrast to other joining methods, such as bolting or riveting, adhesive bonding has no unfavourable effect on the parts to be connected. There are no interruptions by holes which create stress concentrations and disrupt visually smooth and flat surface of joining parts. An important benefit of glued connections in facades is an elimination of local thermal bridge in comparison with bolted connections. For these reasons, gluing is a very useful bonding method for façade applications. Low strength, elastic and durable silicone sealants are applied in facades for a long period of time, but there is a lack of information about semi-flexible and semi-rigid adhesives with higher strengths. In the development of adhesively bonded joints for facades, long-term durability is an important area of attention.
An investigation of glued joints composed of two types of adhesives (silicone terminated polymer and acrylate adhesive) applied in double lap shear connection exposed to artificial ageing conditions. The study comprises two basic substrate materials, blank aluminium and galvanised steel, with smooth or roughened surface. Moreover, aluminium substrate was also applied with anodised covering. Material and surface treatment has a great influence on not only adhesion and thus strength of the joint, but also on the resistance to ageing (effect on adhesive forces at the glue-substrate interface) and failure mode of particular joint. Furthermore, every necessary surface treatment creates higher labour intensity, higher time consumption and thus increased costs.
Structural adhesive joints were exposed to laboratory ageing conditions in a following stage of the experimental study. Due to an absence of particular code intended for structural adhesive joints in facades, two artificial ageing procedures were chosen - ETAG 002 and ISO 9142 - Procedure E4 (Exposure to neutral salt spray and elevated temperature and humidity). Mechanical properties and failure modes of joints exposed laboratory ageing were compared with joints that were not exposed to ageing and influence of artificial ageing method were assessed.
Acknowledgement
The authors gratefully acknowledge the funding by the Ministry of Education, Youth and Sports, Czech Republic, under grant LD15078.

key words: adhesive joint, artificial aging, acrylate adhesive, silane terminated polymer, metal substrate



Upper left and middle: Numerical models for assessing the structural behavior of glass facades (author: Filipe Santos); Upper right: Fire-test of glazing at Pavus laboratory, Czech Republic (author: Klara Machalicka); Lower (from left): Outdoor test-facility of a curtain walling (EN 13830), full size air tightness (EN 12153) and water tightness (EN12155) testing, full size facade testing of static wind load (EN 12179), full size water tightness (EN12155), Switzerland (Lucerne University of Applied Sciences and Arts).

Evaluating the structural performance of adaptive facades: general rules and guidelines for classification, experimental testing and numerical modeling

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4 RISE Research Institutes of Sweden, Sweden
5 Klokner Institute, Czech Republic
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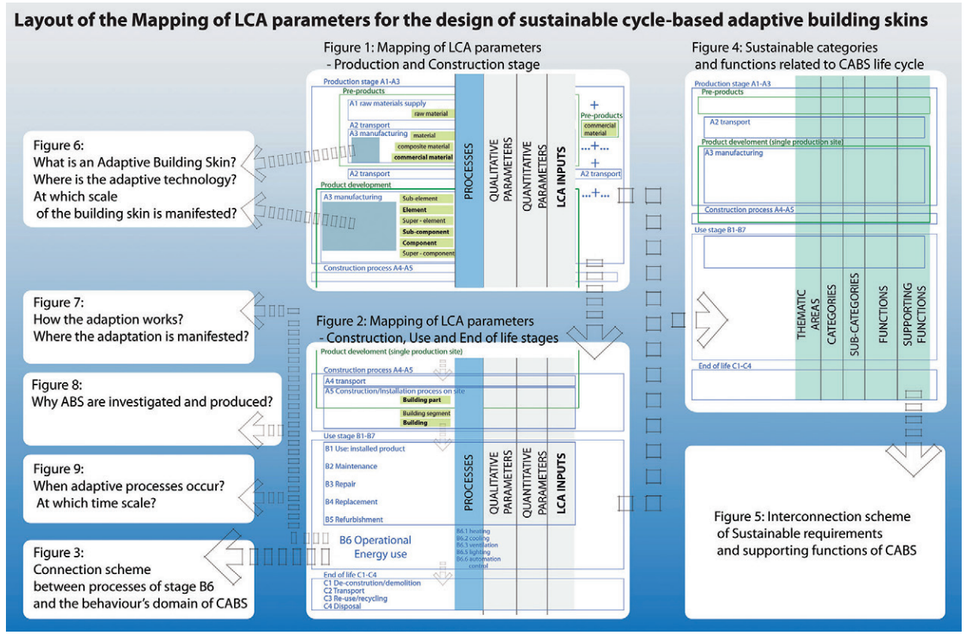
conference # 3608

Modern building envelopes are high-tech components that must meet requirements and constraints regarding architecture/urban planning/aesthetics, energy efficiency, indoor environmental quality, buildability and value. If a facade can respond to all the transient conditions while maintaining occupant satisfaction without imposing additional loads on the building services, it can be considered “fully adaptive”. However, an adaptive facade needs to fulfil a fundamental role as assigned to the structural performance of the same assemblies, under ordinary as well as exceptional loads, hence requiring specific safety levels and design concepts. Most of the systems representative of this next generation of facades typically consist of highly adaptive envelopes, generally involving smart materials, kinematic mechanisms, etc.. In this regard, the current lack of standardized procedures to evaluate and test the structural performance of adaptive envelopes and components represents the first barrier towards their widespread adoption. This is especially true in the case of strategic buildings, in which the facade could be exposed to exceptional loading conditions or the building envelop could have a significant contribution to the robustness of the entire structural system. Similarly, there currently are no guidelines and recommendations for the numerical modelling of the mechanical performance of adaptive facades.
In this context, the activities carried out by the EU COST Action TU1403 “Structural Task” aims to provide a proposal of classification for novel structural skins considering their structural properties and expected performances. The Structural Task program will provide an overview of important experimental facilities available in Europe for testing the static, dynamic, long-term and fire performances of adaptive systems.

key words: adaptivity, structural performance, classification, experimental, numerical modeling



A design-based LCA framework for adaptive building skins - Planning for short-term reaction with long-term sustainability

Manuela Crespi; Sandra Persiani; Alessandra Battisti
Rome, Italy
conference #3618

With the aim to address the sustainability of life cycle aspects in adaptive building skins a mapping of the main parameters and variables characterising the Life cycle assessment of Adaptive Building Skins (henceforth ABS) is proposed.
At present, Life Cycle Assessments of building skins are mainly carried out in a later design stage and especially after construction, although stakeholders surveys have highlighted the need for providing tools for the assessment of the environmental impacts during the early design phase which are not a limit to the design creativity. This mapping outlines a method to optimize ABS component's design by combining LCA parameters.
Among the first methodological references, the International and European guidelines have indicated the steps of an LCA process that includes identifying the goal and scopes, the system boundaries and the processes that are expected to produce an impact. By analogy, the mapping includes these steps. A systematic approach allowed to conceive ABS as a system characterized by sets of interacting parts with specific multifunctions, behaviours, processes and sustainable goals. The outcome consists of nine figures connected each other, forming a single systematic mapping. Quantitative and qualitative LCA parameters are listed, and the effective LCA inputs needed for quantitative calculations are arranged by Life cycle phases with a hierarchical list of building's products composing the building skins. A connection scheme between processes of operational stage have been identified as "the Behaviour's domain". Each process has been coupled to sustainable categories and functions. A systematic scheme links the sustainable requirements to supporting functions. A systematic review of the state of the art of ABS illustrates what an adaptive building skin is, where it is located in the adaptive feature, how and when it functions and why these are built.
Among the LCA parameters investigated in the Production phase it can be highlighted the Scale of adaptation and the type of System's family. In the Construction stage the transport of envelope's super-components to the building site is energy consuming, considering the need of special means of transport. Regarding the Use phase the dynamic behaviour is the most significant characteristic of an ABS so there is no doubt that operational parameters must be considered such as Service life and Adaptability.

key words: Life Cycle Assessment, building skins, adaptive, systematic mapping, cyclic architecture, parameters

Blind point connection of laminated glass pane

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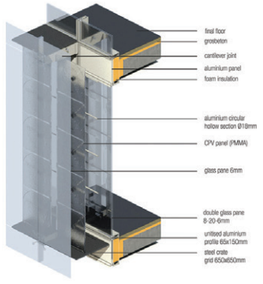
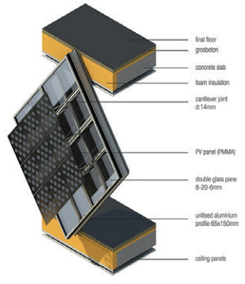
co-authors: conference #3619

Laminated glass is nowadays widely used structural material. It is not only because of its exceptional strength and durability but also due to its appearance. Using transparent building material opens up endless possibilities for architects, however, apart from design of the laminated glass panes, the connections to other parts of structure must be also designed. This can be a challenging task because European standard for design of glass structures is still not available. Therefore the design is often based on experimental approach.
There are many methods for connection of glass panes, however, the blind point connection brings some new features. It consists of stainless steel element forming kind of countersunk bolt head which is embedded in the glass pane in such a way the exterior surface is not affected by the connection elements. This represents innovative solution and results in perfectly smooth exterior glass surface. This brings new opportunities for architects as the glass surface is very aesthetic, not disturbed by the anchor elements. In addition, it improves the functionality in comparison to other types of bolted connections. Water penetration through the connection is impossible because the outer glass pane is not punched by the connection elements. The biggest advantage, however, is better thermal property of double glazing as the connection could be used in the interior glass pane and the air gap between the panes is not interrupted by the steel elements.
The aim of this study is to describe experiments with bolted blind point connection. These experiments were focussed on centric pull-out loading to investigate behaviour of the connection and failure modes. The tested specimens consisted of 10 mm float glass, 4 layers of SentryGlass foil (0.38 mm each) and 10 mm heat-strengthened glass with embedded stainless steel blind connection with HDPE liners It was found the glass failure is unlikely but de-lamination occurs and spreads with increasing load.
Numerical finite element model used for analysis of the connection is available. It is created in Ansys software using 3D solid elements. The model was used to evaluate the influence of some significant parameters on the response of the connection, i.e. thickness of the glass panes, size and shape of the embedded stainless steel elements and some others.

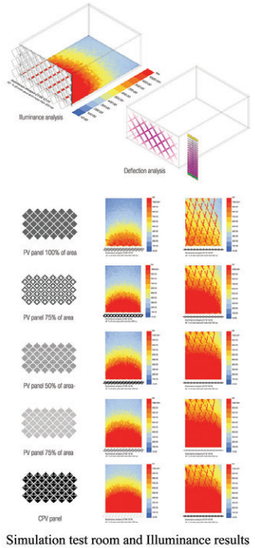
key words: laminated glass, blind point connection, bolted connection, experimental evaluation, numerical model



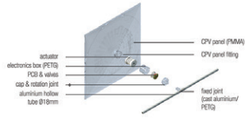
Double-skin facade concept



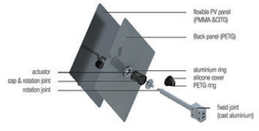
Single-skin facade concept



Simulation test room and Illuminance results



Double-skin facade concept detail



Single-skin facade concept detail

Architectural concepts of an adaptive solar facade as retrofit and building integrated solutions

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conference #3628

Building envelopes form the mediator between interior and exterior environment, while playing an essential role in building performance and occupants' well-being. Within this context, adaptive building envelopes constitute a viable solution towards the vision for zero energy buildings, able to respond to user comfort and energy demands in real-time.
In this respect, an Adaptive Solar Facade (ASF) system has already been proposed (Nagy, 2016) and tested in real conditions. The ASF is a photovoltaic shading system consisting of thin film panels able to regulate buildings' solar insolation while simultaneously generating electricity. Accordingly, the balance of electricity production and adaptive shading can, in some cases, offset a considerable proportion of the building energy demand (Jayathissa, 2016a).
However, Adaptive Solar Facade concepts proposed to date, are exclusively implemented as external building shading components (Jayathissa, 2016b). A double curved network of pipes, attached to a structural frame is required to mount the photovoltaic panels, route necessary utility lines and provide the structural strength against wind loads. Although this works as a building retrofit solution, there is a structural redundancy when applied to new buildings, as a rather robust structure is often required for the building facade itself.
To this end, two architecturally integrated versions of the ASF system, able to minimise structural redundancy and visual intrusion, are anew introduced. The first is an add-on system for double-skin unitised facades which may be utilised either as an add-on to existing facades or as an integrated component to newly designed ones, always within their cavity space. The attachment to existing facades is primarily achieved through glass fins and secondarily through aluminium tubes, which essentially support the PV panels. The joint between the PV panel and the horizontal tube, adjustable 38 to different sun positions and fitted on the soft actuator that moves the PV panel, is materialised through a cantilevering cast aluminium/PETG component which aims at performance maximization. For the PV panel, a translucent Light-guide Solar Optic (LSO) is employed, enabling shape and dimension variations according to the needs of interior illuminance levels and electricity production.
The second is an integrated system of a novel single-skin unitised facade that can be customised with respect to building's climate region, the desired structural performance, energy production and illuminance/shading levels.

key words: adaptive facade, BIPV, facade engineering, daylight, transparency

bAm|hitting the meatspace - a new symbiosis between the analogue and digital in swarm robotic architecture

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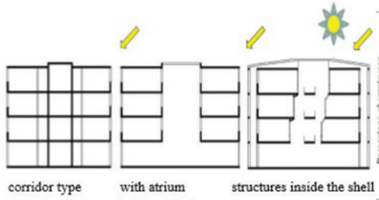
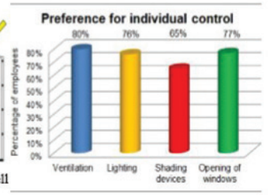
conference #3629

bAm is an architectural robot. It has got its own artificial intelligence. This artificial intelligence enables the bAm to recognize context, to communicate with humans and other breathing beings, to move and to connect with others of its kind. Together, they are able to create interactive and adaptive structures. bAm is a cross between sculpture and architecture, art and engineering, nature and technology. There are no overall rules. Every interaction is based on the artificial intelligence of each single module. Because the machine learns, the robots are able to develop themselves further autonomously. Hierarchy and organization as well as typologies are decentralized. The geometry of this architecture is not predefined or controlled but it is following clear rules. A big advantage of this kind of architecture is the adaptability when confronted with changing context. By disconnecting and reconnecting, the single robots can even react to enormous changes of environment. There is no visible centre or symmetry that could be broken. A bAm is able to detect a wide range of possible faults on its own, and tries to fix them autonomously. If a module is damaged, it is able to disconnect from the structure. Nearest neighbours will fill the gap. Adaptive, self-organizing and learning architecture is created. The design is kept simple. Even amateurs can repair, adapt, program or further develop it. The bAm are not bound to points of view. They are not fixed on sites. In many ways, bAm is the idea of bringing architecture to life.
Christoph Müller developed the concept of bAm during his PHD supervised by Manfred Berthold at TU-Wien. Since then, two additional versions have been made. The third version bAm V3 – ice, has been built 20 times in the atelier of and in strong cooperation with P.Michael Schultes and his team of experimonde. During this time, an entanglement of the digital and the physical, of the human intent and the controlled machine has taken place.
For example, the abilities of the robots would not have been developable without an algorithm for connecting together. On the other hand, this algorithm would not have been developable without the knowledge of the robots' abilities. We were thus fascinated about this strong relation between the two underlying notation models and how close they come together when connecting them at the pure level of code.
The logic of the aggregation in the swarm of bAm is strongly based on the interplay of the cyberspace and the meatspace. There is a boid-based logic to bring the particle-system together in the digital space.

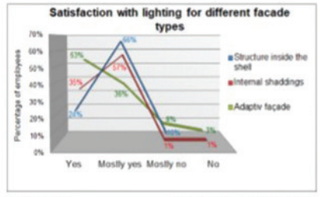
key words: architectural swarmrobotics, physical, digital, embodiment, computation



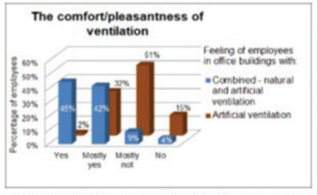
Considered types of office buildings

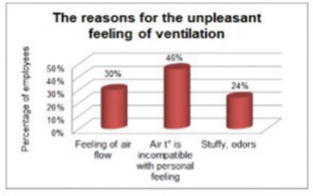


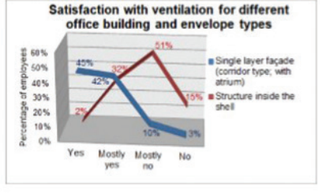
Employees need individually to set up indoor environment



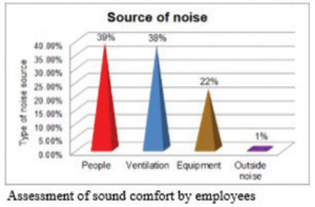
Satisfaction with lighting

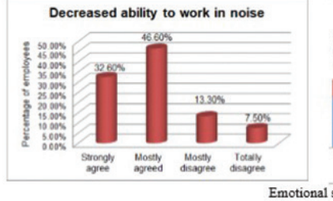




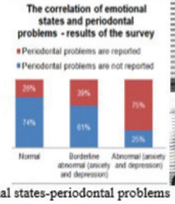


Assessment of the comfort of ventilation by employees

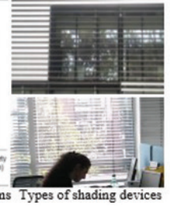




Assessment of sound comfort by employees



Emotional states-periodontal problems



Types of shading devices

Employees' evaluation of comfort / questionnaire results Assessment of physical factors/stressors

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conference #3603

Employees often spend more than 40 hours per week at work in offices. Working comfort is essential for quality of work, greater productivity and creativity and the preservation of health. In order to achieve high working comfort, advanced facade technologies are being developed that allow adaptation to the changeable external environment, usually using systems of centralized control (Building IT). This can be a psychological stressor on the employees who need to set up the indoor environment individually.

The research is focused on how employees evaluate the achieved comfort in different office types and facade technologies. It highlights factors that interfere with a pleasant atmosphere, or disrupts comfort, and aims at perceiving how human health is affected. These factors act as stressors and can be physical temperature, noise, light, air-quality and social-privacy and personal environment. Due to new technologies, the facade can be adaptable to the outside environment using a system which is operated manually, semi-automatically and automatically. For systems based on semiautomatic and automatic control, indoor environment comfort is set to standards, which can be a psychological stressor on employees. The research highlights some effects of these stressors.

The research was performed with a questionnaire that included individual experience of physical and social factors, i.e. stressors. The survey took three types of offices into consideration. : private, shared (< four) and team room (between four and nine employees). Combined natural and artificial lighting is mostly used in offices. Ventilation types: only mechanical or combined with natural.

The analysis indicated that employees prefer the possibility of individually adjusting the indoor environment. The possibility of opening windows and combining natural and mechanical ventilation creates pleasant sensations, while ins some scenarios employees feel that ventilation is mostly unpleasant and often noisy. Employees experience that noise comes mostly from people, usually in team offices, as well as ventilation, and less so equipment. Most employees agree that there is a decreased ability to work in the noise, especially when working on new tasks.

Some effects of the impact of these stressors are analysed through a survey. The correlation between emotional state and periodontal problems is observed. From the aspect of the emotional state of employees, the following cases are selected: normal, borderline abnormal (presence of anxiety and/or depression) and abnormal (presence of anxiety and/or depression). Considering the group with normal emotional state 26% reported periodontal problems, while this percentage was 39% in the case of borderline abnormal and 75% in the case of abnormal. This consideration was chosen because people with a changed emotional state are less likely to maintain hygiene, which is especially reflected in the oral hygiene and the appearance of rapid manifestations-periodontal problems. The fact that emotional states can be associated with comfort conditions confirms the importance of integrated design and presents the architectural challenge.

key words: office buildings, facade concept, user comfort, harmful environmental factors.

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