2012

Performance and Form: new pedagogical approaches to designing the building envelope as an adaptive interface

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Abstract
Architecture pedagogy plays a significant role in building a sustainable world. Sustainable design requires a thorough understanding of building energy performance, while the urging issue of a changing climate demands for higher energy efficiency and improved energy conservation. This demand challenges conventional ways to program buildings as well as purely formal approaches to the design of their envelope and spatial composition. It is no longer the question to build for one climate instead with the lifespan of a building, design concepts might need to integrate the ability to adapt to at least two climate conditions: current and future. The question is how to educate students to creatively address those challenges, when especially natural ventilation and day-lighting are complex and dynamic phenomena. Architects in general need to be better equipped during the early design phase with knowledge and design tools to integrate and predict dynamic performances of light and air movement to achieve these sustainable high performance buildings

Disciplines
Architecture | Art Education

Comments
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Introduction
Architecture pedagogy plays a significant role in building a sustainable world. Sustainable design requires a thorough understanding of building energy performance, while the urging issue of a changing climate demands for higher energy efficiency and improved energy conservation. This demand challenges conventional ways to program buildings as well as purely formal approaches to the design of their envelope and spatial composition. It is no longer the question to build for one climate instead with the lifespan of a building, design concepts might need to integrate the ability to adapt to at least two climate conditions: current and future. The question is how to educate students to creatively address those challenges, when especially natural ventilation and day-lighting are complex and dynamic phenomena. Architects in general need to be better equipped during the early design phase with knowledge and design tools to integrate and predict dynamic performances of light and air movement to achieve these sustainable high performance buildings.

The 2011 experimental summer design program ars Berlin of the Beuth Hochschule Berlin was developed between Iowa State University and Beuth Hochschule Berlin with the goal to introduce dynamic performance evaluation software tools into the conceptual design phase. The design projects were based on a pre-existing master plan for an inner urban brown-field rehabilitation site and aimed to develop strategies for adaptable flexible mixed-use building typologies focusing on the building envelope as an interface for light, radiation and air. The strategies established an elevated understanding of energy performance in the urban context and visualized the specific energy flow patterns for wind, light and radiation as they are dynamically shaped and manipulated in dense urban contexts.

While the Modern Movement at the start of the twentieth century postulated lower density for urban agglomerations through 'Light Sun Air', the conceptual design results of this workshop, revealed the potential for novel urban building typologies based on the traditional European city block. Teams built of students and young professionals from three countries (Germany, USA and Italy) worked first time with energy modeling and dynamic daylight simulation software as design tools and integrated quantitative and qualitative day-lighting, illumination and shading strategies as performance parameters into their designs, which they presented in thoughtful analytical iterations with the goal to advance parametric modeling and design skills in the ability to develop a typology and evaluate its performance. While understanding and interpreting public space, circulation and infrastructure issues on the urban level the internal structure and organization of the building added to its complexity.

The proposed building blocks thus developed as part of the boundaries to urban public space while the architectural form and its inside to outside interface derives from the performance predictions as well as spatial considerations striving for a sustainable transformation of the city, which can cope with the expected warming of the Northern European city climate.

Sustainable design is integrative design
This interdisciplinary program developed as collaboration between multiple architecture schools and interested practitioners from the Siena-Grossetto regions to address the triple bottom line of sustainable design (Social, Economic and Environmental) in a five week intensive workshop. As often rightly claimed and understood by the community, sustainable design pedagogy needs to address an integrated approach to energy, health and the operational performance of buildings in order to develop inherent design strategies to transform cities into low carbon economies. The major design goal is clear: getting towards net zero carbon and net zero energy consumption over the course of the year. What is less clear is that architects and engineers need not design with climate data from the past, but for the changing climate of the next 50 to 100 years, if current scientific evidence would be taken as serious as it should. In this particular summer of 2011, emphasis was placed on performance and optimization as form-givers in an urban context. Thus the workshop set out to optimize building orientation in relationship to solar geometry, solar heat gain and radiation challenges and dynamic shading potentials. In order to achieve these goals, quantitative and qualitative design and evaluation tools were integrated in the design process in five distinct workshops with specific goals and learning outcomes.

Challenges of a Changing Climate to Architecture
Because of its dominant factor to mitigate climate change, energy is often considered the most urgent sustainability issue, but adaptability to climate change and thus to enable a building to operate successfully under various climate change scenarios is as crucial (Mumovic and Santamouris 2009). Understanding and interpreting public space, circulation and infrastructure on the urban level as well as structure and organization of the building itself add to the complexity. A combined integration of these parameters add new challenges to the programming of buildings and their envelope. The urban building is thus understood at the same time as an object in and of itself, a comfortable habitat and as part of the boundary of urban space. As Stephane Hallegatte (2006), a French meteorologist outlined; it is no longer the question to build for one climate instead with the predicted lifespan of a building its design concept needs to integrate the ability to adapt. Hallegatte's team at the *Centre International de Recherche sur l'Environnement et le Développement (CIRED)* developed analog maps as communication tools, where major European cities are located at locations, which currently have the climate, those cities might encounter in the future. In these maps, Berlin is located in central Italy close to Rome. Although Hallegatte and his colleagues caution, that climate change adaptation cannot yet fully rely on climate change predictions, this analogy highlights the need to think differently about design and prepare buildings for at least two climate conditions: current and future. One approach would be to transfer the regional knowledge of the building typologies from Italy to Berlin, with the understanding that solar geometry of Berlin needs to be taken into consideration. Another approach evaluated in this paper will be a dynamic adaptive envelope strategy developed with analytical tools, which allow the rapid dynamic development of a multitude of variations.

New parameters - New tools
Berlin's climate is currently characterized as humid continental according to the Koeppen climate classification system with distinct seasons ranging from cold winters to warm to sometimes humid summers with chilly or mild springs and autumns (summer averages range around 22–25°C (72–77 °F) and lows of 12–14 °C (54–57 °F). Winters are relatively cold with average high temperatures of 3 °C (37°F) and lows of -2 to 0 °C (28 to 32 °F). The mass of buildings certainly create a microclimate with approx 4 degrees Celsius warmer temperatures throughout the year than the surrounding rural Brandenburg (http://en.wikipedia.org/wiki/Berlin). The latitude of 52 degree provides very distinct solar geometries, which are certainly unfamiliar to US American students, who are use to sun paths of approx. 40 degree latitude. As Hallegatte's climate maps place Berlin in vicinity to Rome, Italy Rome's climate needs to be investigated. Rome is currently experiencing a Mediterranean climate (Köppen climate classification: Csa). The average temperatures are much higher with averages often exceeding 30 °C (86 °F) and summer lasts for about 6 month. While Berlin is still a heating dominated climate, Rome is definitely a climate where cooling loads in summer have to be avoided at all costs. Therefore the workshop set out to develop adaptive building envelope strategies to reduce cooling load by solar radiation to a minimum, while still enabling occasional winter gains and maximizing daylight harvesting to avoid artificial illumination during daylight hours and to counteract the shorter winter days. These parameters were investigated in detail by exploring Berlin's solar radiation potential in response to the dense urban fabric and the necessity to develop seasonal adaptive shading strategies to develop resilience against a warming climate, while still providing energy efficiency and comfort today.

Nearly all participants had to be introduced to energy and environmental modeling and simulation tools like Autodesk Vasari and Ecotect, which are currently not yet common in most design studio pedagogies. In an initial attempt to understand the impact of solar radiation on daylighting and potential energy consumption, solar geometry and Berlin climate data were studied with respect to the typological sections and diagrams of the city fabric in the newly built inner city quarter in Mitte (*Suedliche Friedrichstadt*). Some teams took the initiative to compare them with sectional relationships of Italian and Spanish urban fabric. Various time steps per day over the course of a year were used as basis for shading and basic daylight studies to understand solar radiation in the context of the urban street cannon and how their proportion might be influenced by orientation and surface geometry. Abstract models and reliefs of the in-between spaces were developed and their proportions manipulated to understand their impact.

A second short atmospheric and qualitative exercise named "A day in the life of a shadow" provided the conceptual formal driver for most designs, which followed. The goal of this exercise was to develop a strategic and typological proposal for a space between a person, the city and the sun and resulted in the development of a variety of distinct shading device. Sectional sequences and a set of hand crafted models and videos were the formal outcome. Additionally the student teams started to grasp the complexity of dynamic strategies.

Typology of the block: Flexibility beyond function
Understanding the contemporary and historic urban typology of Berlin started with the analysis of the Berlin's urban street canyon proportions and provided the basis for the evaluation of the new European Energy Forum (EUREF) master plan with respect to its potential for providing minimum heat gain and maximum daylight harvesting. Berlin's building typology developed about hundred and fifty years ago based on rapid economic growth due to industrialization and population growth. Most buildings had standardized floor plans with standardized openings and façade ornamentation was applied from pattern books and best practices. Structural and spatial typology was developed out of economic necessity with minimum structural members where large wooden beams span from the façade to a central wall and to the back façade with lateral bracing provided by the stair core. Although this outcome might not have been planned from the outset, Still today this strategy proves to be resilient to programmatic changes as it is able to accommodate multiple shades of live- work scenarios and adapted well to changing needs and the strategy of programmatic adaptability could be well suited for sustainable standards.

As Aldo Rossi outlined in *L'architettura della città* (1982) the shape of the city depends on the building's relationship to public space. This is especially true once the original program of the building has changed multiple times as in the case of the typology of the Berlin urban block. The boundary of a building thus reflects the building's position within the urban context. The Janus-like quality of the building envelope oriented at the same time towards the inside as well as the outside, provides separation and connection and offers a unique field for explorations of the in-between.

In addition to Berlin Hamburg's new urban development, the HafenCity was studied. While Berlin's historic inner city was rebuilt on the existing street pattern after Germany's reunification, Hamburg's HafenCity developed on the tabula rasa of the former inner city harbor area. For each site visited accurate proportional relationship of street to façade to courtyard to openings to entrance to threshold were noted according to thresholds between public and private space, spatial sequences as a contemporary equivalent to the Nolli map, social and economic programming and schedule choreography, landscape features and open spaces. The underlying question was if the urban fabric was formed by solitary objects, assemblage of objects or larger blocks which jointly formed the street in order to understand, if the object creates the city or the city integrating the object? The pedagogical outcome was the ability to analysis a given urban situation in respect to solar radiation and energy mediation, which might impact the building envelope.

Strategies for dynamic interaction, dynamic sequence of 'Light Sun Air'
Christoph Reinhart et all (2006) introduced and reviewed the concept of dynamic performance metrics that capture the 'site-specific, dynamic interaction between a building, its occupants, and the surrounding climate on an annual basis' as an alternative design approach to mere static daylight factor calculations. The EUREF site in Berlin incorporated all of the above complexities therefore the team based its dynamic performance design strategy on this previous research work and introduced the student teams to DaySim and Radiance, both non-commercial research tools. In order to achieve the stated objectives of dynamic optimization design parameters included exploitation of day-lighting to reduce artificial lighting during day lit times by investigating daylight factor analysis to maximize daylight use first in winter and reduce heat gain in summer, designing a shading device for the summer which reduces the amount of solar gains and balances this to a maximum use of daylight, daylight autonomy over the course of a year as total evaluation of the overall strategy, occupancy levels, behavior and activities, as well as seasonal optimization of light transmitting surfaces for summer and winter (balance light transmission, heat gain and heat loss. Additional challenges were introduced in seasonal passive solar strategies in winter and seasonal natural ventilation strategies with impact on operability of envelope elements, time-based usage of buildings. Due to the time constraints of the workshop, heat flow by conduction was not addressed by any of the teams.

Each team analyzed the building volume given by the master plan and consecutively used the solar analysis results to modify these volumes and developed strategies for the design of an adaptive building envelope, while cross-referencing those results with analysis of the daylight availability for the interior.

Utilizing a variety of software tools (Ecotect, Radiance, Daysim, Revit, Vasari, Rhinoceros, Grasshopper, Diva) a specific workflow was developed, which started with a concept for a window or light transmitting surface for a typical space condition in the winter, when little light is available. The next step was to investigate typical conditions due to orientation and overshadowing in regard to solar radiation impinging on the building surface. The goal was to light the space sufficiently with as little window area as possible, considering high architectural quality of the space for the user. Finally the teams developed a scheme for the hottest day in summer using the information from a qualified weather tool and explored possibilities to mediate between ideal conditions for winter and summer. The final step in the work flow was to evaluate the overall approach using DaySim and within the DaySim analysis tool box the daylight autonomy (DA) and useful daylight illumination (UDI) to iteratively compare and evaluate design schemes. Based on elaborate research conducted in the field (Reinhart, 2006) the goal for each team was to achieve 75% to 80% of daylight autonomy, while reducing disturbing high illuminance daylight, which would cause glare or too high contrasts. This was the moment in the process when the different quantities of solar radiation reaching the building envelope due to its urban context offered opportunities for the composition of the building.

Urban strategies for a changing climate
Following the analysis of Berlin's urban typology the workshop took the position that flexible and adaptable structures are most resilient to climate change and social change. Therefore the teams were asked to explore program scenarios, which could be adapted to future living or working scenarios or a combination of both. The strategy is also backed by economic analysis and current practices in the HafenCity, where office space is reprogrammed to housing depending on the current demand situation according to local insight provided at our visit. The analytical topics used in the urban analysis process were also utilized in evaluating the new EUREF design proposals and noted in comprehensive diagrams to establish the building as an element of the urban fabric and the city as a social, cultural, economic and environmental construct.

The European Energy Forum (EUREF) in Berlin-Schöneberg currently under development aims to become the first net zero carbon urban neighborhood in Europe. The site was the loca

tion of Berlin's former gas works and the area is still dominated by the 60m high gasometer, which now hosts television talk shows. Following the historic connection of the site to energy issues a think tank and research platform for future energy and mobility solutions is currently emerging. The urban strategies are based on large scale blocks, while the energy strategies are focused on a climate neutral mix of onsite renewable energy resources ranging from geothermal to wind, while the architecture is nondescript, if not to say bland. The master site plan also follows other parameters apart from carbon neutrality. First of all there is the orientation of the site, which faces southeast-northwest due to the historically inscribed urban infrastructure. Secondly the site has highly contaminated soils therefore use of ground was limited, which determined the building footprints to a large degree.

The urban goal was to develop typological strategies, which challenged structural parameter of building depth, current building codes and investigated innovative modes of circulation and foremost adaptability of the envelope as interface for the changing climate and changing seasons, while the urban space could well develop into an in between space, which would be able to mediate the outside extreme climate conditions.

Form, Performance and Adaptability
In the final workshop all efforts culminated in an iterative process to optimize the building envelope performance on multiple levels by balancing solar radiation through shading strategies, day lighting and natural ventilation and by rethinking the interface between occupants, the city and its natural environment. Iterations mediated between least heat gain and maximum quality daylight from the inside out and from the outside in using daylight simulation and parametric models and a physical model of a prototype envelope component. Based on the first four workshops each team tested a set of parameters for this interface between desired interior comfort and urban exterior space applying climate data and future trends. Finally based on simulation and optimization some teams challenged the current master plan and proposed alternatives usually by morphing the envelope to reduce radiation impact.

Conclusion / Suggestion for practice
The success of this integrative workshop can be noted on multiple levels. The intercultural study abroad experience provided career shaping benefits for all of the students and insights into sustainable design pedagogy. Secondly the program furthered each participant's understanding of performance parameters as design tools, which encouraged an iterative form finding process above mere form application processes. Daylight performance is not often properly understood and distinguished from sunlight, but the iterative workflow between the two main parameters highlighted the difference, elevated concept over form and facilitated creative application of complex matter. The future of the program lies in integrating this experimental approach into a thorough evaluation of contemporary design studio teaching and the next step for the program would be to integrate spatial variations into the evaluation and go beyond established organizational diagrams.

Acknowledgements
The authors would like to thank Iowa State University, Beuth Hochschule Berlin, Ente Senese Scuola Edile (Siena) for their continuous support of the ars summer academy berlin the European Energy Forum (EUREF) for granting us access to their location and information and Buro Happold for their continued financial and logistic support of the program and the public events. The 2011 summer program would have not been possible without the backing of Professor Willi Hasselmann and Liss C. Werner's insight and contacts.

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Legenda (Image Captions)

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Fig. 1.2: Aerial site photo (Google Earth)
`Fig. 1.3: European Energy Forum (EUREF) site plan (with permission)
Fig. 1.4: European Energy Forum (EUREF) urban space rendering (with permission)
Fig. 1.5: Site context (Photo: Robert Demel)

Fig. 2: Berlin Genoa Barcelona_ Analyses on the Urban Scale: Maps
Fig. 2.1: Berlin Genoa Barcelona_ Analyses on the Urban Scale (Google Earth)
Fig. 2.2: Berlin Genoa Barcelona_ Radiation and proportion analyses on the Urban Scale Nurna, Tsitiridis ws 10/1
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Fig. 4: Form and performance: Student work for the EUREF campus:
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Fig. 4.2: Jie Tian¬_Haixi Peng_ Mario Krell

Site and Context

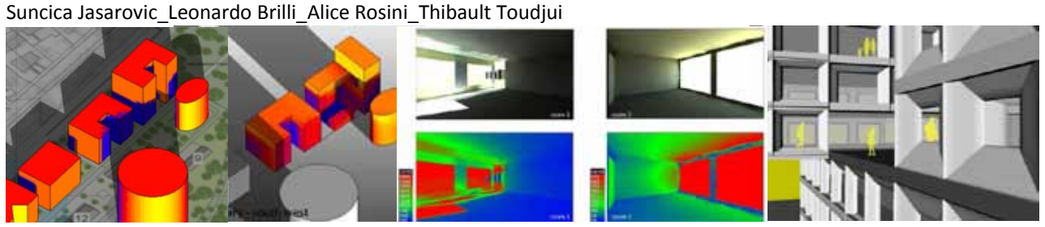
Stéphane Hallegatte Google Earth EUREF EUREF demel

Berlin Genoa Barcelona_ Analyses on the Urban Scale

Google Earth Nurna, Tsitiridis ws 10/1

demel

Suncica Jasarovic_Leonardo Brilli_Alice Rosini_Thibault Toudjui



Jie Tian_Haixi Peng_ Mario Krell