Adaptive Façade Training School 2018 - "Retrofitting Facades for Energy Performance Improvement"
03rd to 07th of September 2018
University of Belgrade, Faculty of Architecture

The report

Prof. Dr. Aleksandra Krstić-Furundžić

Introduction

Facades as part of the building envelope are considered to be the most important for achieving the proper indoor comfort, for reducing the consumption of energy from fossil fuels and thus the CO_2 emissions. The fact that newly constructed buildings represent a small percentage in relation to the total building stock indicates the importance of buildings refurbishment, while retrofitting of facades is crucial for energy performance improvement. Different refurbishment measures are available to improve thermal, light, acoustic and air comfort, as well as aesthetic values. Design of energy efficient buildings is based on achieving appropriate energy performances, i.e. energy savings and energy gains from renewable energy sources.

The point is to achieve active relationship between the building and the environment through the application of heating, cooling, ventilation and daylighting technologies that are based on natural forces (as pressure, temperature and moisture differences) and the use of renewable energy, thus reducing environmental pollution. Establishing active relationship between the building and its surroundings means adapting to natural and built environments, location; climate, annual and daily cycles (changes); various needs of users. In this respect, the concepts of adaptive facades have been developed and are constantly evolving.

One of the objectives of the project "Adaptive Facades Network" - COST Action TU1403, within the framework of European Cooperation in the field of Scientific and Technical Research, is to create the basis for exploiting recent technological developments in adaptive façades and energy efficient buildings, and to help train the future generation of façade R&D professionals in Europe. Therefore, 2nd Training School was organized by the COST Action TU1403 and the Faculty of Architecture, University of Belgrade.

The aim of the Training School "Retrofitting Facades for Energy Performance Improvement", held in September 2018 at the University of Belgrade, Faculty of Architecture, was to educate students on adaptive facade systems and assess the possibilities of their application in façade retrofitting and resulting energy and environmental benefits. In the period of five days, from 03 to 07 September, the teaching process included a theoretical block and workshop (more detailed information about the content and organisation is given in the schedule). During the theoretical block, frontal lectures were held by 12 lecturers, experts in the fields related to innovative facades, from 8 universities from Europe, and five tutors helped the creative work of participants during the workshop. A total of 33 participants, PhD and Master students, from 17 European universities had the opportunity to learn more about the design phases for adaptive facade systems that included: Conceptual Design, Materials and Technologies; Performance Evaluation and Mock Ups & Testing and Modelling/Numerical Simulation.

The organizing committee included Prof. Dr. Aleksandra Krstić-Furundžić, the creator of the Training School 2018, and Ass. Prof. Dr. Budimir Sudimac.

The education process included the following steps:

- Lectures ex-cathedra on concepts and technologies of adaptive facades and façade retrofitting.
- Early stage investigators - ESI workshop. PhD and Master Students had the opportunity to discuss individual research topics within interdisciplinary teams.
- 3-days Workshop on the integration of innovative façade technologies into the building retrofitting.
- Two phases of project presentation in front of the critics and evaluation expert committee – concept presentation and final presentation.

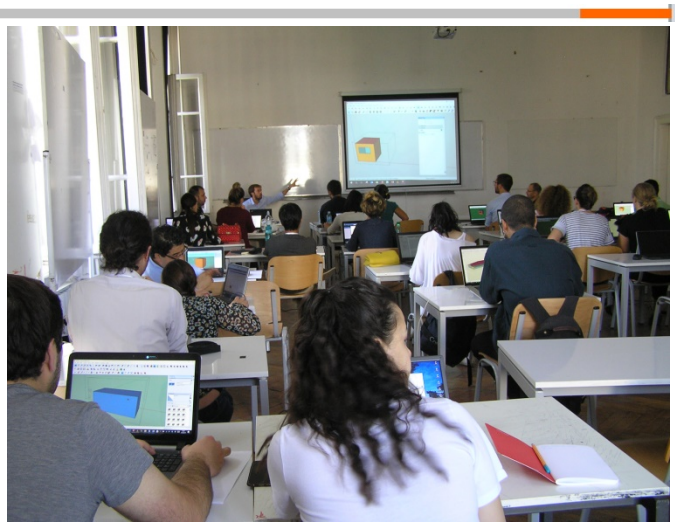
A very intense week of lectures and workshops enabled participants to learn from professionals and colleagues, and meet fellow researchers from other European universities for networking.

Particular importance was given to social activities that included visit to locations selected for case studies (typical Belgrade office and residential building), sightseeing of several historical locations in the city center, welcome dinner, and Belgrade nightlife, guided by locals. This, like all other activities during the Training school, contributed to the strengthening of friendship and business relations among participants.

Schedule of Training School 2018

	Morning 9:00-11:00	11:00-11:30	11:30-13:00	13:00-14:00	Afternoon 14:00-16:00	16:00-16:30	16:30-18:30	Evening 20:00-23:00
Monday	Room 200 **Registration 8:30-9:00** Room 200 **Aleksandra Krstić-Furundžić** Welcome and an introduction to the Training School program **Marcin Brzezicki** Adaptive Facade Concept and Typologies, Kinetic Facades (WG 1) (45 min) **Miren Juaristi Gutiérrez** Smart and Multifunctional Materials and their possible application in facade systems (WG 1) (45 min)	Room 254 **Coffe break**	Room 200 **Mark Alston** Climate Adapted Facades for Belgrade (WG 1) (45min) **Aleksandra Krstić-Furundžić** Building refurbishment in the context of adaptive facades (WG 1) (30 min) **Budimir Sudimac** Green wall systems for energy savings in buildings (WG 1) (20 min)	Room 254 **Lunch break**	Room 200 **Thaelia Konstantinou** ESI Workshop and Teambuilding Part 1 PhD/Master Posters/progress reports discussion of individual themes/topics in interdisciplinary teams (same teams as for the workshop)	Room 254 **Coffe break**	**Thaelia Konstantinou** ESI Workshop and Teambuilding Part 2 PhD/Master Posters/progress reports discussion of individual themes/topics in interdisciplinary teams (same teams as for the workshop)	
Tuesday	Room 200 **Mislav Stepinac** Structural Concepts for Adaptive Facades (WG 2) (45 min) **Chiara Bedon** Structural aspects & case studies (WG 2) (45 min)	Room 254 **Coffe break**	Room 200 **Fabio Favoino** Building performance simulation of adaptive facades (WG3) (45min) **Roman Rabenseifer** Post-occupancy Performance Evaluation (WG 3) (45 min)	Room 254 **Lunch break**	Room 200 **Fabio Favoino** Performance - Time conscious building envelopes (WG 2) (60min) **Aleksandra Krstić-Furundžić, Budimir Sudimac, Nikola Macut** Information on site visit-Definition and scope of the workshop	Room 254 **Coffe break** 15:15-15:30	Excursion ALL Visit to locations for case studies - typical Belgrade office and residential building 15:30-20:00	Welcome dinner
Wednesday	Rooms 217, 218, 219, 220 **Workshop** "Retrofitting Facades for Energy Performance Improvement" Task: Definition and consideration of facade concept / Working in Groups Support by trainers: Marcin Brzezicki, Riccardo Pinotti, Nikola Perković, Aleksandra Krstić-Furundžić, Budimir Sudimac, Djordje Stojanović Room 254 - **Coffe break** - 11:00-11:30			Room 254 **Lunch break**	Rooms 217, 218, 219, 220 **Workshop** "Retrofitting Facades for Energy Performance Improvement" Task: Definition and consideration of facade concept / Working in Groups/ Support by trainers: Marcin Brzezicki, Riccardo Pinotti, Nikola Perković, Aleksandra Krstić-Furundžić, Budimir Sudimac, Djordje Stojanović Room 254 - **Coffe break** - 16:00-16:30		Room 200 **Concept presentation** 10 min each group with external critics: **Jelena Ivanović-Šekularac,** AF-BU, Belgrade and **Anica Dragutinović,** hs-owl Detmold	
Thursday	Room 218 **Riccardo Pinotti** Building modelling using Trnsys software	Room 254 **Coffe break**	Rooms 217, 218, 219, 220 **Workshop** "Retrofitting Facades for Energy Performance Improvement" Task: Elaboration of facade concept by digital simulation and modellmaking / Working in Groups Support by trainers: Marcin Brzezicki, Riccardo Pinotti, Nikola Perković, Aleksandra Krstić-Furundžić, Budimir Sudimac, Djordje Stojanović	Room 254 **Lunch break**	Rooms 217, 218, 219, 220 **Workshop** "Retrofitting Facades for Energy Performance Improvement" Task: Elaboration of facade concept by digital simulation and modellmaking / Working in Groups Support by trainers: Marcin Brzezicki, Riccardo Pinotti, Nikola Perković, Aleksandra Krstić-Furundžić, Budimir Sudimac, Djordje Stojanović Room 254 - **Coffe break** - 16:00-16:30			
Friday	Rooms 217, 218, 219, 220 **Workshop** "Retrofitting Facades for Energy Performance Improvement" Task: Detailed elaboration of the facade concept and preparation of the final presentation / Working in Groups Support by trainers: Marcin Brzezicki, Riccardo Pinotti, Nikola Perković, Aleksandra Krstić-Furundžić, Budimir Sudimac, Djordje Stojanović Room 254 - **Coffe break** - 11:00-11:30			Room 254 **Lunch break**	Rooms 217, 218, 219, 220 **Workshop** "Retrofitting Facades for Energy Performance Improvement" Task: Detailed elaboration of the facade concept and preparation of the final presentation / Working in Groups Support by trainers: Marcin Brzezicki, Riccardo Pinotti, Nikola Perković, Aleksandra Krstić-Furundžić, Budimir Sudimac, Djordje Stojanović Room 254 - **Coffe break** - 16:00-16:30		Room 218 **Final public presentation of the results of the Workshop** 10 min each group with external critics: **Jelena Ivanović-Šekularac,** AF-BU, Belgrade and **Anica Dragutinović,** hs-owl Detmold	Time for party. See the Belgrade nightlife, guided by locals.

Photo documentation of the Lectures (Photos: A. Krstić-Furundžić)



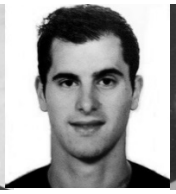
During the Workshop, participants developed concepts to improve the energy performances of facades of two post-war high-rise buildings in Belgrade and learned how these concepts can be validated and improved with actual simulation tools. The research and creative work of trainees was assisted by 6 trainers of different professional backgrounds, which additionally contributed to the multidisciplinary approach, which is generally considered essential in the design of innovative facades. The projects were presented in two phases to the critics. The first phase included presentation of the concept of improvement of the facade of the existing building with an explanation of the approach, various scenarios for facade improvement and criteria for decision making, as well as the functional and visual characteristics of the selected solution. This allowed trainees to get additional suggestions for further project development. The second phase was the final presentation of the entire project, with technical solutions and energy performance analysis. The design solutions have been evaluated by the expert group. All participants received certificates for attending the Training School 2018 in Belgrade.

Workshop Expert Committee

Trainers at the Workshop

Ass.Prof.Dr. Marcin Brzezicki
Wroclaw University of Science and Technology, Poland

Riccardo Pinotti
UNIBZ Free University of Bolzano / EURAC Institute of Renewable Energy, Italy



Teach.Ass. Nikola Perković
University of Zagreb, Croatia

Prof.Dr. Aleksandra Krstić-Furundžić
University of Belgrade, Serbia

Ass.Prof.Dr. Budimir Sudimac
University of Belgrade, Serbia

Assoc.Prof..Dr. Djordje Stojanović
University of Belgrade, Serbia

Critics

Prof. Dr. Jelena Ivanović-Šekularac
University of Belgrade, Serbia

Teach.Ass. Anica Dragutinović
Hochschule Ostwestfalen-Lippe, University of Applied Sciences, Germany

Practical work and research during the 3 days' innovative façade design workshop were organized through 7 workgroups-teams with members of different background (architecture, engineering, building physics), who have a research interest in facade design and engineering, and adaptive facades in particular. Under given design conditions, physical circumstances and technological constraints, using up-to-date knowledge, for certain types of buildings in Belgrade, facade improvement has been created in order to achieve better functional, energy and environmental effects. The trainees have expressed a responsible approach in considering the issue of keeping or replacing the existing façade and proving their attitudes.

Photo documentation of the Workshop (Photos: A. Krstić-Furundžić)



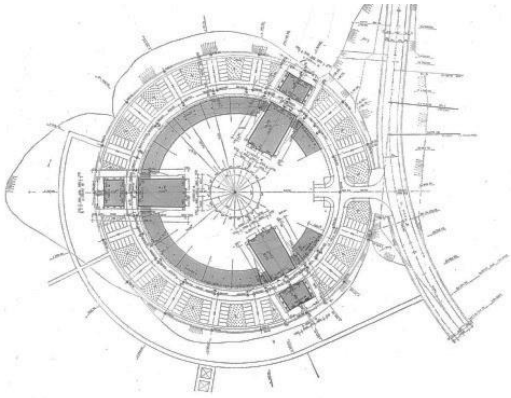

Photo documentation of the Social events – Lunches and Welcome dinner (Photos: A. Krstić-Furundžić)




Workshop - Case studies

Case study I - The task was to create a facade improvement of the "Beogradjanka" office building for a typical office area at the height of one floor using the concept of an adaptive facade. The building is located in the central zone of Belgrade, and it can be considered as one of the recognizable symbols of the city. It is high-rise stand-alone building with glass suspended façade (curtain wall), built in the post-war period 1969 - 1974.

Case study II - The task was to create an improvement of the facade of one of the three residential buildings called the East Gate of Belgrade, Rudo, for the proposed floor at the height of one floor using the concept of an adaptive facade. These high-rise stand-alone buildings are located in the suburban settlement Konjarnik and represent a benchmark when entering the city from the eastern direction of the highway. The buildings are constructed in the post-war period 1973 - 1976 and have a reinforced concrete prefabricated structure and reinforced concrete precast facade parapets.



Conclusions

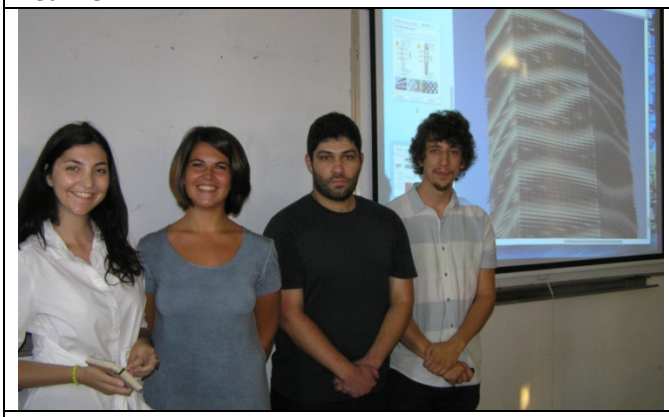
The process of designing the improvement of the facade implied several stages. On the first day of the Workshop, the existing situation, limitations and disadvantages were considered, and the concepts of facade with the

integration of innovative facade technologies were defined and discussed. The next two days were dedicated to the elaboration of new facade concepts by digital simulation and modellmaking, as well as numerical simulations to verify the energy consumption for heating and cooling. In the case of a business building, it can be noticed that some of the teams took into account the fact that the building is one of the symbols of the Moderna period with dark color and hexagonal shape, and therefore proposed a replica of the existing facade using innovative technologies. On the contrary, there was a vision that the existing facade should be completely replaced with a new innovative concept. Both approaches have resulted in interesting and realistic solutions with positive effects. In the case of a residential building, the improvement of the existing facade is considered suitable and the application of adaptive systems as a preferred solution in order to improve the energy performance and appearance of the building.

The overall/general impression is that trainees through their projects have shown a significant understanding of the design issues of innovative facades. A very balanced quality of projects has made the selection of the best proposals complex, but three projects have been awarded, among which are two proposals for improving the facade of the office building and one for the residential building.

Workgroups - Teams

Case study I – Office building		
Team 1	Ahmed Felimban Ali Aghazadeh Ardebili Martina Di Bugno Magdalena Patrus Nevena Lukić	Delft University of Technology, Netherlands University of Trieste, Italy University of Pisa, Italy University of Bath, United Kingdom University of Belgrade, Faculty of Architecture, Serbia
Team 2	Tiantian Du Marina Bagarić Zein Omar Arqoub Al-Doughmi Ceciilie Gry Jacobsen	Delft University of Technology, Netherlands University of Zagreb, Faculty of civil engineering, Croatia Cardiff University, United Kingdom The Royal Danish Academy of Fine Arts, School of Architecture (KADK), Denmark
Team 5	Aleksandra Ugrinović Dijana Savanović Mariana Velasco Carrasco Paolo Bonato Yeşim Keskinel	University of Belgrade, Faculty of Architecture, Serbia University of Belgrade, Faculty of Architecture, Serbia University of Nottingham, United Kingdom Energy Engineering, Politecnico di Milano, Italy Izmir Institute of Technology, Turkey
Team 6	Ana Kontić Milan Varga Valentina Frighi Michael Michalis	University of Belgrade, Faculty of Architecture, Serbia University of Belgrade, Faculty of Architecture, Serbia University of Ferrara, Department of Architecture, Italy University of Cambridge, United Kingdom
Team 7	Miroslav Vulić Neda Džombić Yorgos Spanodimitriou Mohataz Hossain	University of Belgrade, Faculty of Mechanical Engineering, Serbia University of Belgrade, Faculty of Architecture, Serbia University of Campania "Luigi Vanvitelli", Italy University of Nottingham, United Kingdom
Case study II – Residential building		
Team 3	Federico Bertagna Ariadna Carrobé Montalvo Juan Manuel Cruz Nikola Macut Mirjana Miletić	University of Pisa, Italy University of Lleida, Spain Norwegian University of Science and Technology (NTNU), Norway University of Belgrade, Faculty of Architecture, Serbia University of Belgrade, Faculty of Architecture, Serbia
Team 4	Jorge Luis Aguilar-Santana Anka Mirković Berk Ekici Milica Petrović Ashal Tyurkay	University of Nottingham, United Kingdom University of Belgrade, Faculty of Architecture, Serbia Delft University of Technology, Netherlands University of Belgrade, Faculty of Architecture, Serbia University of Antwerp, Belgium

Team 1	Team 2
	
Team 3	Team 4
	
Team 5	Team 6
	
Team 7	

Awarded workgroups - teams:

Team 7 – Retrofitting the façade of the office building

Team 1 – Retrofitting the façade of the office building

Team 4 – Retrofitting the façade of the residential building

(Photos: A. Krstić-Furundžić)

List of lecturers with topics:

Dr. Marcin Brzezicki Wroclaw University of Science and Technology, Poland, lecture: Adaptive Facade Concepts and Typologies

Miren Juaristi Gutiérrez, University of Navarra, Spain, lecture: Smart and Multifunctional Materials and their possible application in façade systems

Dr. Mark Alston, University of Nottingham, Faculty of Engineering, lecture: Climate adapted facades for Belgrade

Dr. Aleksandra Krstić-Furundžić, University of Belgrade, Faculty of Architecture, lecture: Building refurbishment in the context of adaptive facades

Dr. Budimir Sudimac, University of Belgrade, Faculty of Architecture, lecture: Green wall systems for energy savings in buildings

Dr. Mislav Stepinac, University of Zagreb, Faculty of civil engineering, Croatia, lecture: Structural concepts for adaptive facades

Dr. Chiara Bedon, University of Trieste, Department of Engineering and Architecture, Italy, lecture: Structural aspects & case studies

Dr. Fabio Favoino, TEBE Research group, Department of Energy–PoliTO, Italy, lecture 1: Building performance simulation of adaptive facades, lecture 2: Performance, Time conscious building envelopes

Dr. Roman Rabenseifer, Slovak University of Technology in Bratislava, Slovakia, lecture: Post Occupancy Performance Evaluation

Riccardo Pinotti, UNIBZ Free University of Bolzano / EURAC Institute of Renewable Energy, Italy Building modelling using Trnsys software

Dr. Thaleia Konstantinou, Delft University of Technology | TU · Faculty of Architecture, Manager of Early Stage Researchers (ESI) Workshop/Session