BUILDING PHYSICS REQUIREMENTS AND ARCHITECTURE STUDENTS

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ABSTRACT

The environmental performance of buildings needs to be considered in the early stages of the design process. Therefore, emphasis is nowadays placed in integrating the teaching of building performance with the design studios at schools of architecture. Preparing students for the complex role of an architect as a coordinator of all the aspects of a building design is gaining more and more importance.

This article describes and compares the methods of teaching building performance to architecture students at several universities in Europe and in the USA. It identifies the main tendencies in the syllabuses of building physics courses and is especially targeted to the relevance of these courses to the design studios at those schools. It also reviews some of the learning materials, recommended or accessible to students of those courses.

To achieve a relevant comparison, each of the countries where these schools are located is described in terms of the specific conditions of building physics design and the resulting problematics for an architect. These conditions include technical standards and requirements, the methods of building performance evaluation used and the climate.

Keywords: Architectural education, Learning materials, Building physics, Daylighting

INTRODUCTION

The energy efficiency of buildings and their quality interior environment are the key subjects in contemporary architectural production. The architect plays the role of a coordinator in the design process and it is his responsibility to fulfil all (often contradictory) requirements. Decisions made in the early stages of the design within the architectural study have a major impact on the final quality and also the cost and effectiveness of the subsequent design finalization and construction process.

The main trends that the education at architectural universities is currently following is the complexity of education and the interconnection of individual disciplines, as well as the increasing emphasis on sustainability. [1]

This article discusses the way architectural universities prepare students for the role of an architect in terms of meeting today's requirements of building physics. The aim of this article is to determine the extent to which it is possible to use the curricula of the best rated schools as an inspiration in teaching building physics. The article endeavors to find out which aspects of teaching can be appropriated and applied for other architecture universities and which are country-specific.

The teaching of building physics is analysed at the following four universities:

- ETH Zürich Swiss Federal Institute of Technology
- Faculty of Architecture, Czech Technical University (FA CTU),
- University of California Berkeley (UCB)
- Massachusetts Institute of Technology (MIT)

Switzerland is one of the world's most developed countries from the sustainability point of view, so the ETH Zürich, which is also among the five best-rated architectural universities, was included in this overview. Furthermore, the two best-rated architecture schools in the USA were included – the University of California Berkeley (UCB) and the Massachusetts Institute of Technology (MIT). The Faculty of Architecture of Czech technical University (FA CTU), where the authors are teaching building physics, is also a part of the comparison.

To achieve a relevant comparison of various schools curriculums, it is first necessary to define the country-specific conditions and the resulting requirements for architectural practice in terms of building physics.

These are primarily the legislative requirements of regulations and standards and the monitored quantities (and their values) and the methods used to assess the fulfilment of requirements. The overview below will cover the regulations that are particularly relevant at the early stages of designing a building.

For lighting technology, the insolation and daylighting of the buildings interior is the most important. The artificial and combined lighting of workspaces is usually designed later in the design process and is not so essential for the basic architectural form.

From the standpoint of thermal requirements, the conception of a building thermal envelope plays the primary role in the earlier building design, meaning the thermal qualities of constructions in one, two and three dimensions, in terms of heat transfer and distribution of moisture.

Acoustic requirements are related both to the protection against the negative effects of noise and to the spatial acoustic properties of the designed spaces.

The legislative requirements are closely linked to the climatic conditions. These are evaluated for the states and cities where the above-mentioned schools are located. That means Switzerland and Zürich for ETHZ, Czech Republic and Prague for the FA CTU, California and San Francisco for Berkeley and Massachusetts and Boston for MIT.

Further, the article describes the Compulsory subjects during the bachelor degree in which building physics is taught at the individual schools. are selected. Common features and, above all, differences in individual syllables are identified.

LEGISLATIVE AND CLIMATIC CONDITIONS

All the countries surveyed have statutory requirements for indoor environments. In the Czech Republic and Switzerland, these requirements are based on European standards adapted to the local environment.

In Switzerland, there is a building law building law for the entire country which also includes a set of SIA standards (Société suisse des Ingénieurs et des Architectes). The standards have several categories, the first of which (normes au sense strict) is obligatory. Furthermore, the European standards (EN) in their national modification (EN SN) apply.

The Swiss legislation approaches the building physics requirements from the environmental standpoint. This specific is most pronounced in the legislation relating to the daylight. The requirements for the illumination level (maintained illumination Em [lx]) are based on the European standard. [2] *Until now, there has never been any specific quantitative requirement for natural lighting in the Swiss regulation. This does not mean that this aspect is not treated, but the way to approach it is to calculate the lighting electricity consumption by taking into account a few isolated settings.* [3] The evaluated factor in this case is the electricity consumption for lighting [kWh / m2]. [4]

The Czech Republic has a building law and associated implementing decrees. Standards (ČSN) only become mandatory if they are cited by in the law. The requirements of the Czech standards for indoor environment are conceived in terms of user comfort. Limits set for insolation, daylight, noise, and some of the thermal properties (e.g. drop in floor temperature touch) are of a hygienic natures. Others requirements, particularly thermal ones, have energy efficiency as their goal.

In California, building requirements are regulated by the California Code of Regulations, Title 24 Building Standards Code. Its latest version has been in force since January 2017 (2016 California Building Standards Code).

In Massachusetts, the Massachusetts State Building Code (780 CMR) regulates the building requirements (its ninth edition is effective from January 2018).

The Massachusetts State Building Code and Title 24 are both based on the 2015 International Building Code (IBC), the 2015 International Existing Building Code (IEBC), and the International Energy Conservation Code (IECC), with amendments.

US statutory requirements are generally less strict than those in Europe. In America, however, a number of other assessment methods, such as ASHRAE and IESNA, are used to evaluate the environmental performance of buildings beyond the law.

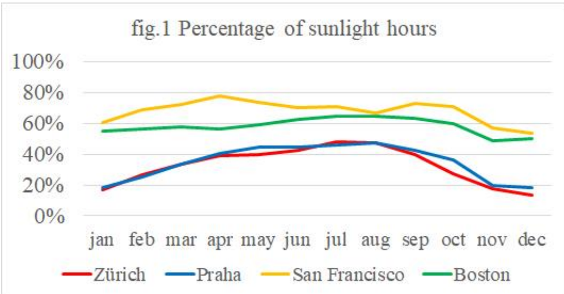
The light conditions in a given country can be effectively depicted by the ratio of sunshine hours to daylight hours. (fig.1) Boston and San Francisco have significantly more sunshine (59% and 69% on average), compared to the two European countries: (Prague 37% and Zurich 35%). [5] [6] [7]

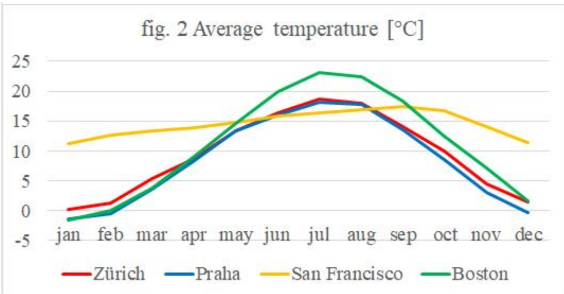
This ratio, together with the fact that the requirements of the Czech legislation on the building and physical properties of buildings focus primarily on user comfort, provides a possible explanation of why the Czech Republic is the only one of the countries surveyed, which has statutory requirements for the insolation of residential buildings (90 minutes of sunshine required 1.3.). [8]

Table 1 Sunlight and daylight hours

		jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	year
Zürich	sunlight hours	48	77	125	159	186	204	230	208	151	93	50	35	1566
	daylight hours	278	288	370	409	468	476	480	440	377	337	280	265	4468
	%	17%	27%	34%	39%	40%	43%	48%	47%	40%	28%	18%	13%	35%
Praha	sunlight hours	50	72	125	168	214	218	226	212	161	121	54	47	1668
	daylight hours	268	283	369	414	479	489	492	447	378	333	272	253	4477
	%	19%	25%	34%	41%	45%	45%	46%	47%	43%	36%	20%	19%	37%
San Francisco	sunlight hours	186	208	269	309	325	311	313	287	271	247	173	161	3062
	daylight hours	307	303	371	396	441	442	442	430	372	347	304	298	4453
	%	61%	69%	73%	78%	74%	70%	71%	67%	73%	71%	57%	54%	69%
Boston	sunlight hours	163	168	214	227	267	287	301	277	237	206	143	142	2634
	daylight hours	294	296	371	402	453	457	462	429	374	342	294	283	4457
	%	55%	57%	58%	56%	59%	63%	65%	65%	63%	60%	49%	50%	59%

Average temperatures in individual countries during the year (Figure 2) indicate that Switzerland, the Czech Republic and Massachusetts have large temperature differences during the year. In buildings, it is necessary to take into account both the influence of very low temperatures in winter and high in the summer.

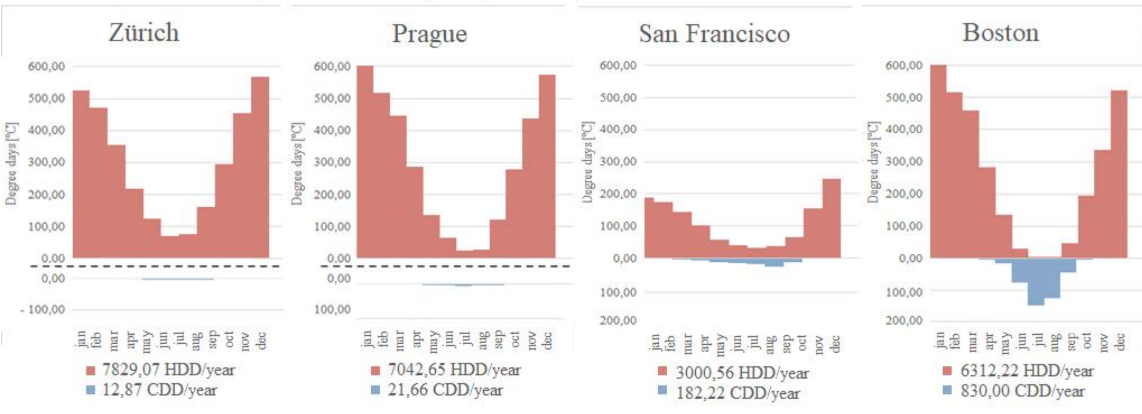




One of the factor best describing the requirements of thermal protection both in the winter and in summer are the heating degree days (HDD) and Cooling degree days (CDD). The charts bellow (fig.3) describe the average values in the period of 2081-2010.

In USA, the base temperature used for calculating degree days is 65 °F (18,3 °C) for both the HDD and CDD. [5] For Europe, the data was appropriated from Eurostat, which uses the base temperatures of 15 °C for HDD and 24 °C for CDD. [9]
Those different base temperatures were kept for the comparison, as they illustrate the difference in demands for the final interior environment temperature.

fig. 3 Heating and cooling degree days



Acoustic requirements are not dependent on climatic conditions. In all the countries concerned, noise insulation requirements for building structures are laid down. There are also noise limits for the interior and exterior environments of buildings. While the European legislation sets limits for interior noise from external sources, the International Building Code (2015 IBC), whose section 1207 – Sound transmission is appropriated by both California and Massachusetts, does not have limits for interior noise from external sources, relying instead on the urban planning division. [10]

THE SUBJECTS OF BUILDING PHYSICS AT INDIVIDUAL SCHOOLS

ETH ZÜRICH

Of all the schools studied, by far the largest space is devoted to the teaching of building physics at ETH Zürich, which provides beginning architects with a comprehensive knowledge of building physics sufficient even for civil engineers.
Practical exercises (and extensive examinations) are also focused on complex physics calculations. Especially thermal technology, with particular emphasis on the distribution of moisture in structures, is taught with a very professional, precise approach.

Bauphysik I - Heat and Acoustics [12]
2. semester, 3 hours of lecture per week
Scope: Heat: Stationary heat transport: conduction, convection and radiation
Heat transport through transparent elements
Acoustics: Basics of noise protection and room acoustics
Course completion: an exam which is a part of an exam block 2 with the Baumaterialen course, theoretical and practical part – calculations

Bauphysik II – Moisture [11]
3. semester, 3 hours of lecture per week
Scope: to develop a basic understanding of mass transport and buffering, to become aware of potential moisture-related damage and health risks, to learn how to design building components and assess their hygrothermal performance
Course completion: an exam, which is a part of an exam block 3 with the Bauphysik III course, theoretical and practical part – calculations

Bauphysik III – Energy and comfort, urban physics [12]
4. semester, 3 hours of lecture per week
Scope: Basics of thermal comfort, the energy balance of buildings and urban physics
Course completion: an exam, which is a part of an exam block 3 with the Bauphysik II course, theoretical and practical part – calculations

Energie und Klimasysteme II [12]
6. semester, 2 hours of tutorial per week
Scope: Urban Energy Systems, Renewable energy production at the building, intelligent buildings and automation, Integration of components and systems, day and artificial light, water systems
Tutorial: basic physical principles, concepts, components and systems for efficient and sustainable supply of buildings by electricity, light and water
Lighting technology is taught in the context of energy efficiency, which is linked to Swiss legislative requirements.

FA CTU

FA CTU has a relatively small space for teaching building physics. The lectures cover all the subjects of building physics thoroughly. The practical part of the course focuses mainly on verifying the fulfilment of legislative requirements. Due to the requirements of Czech legislation, most of one semester is devoted to the insolation and daylighting of residential buildings. The application of practical knowledge is addressed in the design studios and is dependent on the particular teacher

Stavební fyzika I (Building physics I)
3. Semester, 1 hour of lecture and 1 hour of practice per week
Scope: Insolation, daylight, acoustics
Practice: computationally verifying the design's compliance with the legislative requirements for insolation (majority of the semester) and daylighting of residential buildings and the sound pressure level in the protected outdoor area of buildings.
Course completion: Final test - practical part (insolation) and theoretical part

Stavební fyzika II (Building physics II)
4. semester, 1 hour of lecture and 1 hour of practice per week
Scope: Thermal physics
Practice: Computationally verifying the design's compliance with the requirements for the heat transfer coefficient and distribution of moisture in one and two dimensions, a drop in the floor touch temperature and the summer heat stability of a room

UCB -

One compulsory subject is devoted to building physics during a bachelor's degree, covering thermal engineering and daylight and also dealing with insolation and solar control. Then there is one subject that deals with acoustics.

ARCH 140 Energy and Environment [13]
6.or 7. semester, 3 hours of lecture and 3 hours of practice per week
Scope: building thermodynamics, daylighting, and solar control
Practice: computationally (using software methods) simulating and verifying building properties from a thermal, energy and lighting point of view
Course conclusion: Group project (teams of 3-4) – students work in to redesign the façade of an existing building to balance solar control and daylighting.

ARCH 144 Introduction to acoustics [14]
6. or 7. Semester, 3 hours of lecture/discussion per week for five weeks
Scope: acoustics
tutorial: building acoustics, mechanical equipment noise and vibration control, office acoustics, design of sound amplification systems, and environmental acoustics

MIT

At MIT, one compulsory subject is devoted to building physics in the bachelor's study program. The course deals with thermal engineering, daylight and acoustics approaching the entire subject matter from the environmental standpoint. There are other optional courses in the graduate study program, covering daylighting, building acoustics and thermal physics, but those are offered irregularly.

4.401/4.464 Environmental Technologies in Buildings [15]
5. or 6. Semester, 3 hours of lecture and 1 hour of practice per week
Scope: thermal engineering, daylighting and acoustics
Practice: Computationally (using software methods) simulating and verifying building properties from a thermal, energy and lighting point of view
Course completion: Group project - to developing an environmental concept for a small office building, presentation covering the overall design approach and environmental features, a thermal analysis and predicted energy use and a daylighting analysis
Group presentation – daylighting and energy use of an existing building

CONCLUSION

The major difference in the legislation, relevant to building physics, concerns the lighting technology. The Czech standards are mostly of a hygienic nature, focusing on the visual comfort of users. The Czech Republic is also the only one of the countries evaluated that has statutory requirements for building insolation. Lighting regulations in Switzerland and the USA mostly focus on energy efficiency.

The thermal technology requirements are comparable; the difference is linked to the climatic conditions. The requirements for the acoustic properties of the structures are comparable in all evaluated countries. In the USA, however, there are no statutory limits for the noise from external sources (which is addressed at the spatial planning level).

In all the schools, the lectures cover the field of building physics, taking into account the local specifics described above. The main differences are in the practical part of the courses and the scope and content of the course completion).

Both American universities include a group design project that links the knowledge of all aspects of building physics and their practical application in design. This method of practical application of the curriculum would be very useful to include in other schools.

The main challenge in ais the differing structure of study programs in individual schools and the related different hourly subsidies. Another complication is the difference in legislative requirements - in the Czech Republic, it is necessary to detail the insolation and daylighting in the architectural study and it is therefore necessary to prepare the students.

Despite the obstacles, it is commendable to regard educational trends of the architectural universities as a source of inspiration in the development and adaptation of curricula, particularly in terms of the practical application of acquired knowledge.

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