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2010年建筑环境科学与技术国际学术会议论文集

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中国建筑学会建筑物理分会
东南大学建筑学院
城市与建筑遗产保护教育部重点实验室
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前　　言

在绿色低碳的背景下，建筑物理已成为建筑设计、城市规划、建筑环境、建筑节能、建筑遗产保护和绿色建筑等领域不可或缺的支撑学科。在持续深入研究自身需要解决的问题的同时，建筑物理最新的理论和技术被及时地运用到上述领域，直接影响并推动了它们的发展。

2010 年是中国建筑学会建筑物理分会成立 50 周年。借此契机，由建筑物理分会和东南大学联合主办，新疆大学和合肥通用机械研究院协办，并由美国 Syracuse 大学和 *Journal of Building Physics* 作为国际合作方的具有重要意义的“2010 年建筑环境科学与技术国际学术会议”(简称 2010 BEST-CN)将在南京举行，本次会议旨在聚集国际国内来自高校、科研院所和企业的专业人士，共同讨论与建筑物理、建筑节能、遗产与风土建筑、绿色建筑等相关的议题，并庆祝建筑物理分会成立 50 周年。

本论文集共收录来自国际专家的特邀报告 6 篇，征集学术论文 175 篇，其中建筑热工及建筑节能 92 篇，建筑声光 19 篇，遗产建筑和风土建筑 25 篇，绿色建筑相关 39 篇。作者来自美国、加拿大、以色列、波兰、日本、瑞典及国内的众多高校、科研院所和企业，具有广泛的国际性和代表性，反映了建筑物理及相关领域的前沿学术动态。本论文集的出版受到国家科技部“十一五”科技支撑计划课题(2006BAJ04A10 和 2006BAJ03A04—01)的资助。北京世纪建通技术开发有限公司、北京声望声电技术有限公司、上海申模计算机系统集成有限公司、德图中国等对本次会议提供了大力支持，特此一并致谢！囿于编委会水平有限，对于论文集可能存在的错误，欢迎各界人士批评指正。

2010 BEST-CN 会议论文集编委会

2010 年 4 月 18 日

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特邀论文

建筑热工与建筑节能

建筑声学和建筑光学

遗产建筑和风土建筑

绿色建筑及其它

Building physics is the key to design of energy efficient, durable, and well adapted to the climate buildings

* Mark Bomberg

(Syracuse University, NY, USA)

Abstract: In this conference we would like to highlight three issues, considered to be the core of methodology used for achieving durable, energy efficient buildings with a good indoor environment:

1. The sustainable value of building is determined by its energy efficiency, durability and the indoor environment, which may or may not include use of the "green" materials.

2. The sustainable buildings need a design process based on a systems approach instead of the focus on one-issue solutions.

3. Changes in socio-economic conditions of construction brought us to the point when despite of a vast industrial know-how based on tradition we need a new vision of process integration.

Every building needs to be treated as a system in which every component is one piece of the puzzle. This approach may lead to many small actions undertaken in concert to achieve a major impact. On the other hand, the quick fix efforts for one or more components in the building envelope, at best, may not achieve enough, and at worst, may cause damage. The systems approach requires interaction of experienced practitioners of all types and means to ensure that the design intent is realized though the mock-up building and commissioning tests.

Keywords: energy efficiency, durability, climate, building physics, design of building enclosure, envelope

FOREWORD

I am grateful for the opportunity of addressing the first Building Physics Conference held simultaneously in Mandarin and English, and called 2010_BEST_CN(building and environment, science and technology) that intends to review world-wide developments of Building Physics and focus the discussion on the situation in China.

Scientific speakers, using English on the international arena, must define terms used in their papers. Interpretation of English terms often varies depending on the region and focus of the group using a term.

Once, in a team of Americans and Canadians working together, a sharp division was created during a discussion on a window flashing. An hour later it became obvious that flashing is understood as rainwater protection in theUS while in Canada it is serving as means of water removal to the outside. In North America(NA) one uses a term "building science" that was defined by Hutcheon

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(1972) in the following manner[①]:

"Knowledge about building, called, for convenience, building science, is valuable largely because it is useful in predicting the outcome of the result of some building situation. …Rational design is possible only when there is a capability to establish, each time a choice is made, the probability of a particular result."

This formulation defines the objective and does elaborate on the process to achieve this objective. InEurope one uses a different approach. A new academic discipline was defined through a number of books. Initially called "stroitielna tieplotechnika"(Russian-heat technology for buildings), "heat and moisture problems" and "general building technology" in other countries until the whole academic world accepted the term of *building physics* (German "Bauphysik", Scandinavian "Byggnadsfysik" and Russian Stroitielnaja tieplofizyka).

Today the building science is a loose concept that includes heat, air moisture(HAM) transfers and their effects on materials and structures, sometimes denoted as "hygrothermal" issues. On the other hand, building physics is a well defined, multi-disciplinary, academic discipline that involves parts of applied physics(acoustics and vibrations), structural engineering(fire behavior of structures), material science(durability of materials under specified environmental conditions), elements of mechanical engineering(interaction of HVAC with structures and people) and even elements of industrial hygiene(human responses to environment, pollutants etc). With the growing interest on problem solving methodologies such as the risk analysis and performance-predicting tools the difference between building physics and building science is disappearing. I, for one, believe we can phase out the term building science from any scientific discussion and use the term of building physics.

There are more definitions to review. Stevenson[②] once said "*Man is a creature who lives not upon bread alone but principally by catchwords*". This quip comes to mind when we realize how many misleading terms one can find in the daily press in relation to qualifying buildings that are *built with a view to energy efficiency, durability, indoor environment and other aspects of sustainability*. "Passive houses" category that was started in Germany is often called "active houses" when they incorporate solar and geothermal heat, "net zero energy houses" is the term used to replace the old "low energy houses" or the "super-insulated houses" and finally term "green" buildings highlights that someone has also considered the environment.

In this respect Lstiburek(2008) stated:

"Conservation should not be news. This was all figured out long before by some smart folks, some of who are still alive, who are still smart, but mostly bemused at what passes for green today. Let me first define what green should be focused on if I was in charge: 80% energy, 20% everything else, such as water and materials. The new "golden mean" of 80:20 will achieve perfect harmony and proportion for buildings and the built environment. Before you can have a "green" building, you need a building first. This building needs to be able to stand up, not be blown away in a hurricane, not fall down in an earthquake, not burn, not leak rainwater, not be moldy, not rot, not corrode and otherwise be able to meet applicable building codes such as having a basic provision for ventilation like that specified by ASHRAE Standard 62.1. This is the starting point for the 80 : 20 "golden mean." No points for IAQ, comfort, and durability since they should already be part of the basic building. The "everything else" comes after the basic building requirements are met. To me, that principally means water conservation and materials.

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① Lecture at Indian Research Institute in 1972 reprinted in J. of Building Physics in 1998 use computer search SAGEonline

② Robert Louis Stevenson, 1881, Virginibus Puerisque, I, chapter 2

The public perception of sustainable design is, however, promulgated by the green programs such as "LEED" and these programs, generally, do not handle energy efficiency. Shortcomings of green programs in terms of energy efficiency and durability are easy to explain since these programs were created entirely for their social aspects while the concept of sustainability is defined in three dimensions: economic, technical and social. While the term "green buildings" has become a buzzword for environmentally driven impulses, a definition is needed that addresses a cost-benefit analysis. To avoid ambiguity instead of "green" we will use the term "*high performance building*" that was defined by congress in the US Energy Policy Act of 2005 as follows: *The term "high performance building" means a building that integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, life cycle performance, and occupant productivity.*

The scope of design is well understood in the technical circles , for instance the Green Guide (2006) of ASHRAE states:"Some characteristics of green design have no impact in terms of maintaining ecological balance, including indoor environmental quality(IEQ), and important element of green design". Definition of sustainability used by ASTM is similar to that explained in the Green Guide(2006), namely:

The design that that achieves high performance, over the full life cycle, in the following areas:

1) Minimizing natural resource consumption including utilization of renewable energy resources to achieve net zero energy consumption;

2) Minimizing emissions, especially those related to indoor air quality, greenhouse gases, particulates or acid rain;

3) Minimizing solid waste;

4) Minimize negative impacts on site ecosystems;

5) Maximum quality of indoor environment, thermal regime, illumination, acoustics/noise, and visual aspects to provide comfortable human perceptions.

Comparing the scope of building physics with the above definition, one can see a large overlap between them. After all Building Physics is concerned with the building performance over the service life(durability) and topics listed in point 5 of the above.

Now when we the objective of building physics and high performance buildings we can start our discussion why this discipline of engineering science started 75 years ago became the Cinderella of 21st century buildings. To realize what is happening now we need to go back as much as one hundred years ago.

THE ROOT OF THE PROBLEM

One hundred years ago, an architect was in control over all trades and his/her vision was understood by all people involved in the construction. This is not the case today. Possibilities of many structural combinations with reinforced concrete, steel, masonry and glass relegated the architect to "become one member of the team", a person dealing with the spatial design but not necessarily directing other aspects of performance. We seem to have arrived to a puzzle in which each member of the team is responsible for quality of one piece but really none is concerned with the synergy when the pieces are put together. Finally, when the structural glass came to the practical use, many architects became so fascinated by the appearance that the word "performance" seems to have disappeared from their vocabulary.

If you think that these statements are an exaggeration, look at the energy efficiency. The white paper from BEST1(2008) reports theUS situation:

"Average energy use of commercial buildings in 1990 was 315 kWh /m^2. Since 1990 energy use in commercial buildings steadily declined, reaching 250 kWh /m^{2i} in 2002. Note, however, that this was equivalent to the energy use of commercial buildings in mid 1920. So, a masonry building without insulation built nearly one hundred years ago consumed as much energy as a shiny, glass-clad building constructed today! This of course says nothing about the increased functions that current modern buildings are now fulfilling compared with what was needed in 1920."

In the contemporary office building the office equipment and computers use on average 10% but lighting uses 28% of the total energy. We have no figures for 1920's but obviously lights were less efficient than now, so how is it possible. It is difficult to understand why we do not use much less energy than used in the 1920's. The author, who is functioned as the editor of this paper removed this info from the final version of the paper as not validated with statistics. Later on, when listening to a presentation of statistics from 4,400 dwellings in high-rises, the author had to accept this statement as a proven fact. Despite having to our disposal excellent thermal insulation materials, thermal mass, air barriers and many other energy saving measures the role of the architect who understand the form and the function appears to be lost. To add insult to injury as the saying goes, over 50 years(1950 to 2000) emissions attributable to buildings increased three times.

At the same American Institute of Architects and ASHRAE agreed that by year 2030 we need to come back in the new construction to being carbon neutral, a case last seen on North American continent in the mid 19[th] century. Of course it is possible but *to create energy efficient, durable and comfortable buildings either new or rehabilitated existing buildings requires a different thinking paradigm*

To understand what need to be done to achieve such an ambitious goal we start with a review of environmental control(heat, air and moisture control) in buildings over last 60 years.

SHORT HISTORY OF ENVIRONMENTAL CONTROL IN NA BUILDINGS

In reviewing the environmental control we will first review typical residential walls and then add issues related to commercial and institutional buildings.

Control of air and moisture movement in wood-frame residential walls

A number of significant developments took place in NA in the 1930's starting with the use of building paper weather barriers. The building(Kraft) paper was placed on the external side of the wall sheathing, impeding the movement of air and rain while permitting some moisture to permeate to the outdoors. To improve thermal comfort, wall cavities were filled with insulation—first using wood chips and later with mineral and fiberglass batts. Scientists observed that the presence of thermal insulation in the wood frame cavity lowered the temperature on the outer side of this cavity, leading to a possibility of vapor condensation. To reduce the flux of moisture the water vapor barriers were introduced. Effectively a modern wood frame wall was created(Bomberg and Onysko, 2002).

High tolerance wood frame walls

In a 1930's-built wood-frame house there was a water resistive barrier(WRB), made of Kraft paper that acts as a smart water vapor retarder i. e., is capable of changing from a water vapor retarder(when dry) to a breather(when wet). This WRB did not eliminate the airflow through the