Analyses of Public Utility Building - Students Designs, Aimed at their Energy Efficiency Improvement

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Abstract. Public utility buildings are formally, structurally and functionally complex entities. Frequently, the process of their design involves the retroactive reconsideration of energy engineering issues, once a building concept has already been completed. At that stage, minor formal corrections are made along with the design of the external layer of the building in order to satisfy applicable standards. Architecture students do the same when designing assigned public utility buildings. In order to demonstrate energy-related defects of building designs developed by students, the conduct of analyses was proposed. The completed designs of public utility buildings were examined with regard to energy efficiency of the solutions they feature through the application of the following programs: Ecotect, Vasari, and in case of simpler analyses ArchiCad program extensions were sufficient.

1. What does the fundamental task involve?

Architecture students in the course of their studies prepare at least a few designs of public utility buildings as a part of specialist design class. Typically, these could be educational facilities (kindergartens, schools, higher education institutions), health care facilities (out-patient clinics, hospitals, health resorts, public nursing homes, etc.), cultural facilities (multi-screen cinemas, theatres, concert halls), sports, tourism, commerce and service facilities, etc. Owing to the high complexity of dry buildings as well as a limited amount of time (students have one semester), designers are focus on functional and space issues, construction and material issues as well as aesthetic matters. Energy related, pro-environmental issues are not solved or considered in secondarily, after finishing the concept of the objects.

Within the scope of the course of “pro-environmental architectural design,” a student chooses one of already completed designs of a public utility building which he/she then analyses and evaluates in terms of ecology in architecture. This is a new factor, which needs to be taken into consideration in the process of design, and among numerous pro-ecological architectural solutions a lot of attention is paid to energy-related matters in architecture.

2. What Aspects Are Analysed?

Several public utility building designs were analysed. The completed designs of public utility buildings were examined with regard to the energy efficiency of the solutions they feature through the application of the following programs: Ecotect, Vasari, and in case of simpler analyses (shading, insolation of building planes) ArchiCad program extensions were sufficient.

The following aspects needed to be examined:
• location: Is a building properly positioned relative to the direction of the world? Does the southern façade receive sufficient amount of insolation? Isn’t the building shaded with other structures – chiefly at the time of equinox – 21.03 and 23.09?
• shape of the building body: Is it shaped in such a way that its own shadow interferes with room light? Which building body planes receive the most solar energy? Are internal patios and breaks in the body of the building properly shaped?
• amount of daylight and of solar radiation in particular rooms: How much light do the provided window openings allow into the rooms? How do they function in intense insolation? Is the body of the building sufficiently “open” to southern insolation?
• annual thermal balance, itemized into individual months: What is the demand for heat at specific, constant coefficient value of external envelopes insulating power (solid walls $U=0.15 \text{ W/m}^2\text{K}$, roofs and flat roofs $U=0.1 \text{ W/m}^2\text{K}$, ground slab $U=0.1 \text{ W/m}^2\text{K}$, windows $U=0.7 \text{ W/m}^2\text{K}$, glass curtain walls, doors $U=1.2 \text{ W/m}^2\text{K}$). Was it calculated than: what proportion of thermal energy demand is covered by solar radiation gains, what proportion is obtained from gains generated by people and devices, and how much needs to be supplied from conventional sources of heating? For the summertime, the question is: how much energy will be consumed by the air conditioning that cools the buildings?

Figure 1. Design and analysis of the Medical Clinic building – A summary analysis of the object before and after the changes (shading, lighting sunlight envelope planes of the building, interior lighting by daylight, the annual heat balance)
Note – To ensure the comparability of results, all the designed buildings featured the same insulating power properties of external envelopes as specified above. The building had the same insulation power of external envelopes before and after design changes.

As a result of the conducted analyses, the authors themselves recognized significant defects of their own solutions. Such defects needed to be listed and described. The most frequent defects included:

- failure to take into account the differences in insolation of the body of the building on southern and northern façades,
- inappropriate location of rooms in the building relative to the directions of the world,
- inappropriately shaped body of the building (high value of the ratio defining the relation of external planes to cubature), breaks causing high shading, excessively shaded patios,
- inappropriately designed window openings and curtain walls,
- lack of solutions related to operation of the building in the cold and hot seasons.

3. Corrections or a Complete Change of the Original Designs?

The flaws found in analysed designs had to be corrected. Additionally, designers were provided with extensive information on simple and efficient passive systems of using solar energy. Design corrections eventually became substantial redesigns. Knowing the functional diagrams of previously designed buildings, designers found it easy to incorporate changes and the supplementation of new solutions increasing energy efficiency. Consequently, the architecture of the facilities became different from the original one. The changes involved:

- remodelling the form of a building, in order to decrease the building’s own shadow, e.g. softening breaks or reforming them in such a way so as to prevent them from shading adjacent parts of the building;
- shaping the form of the building in such a way that a longer façade has been created on the southern side;
- redesigning a room layout so as to enable temperature zoning of building rooms (warm from the south or the centre of the layout, cold from the north or as an external buffer from the windward side);
- addition of a greenhouse / conservatory as an integral structure element;
- incorporation of other passive systems of acquiring thermal energy from solar radiation;
- conceptual solution of air circulation in winter and summer time;
- proposal of a system of heat recuperation from ventilated air and a way of preliminary heating of air introduced into the ventilation system;

After the completion of so many analyses and necessary changes, the building designs became new, different designs of the same functional program but solved in a new form, re-examined in terms of energy. A conservatory (greenhouse) is now one of the fundamental elements integrally connected with the building. It constitutes not only a supplementation of entrance, recreation, catering and other types of space, but it is also an element improving the building’s energy balance. The energy aspects related to that solution must be examined and solved. The functioning of the space during winter and summer time also needs to be considered. Several aspects that needed to be solved by way of schematic diagrams include: cooling, heating, air circulation and the use of air from the greenhouse.

4. Energy Analysis of the Redesigned Building

New building designs were subjected to similar examinations as the original designs, whose focus was on:

- location,
- shading,
- shape of the form of the building,
- daylight amount and amount of insolation in individual rooms,
- annual thermal balance including an itemization of individual months.
According to the assumption, all external construction envelopes in a new and in the original design feature the same thermal insulating power. This enables a comparison of thermal balances devised for original and post-conversion designs. The differences in thermal balance results exclusively from different architecture of both form of the building and not from any mechanical increase or decrease of thermal insulating power of external envelopes in the designed body of a building. As demonstrated through calculations and simulations, energy efficiency of the redesigned building is significantly greater than that of the original building, while the participation of passive systems in the thermal balance is very substantial. Such systems enable significant savings in the consumption of conventional energy carriers. Both in the autumn and in the spring, those gains eliminate the use of conventional heating, which is clearly visible in the diagrams simulating heating in particular months. The conducted calculations of thermal balance for the original and redesigned buildings energy savings are up to 50%. It should be emphasized that the savings result from a change in space solutions and new function layouts, and not from increasing insulation power of external envelopes in newly designed buildings. The insulating power of the envelopes remains unchanged, in order to demonstrate to designers/architects how significant is the role that architectural solutions of a building play in energy efficiency (form, function, construction).

An analysis of monthly thermal balances demonstrates that after the incorporated changes, the buildings of more compact form demonstrate lower losses related to thermal transmittance (coloured red in the diagram) and simultaneously higher gains related to passive systems of solar energy use (coloured yellow in the diagram). The thermal balance of the buildings does not precisely account for the use of warm air from conservatory in the ventilation system. Moreover, the benefits from introducing ground-coupled heat exchangers and recuperators into the ventilation system of the building are not taken into consideration.

5. Conclusions
The 21st century designs of public utility buildings should always be energy efficient and feature other pro-environmental solutions. Energy efficiency must not be an element supplemented in a technical design through an increase of thermal insulation layers and the application of glazed surfaces of higher thermal transmittance. The addition of liquid or photovoltaic collector to a building has become a newsworthy event. The analyses conducted with the use of Ecotec and Vasari programs revealed energy efficiency related defects in the building designs. The analyses demonstrated that form and internal space layout have a significant impact on the energy efficiency of a building. Buildings of the same functional program and similar cubature, but with modified architecture are twice as energy efficient. It must be concluded that an energy efficient building using simple architectural passive application of solar energy must be developed from the start in keeping with such assumptions. Consequently, its energy efficiency is substantially higher than the one obtained through an increase in thermal insulation of external envelopes. Therefore, the role of an architect is a crucial one, since an architect ought to consider energy efficiency from preliminary design concept.

Energy efficiency further entails the right form and space layout of a building, and even function solutions, not merely insulation elements of external envelopes and some technical gadgets.

An ideal solution would involve the existence of advanced Building Information’s Managements-type computer software that would provide remarks on an ongoing basis in the course of concept formulation, informing of the energy efficiency of a developed body of a building. Each change incorporated by a designer would be assessed and presented as a commentary on energy efficiency results. Such helpful operation of BIM programs would provide significant assistance in making the right design decisions. I am convinced the use of such programs is a question of the not so distant future.

References
[1] Edwards B.W., Naboni E. (2013). Green buildings pay. Design, productivity and ecology. Routledge Taylor, London, New York
[2] Guzowski M. (2010). Towards zero-energy architecture. New solar design. Laurence King Publishing Ltd. London

[3] Mikoś J. (1996, 2000). Budownictwo ekologiczne, (Ecological building). Wydawnictwo Politechniki Śląskiej, Gliwice, (in Polish).

[4] Pearce A.R., Yong H.A (2012). Sustainable buildings and infrastructure, paths to the future. Routledge Taylor & Francis Group, corp. London, New York

[5] Wołoszyn M.A. (1991). Wykorzystanie energii słonecznej w budownictwie jednorodzinnym, (The use of solar energy in single family housing), Centralny Ośrodek Informacji Budownictwa, Warszawa, (in Polish).

[6] Wołoszyn M.A. (2013), Ekorewitalizacja. Zagadnienia architektoniczne, (Eco-revitalization, Architectural issues), Exemplum, Poznań – Szczecin , (in Polish).