The flat roof design - a contribution to the methodology of architects' education

Robert A. Marcinkowski

Cracow University of Technology
Kraków, Poland

ABSTRACT: Flat roof design is a part of the course of *Construction* run by the Institute of Building Construction in the Faculty of Architecture of Cracow University of Technology, Kraków, Poland. In this article, the author discusses selected issues of modern engineering education. Technological progress has resulted in a continual increase in the number of technologies and technical solutions available and implemented in contemporary construction systems. This also concerns new types of flat roof design constituting the standard matter offered in the 3rd semester (the project lasting approximately nine weeks). These issues involve updating technical knowledge, expansion of teaching programmes, negative impact of overwork on the results of teaching, and problems of selecting information in formulating teaching programmes and tasks for students. Conclusions interspersed in this article are based on discussions among academic teachers and on the author's individual teaching practice. The article presents proposals for project tasks for students, as well as examples of work undertaken according to this programme.

Keywords: Architecture, flat roof functions, malfunctions, educational process

INTRODUCTION - CONTEMPORARY FLAT ROOFS IN POLAND

Flat roofs dominate in the landscape of many modern cities. The example presented below shows residential estates in Kraków, but similar pictures could be taken in numerous urban areas of many countries.

Figure 1: Flat roofs are a typical element of the landscape of contemporary cities. (Kraków, Poland - photo by R. Marcinkowski, 2007).

The common shortcoming of the flat roofs presented above is the lack of functional usability. They do not improve the quality of life of users and, therefore, do not meet the basic criterion of architectural definition.

Widespread use of flat roofs does not mean that they were always correctly constructed. These remarks concern the issue of what the roofs were historically and what they might/should be in the future, and how to translate these demands into the language of academic teaching.

Although they look similar, during the last half-century, flat roofs were built for different reasons and according to different technologies.

From the point of view of the communist authorities, the traditional forms of houses and traditional carpentry were not enthusiastic enough for the new era. Since the 1960s, flat roofs have been promoted (in fact enforced by law) as a symbol of modernity and progress, even in the countryside.

These implementations, however, were not accompanied by a knowledge of the physical aspects of building, so flat roofs had bad thermal properties and were subjected to dampness and biological corrosion. A typical mistake was (and still is) covering the roof from the top with the damp-proof membrane without fitting a vapour barrier. The process of diffusion from the inside of the house resulting in condensation is illustrated in Figure 2. Degradation, then, takes place quickly, turning lightweight concrete into a pile of crumbling debris. These issues of building physics have been precisely described in by Płoński and Pogorzelski [4], and Pieniążek [5], but are not a part of *common* knowledge.

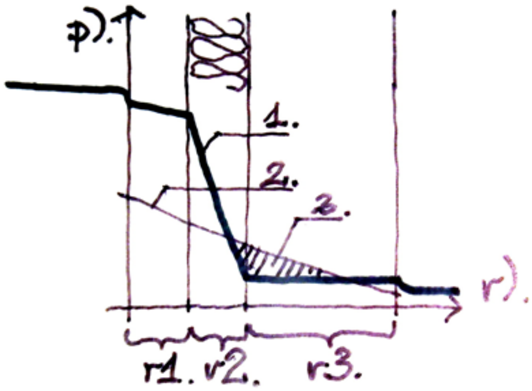

Figure 2: Flat roofs were often humid or leaking because of repeated mistakes. The diagram illustrates the process of condensation of water vapour in the roof with waterproof insulation positioned only from the outside (drawing by R. Marcinkowski, 2016). Axis markings: p) water vapour pressure; r) diffusional resistances: r1 - of the structure, r2 - of thermal insulation, r3 - of waterproof membrane. Diagrams: 1) pressure of condensation; 2) real pressure. Shaded area 3 is proportional to the amount of condensate per unit of time.

Some improvements have been made since *re-discovering* the advantages of traditional empty, ventilated roof space and the introduction of ventilated roofs. It is remarkable that the process of re-discovering the traditional technologies still continues today. Traditional carpentry appears to be a cheap and sufficient technology for thermo-modernisation works. On the other hand, the *tradition* of leaking terraces was the norm until the introduction of reversed/inverted roofs described below.

The term *tradition*, though sarcastic, is not far from the truth. Flat roofs were also defective in the buildings considered today to be the contemporary classic of architecture:

> *Villa Savoye's roof began leaking almost immediately after the Savoye family moved in. Le Corbusier only narrowly avoided a lawsuit from the family because they had to flee the country as France succumbed to the German Army in WWII* [1].

FLAT ROOFS IN TECHNICAL AND HUMANISTIC ASPECTS

Reversed or rather inverted (as translated into English by Markiewicz [3]) flat roofs become possible, thanks to the appearance of waterproof thermo-insulating materials. The thermal insulation positioned over the waterproofing insulation (and thus named the reversal to the traditional order) resulted in stopping the water vapour diffusing from inside the building before cooling. Thus, the problem of condensation and dampness has been eliminated. To be precise, it has been eliminated from the flat roofs, because it still exists; for example, in underground parts of the building (described by the author more widely elsewhere [2] or around glazing).

Flat roofs had already been created in antiquity, but in a favourable climate, without the risk of condensation of moisture and freezing and, therefore, no knowledge of building physics was needed. Problems appeared with the cultural expansion and the transfer of patterns to new environments.

If one could define architecture as shaping space according to human needs, one finds that flat roofs would make sense when having usable functions. In areas of extremely high building density, they could be used to replace the non-available terrain. The functional use of flat roofs could also increase the comfort of living as recreational and garden areas or generally, improve the contact of inhabitants with the daylight.

The need for functional adaptation of roofs is evident when one considers how popular roofs available and open to the public are to both tourists and citizens. Examples include the Herbewo Building in Kraków and the NEMO Museum in Amsterdam. (The latter is also considered to be a *contemporary classic,* but required constructional corrections because of leaking).

Today flat roofs are also used for economic reasons, but understood differently than for cost reduction. It is about maximising the intensity of building, cubature and usable areas within the given limits. Also, the technical failures that occur today are due to other reasons:

- Lack of technical knowledge results in contractors winning the auctions, but not realising the real requirements and the related difficulties.
- Even serious mistakes can bring profits, if the contractor is able to avoid material liability (which unfortunately is a frequent situation in the real estate market).

TECHNOLOGY AND COMMERCE: PROGRESS AND INFORMATIVE CHAOS

Technological progress requires the correction and evolution of the educational process. The obvious threat is the outdating of material. Teachers are often advised to incorporate every new technology proposed by numerous corporations into their teaching programmes. On the other hand, there is a risk of *overloading* students with fragmented knowledge, caused additionally by not having enough integrated teaching programmes. The problem is which (if any) corporation should one choose? The market of the Internet is overwhelmed or rather cluttered with knowledge *seemingly actual* just a few years ago.

The goals of the corporation and the university differ diametrically on one point. A corporation is not interested in the knowledge of students (enabling them to critical comparisons), but rather in replacing it with a specific product.

THE PROJECT TASK AND SAMPLES OF STUDENTS' PROJECTS

In the educationally optimised process, the flat roof project should not be a separate study, but should rather be a part of a larger, holistic project. But, attempts to integrate teaching subjects encounter a new barrier today: the assessment system - conducted separately by all institutions, which leads to competition rather than to the opportunity for cooperation. For instance, shared classes are problematic in official accounts and could result in worsening the *measurable outcomes* of the learning.

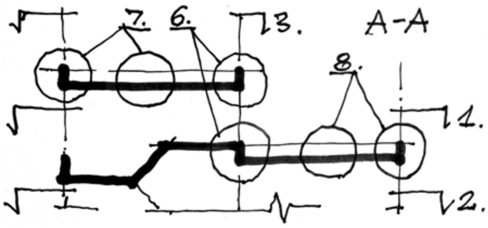

Figure 3. Illustration of project task. The sketch only roughly presents a section of a building. It intentionally does not describe precisely the technology and reduces the volume of drawings, but gives students the list of basic problems, analogical to the check-list used during assessment of projects (drawing by R. Marcinkowski, 2013).

Teaching foreign students in the Erasmus Programme gave the author a good opportunity for comparisons of the graphical representation of projects used in different countries. What is important is that the comparison concerns more the graphical representation itself than general values of solution. Direct implementations of the whole project usually do not make sense, because of:

- differences in climate and resulting in different constructional solutions in different countries;
- differences in levels of available technology;
- cultural differences, resulting in the adoption of certain technologies without clear rational premises.

The project task shown in Figure 3 in fact requires designing two types of flat roof (although on a small space):

- Ventilated roof - as an optimal combination of low cost of building and reliability in long-term use.
- Terrace roof, especially with elements of garden architecture - for functional qualities and impact on users' quality of life.

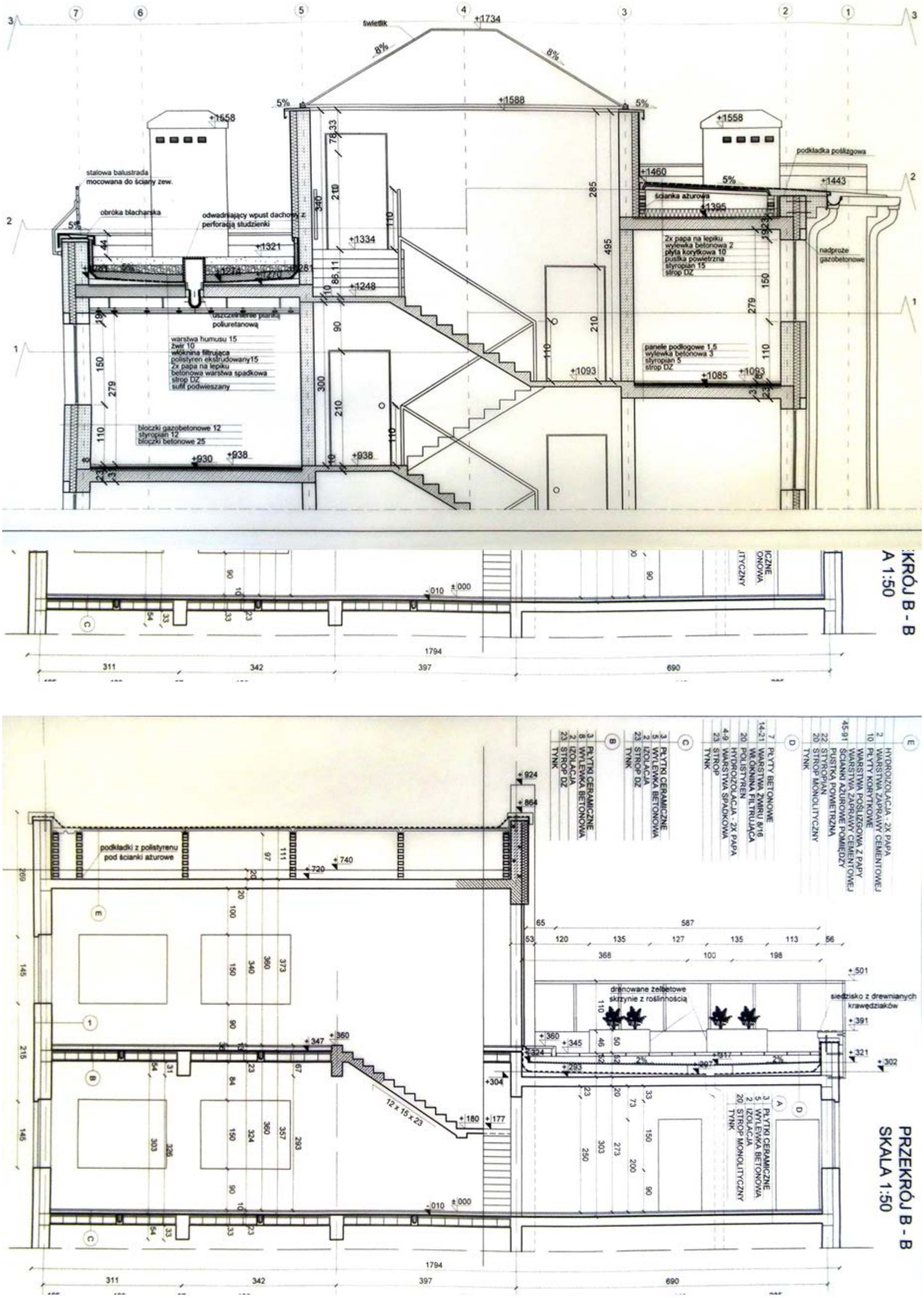

Figure 4: A sample of flat roof design. Projects made in class conducted by the author in the season 2013/2014 (photo by R. Marcinkowski, 2015).

The text part of the task has been compiled as a list of requirements:

Design a section of the building with access to the terrace, on the top floor. Recommended: inverted roof with vegetation cover and partial use of ventilated flat roof.

1. Top floor plan with exit to the terrace, 1:50. Staircase dimensions and all floor levels. Terrace arrangement. Include (as invisible edges) the mediation of the drainage slopes and inlets.
2. Construction of the floor slab below, 1:50. Include position and intersections with main installations, especially ventilation and internal drainage system.
3. Roof plan 1:50. Gradients of inclination. Top and bottom levels. Dilatations. Include (as invisible edges) a view of the ventilating space and minimal inlets of the air.
4. Sections A-A, and
5. B-B 1:50. Perpendicular to each other, including the staircase and details listed below.
6. Section with entrance to terrace 1:10. Set of details along the vertical axis, from the bottom ceiling to the upper roof.
7. Other details of the ventilated roof 1:10.
8. Other details of the terrace 1:10. External edges. Drainage of terrace and green parts of the roof.
9. Heat-humidity calculations. Graphs of temperature and partial pressure of water vapour according to technical norms and lectures on building physics.

On all drawings required: numbered axes, structural and finishing levels, highest and lowest points of drainage slopes, construction of horizontal and vertical partitions with layer thicknesses, complete horizontal and vertical dimensions.

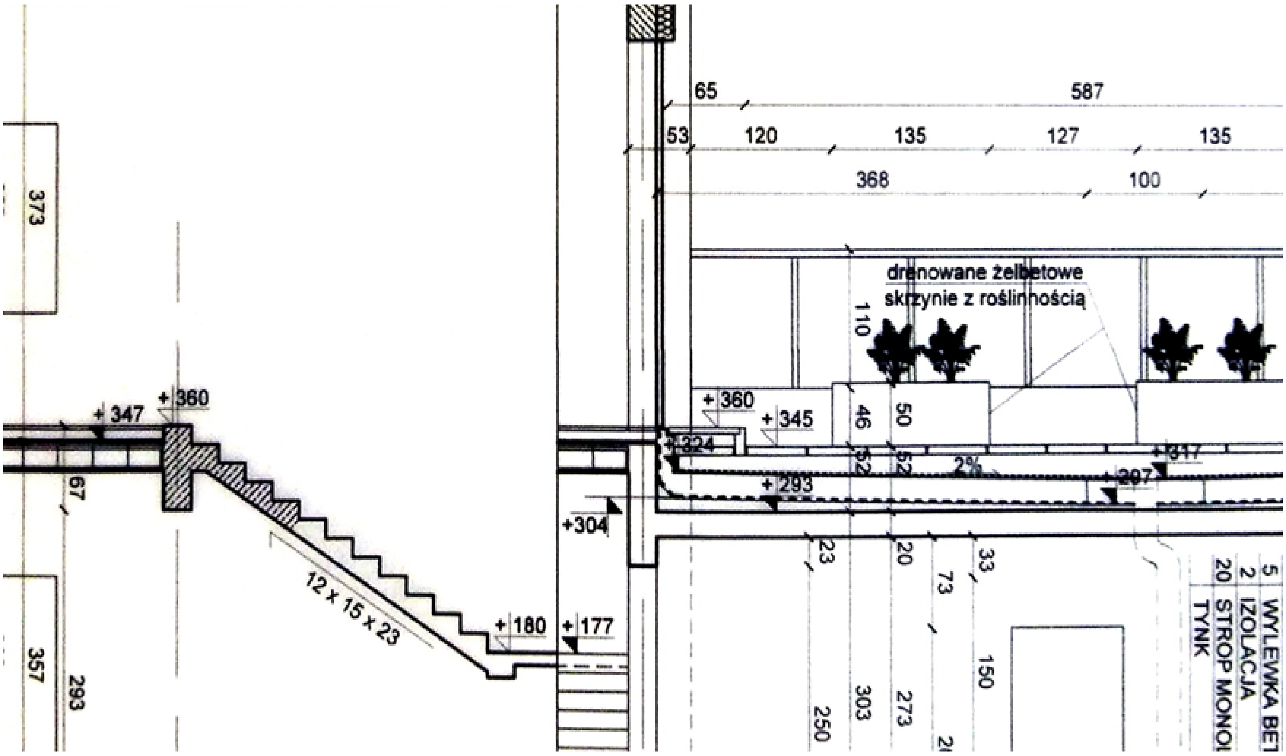

Figure 5: Sample of flat roof design, detail. Project made in class conducted by the author in the season 2013/2014. The drawing includes a student's (accidental) mistake in dimensions in the staircase (photo by R. Marcinkowski, 2015).

The goal of a professional drawing is to achieve data compression, while maintaining readability. Basic antinomies concerning graphical aspects can be briefly described as follows: simplified drawings on a small scale are not accurate enough to include all the information needed. Thus, the schematic section of a building needs many details to show complex information. On the other hand, the details that seem apparently correct on separate drawings, do not necessarily match each other. What is more, splitting a drawing into multiple sheets makes it difficult to detect errors. The typical errors in students' work are:

- Sections and floor plans not matching one another in terms of shape or dimensions.
- Lack of continuity of insulation, especially thermal bridges and points of leaks.
- Situating waterproof membranes over thermal insulation in non-ventilated roofs.
- Structural elements (pillars, beams) not matching one another or not continued in the floor below.
- *Jumping positions* of elements (windows, gutters, insulations, etc) on different drawings.
- Missing layers and/or dimensions defining proper inclinations of drainage.
- Triangle surfaces of roof cover (shown on the plan) made of rectangular prefabs (shown on detail).
- Details copied from different sources, generally not matching the project.

Requirements and basic criteria of assessment in flat roof design are:

- Proper relations of levels. Thickness of terrace/flat roof in relation to structural elements of floor slab, especially different for terraces, normal floors and staircases.
- Precisely defined inclinations of drainage. Structural and finished benchmarks/comparator levels (black and white arrows on the drawing).
- Continuity of thermal insulation. Reduction of thermal bridges.
- Clear and visible waterproofing. Elimination of the typical weak point: connection of insulations to the balcony/entrance door.
- Drainage or protection of doors from snow or rainwater.
- Elements of functional (garden, recreational) arrangement.
- Data compression while preserving readability of the drawing.

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BIOGRAPHY

Robert A. Marcinkowski graduated a Master of Science and Doctor of Science in 1983 and 1996, respectively, at the Faculty of Architecture, Cracow University of Technology, Kraków, Poland. From 2002, he has also been a member of the Polish Writers' Association. His multi-disciplinary talents situate him in the worlds of science, art and culture. In addition to architectural design and teaching at the Faculty of Architecture, he deals with works in the fields of graphic design, visual arts, photography, music and poetry. He was commended at the Biennale of Architecture for a combination of poetic qualities in relation to architecture. In his pedagogical experience, he conducted lectures at different levels, from colleges to postgraduate studies. As an academic teacher, he has led classes and lectures of technical science, mostly in constructions, at the Faculty of Architecture and the Faculty of Civil Engineering. Since 2004, he has led classes in Building Construction Systems and Building Surveying within the Erasmus Programme. As a scientist, he has published articles representing a wide spectrum of knowledge, from typically technical, like traditional timber housing or solar energy in low-budget technologies, to humanistic, including ecological and sociological aspects of life. He has also lectured and published at the Faculty of Philosophy of Jagiellonian University in Kraków, Poland. As an architect, he has realised over one hundred buildings (at least to the state of finished construction) and many small-scale projects of interiors, gardens or partial renovations. He also creates theoretical and studio-based architectural projects not connected directly with the conducted classes. As a musician (guitar), he has recorded a CD album (2004) with his team, and takes part in several artistic events yearly (recently organised by the Cracow Council). As a writer, he has published individual books of poems, and has been included in collected works of poetic and prosaic creations. As a photographer, he has had individual art exhibitions (recently at the NCK Cultural Centre). He creates almost all the illustrative material for his scientific works himself.