World Transactions on Engineering and Technology Education
Vol.16, No.1, 2018

Experience in technical education: the organisation of practical construction training for students in a faculty of architecture

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ABSTRACT: Technical education should make future engineers or architects aware of the consequences resulting from material solutions taken up during the conceptual design stage. Practical skills are acquired from birth and throughout the entire period of education, but contact with actual, practical knowledge only occurs through physical participation in a creative process. Architectural studies, with its broad curriculum as a subject stimulates imagination and broadens general and specific professional knowledge. Sculpture, freehand drawing and building structures stimulate imagination, while building construction and installations point to technological needs. Urban planning places the visions within urban space. Therefore, an aim of this article is to show that proper preparation of a technical design without contact with the actual construction of a project is most difficult or even impossible. The education of architects requires a number of stages and these are outlined. Finally, it is crucial to avoid the dangers arising from the inability to detect significant problems, otherwise they could be too numerous for a project to be completed successfully.

INTRODUCTION

Unauthorised persons including students are excluded from construction sites. Universities are thus left to develop a curriculum dealing with architecture and construction that is a replacement for reality. Modern digital techniques allow the development of a virtual reality simulation of a construction site in the lecture hall using films and presentations. Such a simulation can depict various design solutions during the conceptual design stage and to explore significant construction technology issues during the development process.

The rich and varied construction materials marketplace allows structures to be freely shaped during the design stage. However, the adoption of a specific technology dictates the constituent parts of a construction project in terms of their dimensions.

Just how much a knowledge - both theoretical and practical - matters to a future architect is indicated by George Nelson, who opined *You don't think your way to creative work. You work your way to creative thinking.* George Nelson (1908-1986) was an American industrial designer and one of the founders of American modernism.

THE PROPER SELECTION OF MATERIALS DURING THE DESIGN STAGE

Difficulties that complicate a development project have two main causes. The first is a lack of experience of the designer, who puts the form of a structure before the construction techniques, i.e. without considering the materials to be used in the construction. The second is a lack of consultation during the construction. Of course, there is available a broad base of equivalent technologies, as well as construction materials. These can be used to construct the smallest structures, such as walls, all the way up to industrial scale structures providing unlimited freedom in terms of spatial shaping with perhaps considerably shortened completion time; an example is the monolithic technology using a sliding formwork (Figure 1).

A technology immune to the effects of the errors or negligence of construction workers has not yet been developed. Errors are, unfortunately, often the result of excessively vague information contained in design documentation. This leads contractors to develop their own solutions to eliminate the vagueness, which usually do not require large expenditure or manpower. This generates faults or solutions that do not meet the standards initially set for the project.

The location of window and door openings, the distance between the openings and the corners of a structure should be specified for each partition. Mistakes are most often made when determining the height of a storey, i.e. if the base height of an element is not properly taken into account, it will be necessary to round up the height of the wall to the level of the planned tie-beam, which is the height of the floor slab.

a) b)

Figure 1: The scale of construction technologies (photographed by the author); a) a proper floor plan layout from indivisible elements in the walls of a building. However, a mistake has been made when defining the storey height; b) sliding formwork technology used in constructing concrete silos.

Regardless of dimensioning matters, adhering to technological requirements for joining each element is also a significant issue. Currently, structures are intended to have a near-zero need for energy. Even the smallest thermal bridge or a lack of air-tightness between the materials that constitute a building's envelope can seriously degrade the environmentally friendly nature of the building. Small gaps are usually filled in with cement, which is not permissible by both manufacturers and appropriate professional standards (Figure 2).

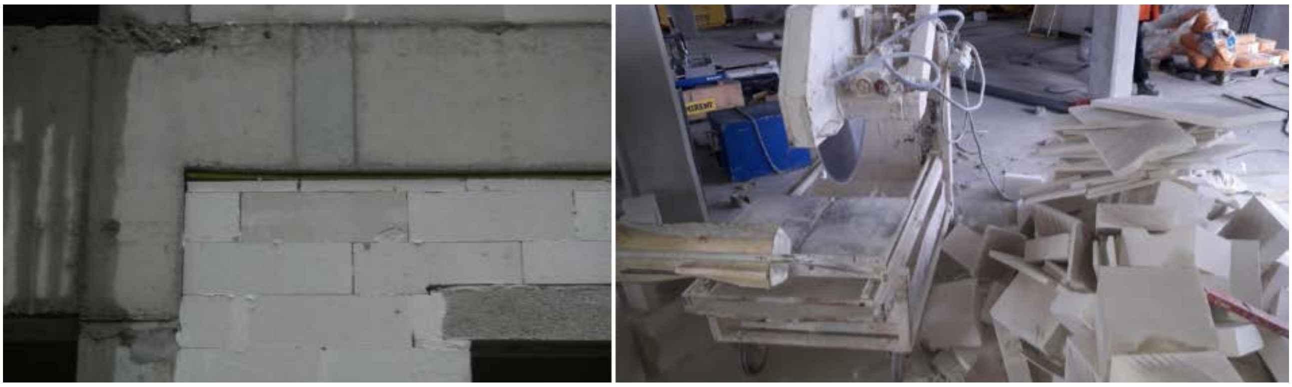
a) b)

Figure 2: Technological errors in building walls (photographed by the author); a) filling in a wall made of ceramic masonry units with cement, an unacceptable technological error; b) a fragment of a wall constructed using an unidentified technology: from bricks, YTONG masonry blocks, concrete and other construction materials, without basic knowledge regarding wall construction [1].

CONSEQUENCES OF SWITCHING TECHNOLOGIES DURING CONSTRUCTION

The consequences of a lack of necessary design information has been discussed above. But, what difficulties can arise when a material or technology is changed during construction? Some small masonry wall material can be resized at the construction site by cutting, without affecting the quality and thermal or structural precision of the entire partition.

Porous concrete masonry blocks can even be manually cut, preserving most of the required technical parameters. However, it should be noted that any additional processing generates considerable construction costs and extends the completion time of tasks.



a) b)

Figure 3: Fragment of a wall built out of YTONG masonry blocks (photographed by the author); a) cutting a *slice* of a block beneath a beam; b) YTONG masonry block waste, an error in material selection during the design stage.

Not matching the dimensions of windows, pillars and the distances of openings to corners both concave and convex generates a considerable amount of waste (Figure 3). In turn, failure to adapt the storey height to the multiplicity of materials requires additional work and the introduction of technical joints to make a specific construction node air-tight (Figure 3). All work of this type is the result of a lack of appropriate decisions during the design stage.

EFFECTS

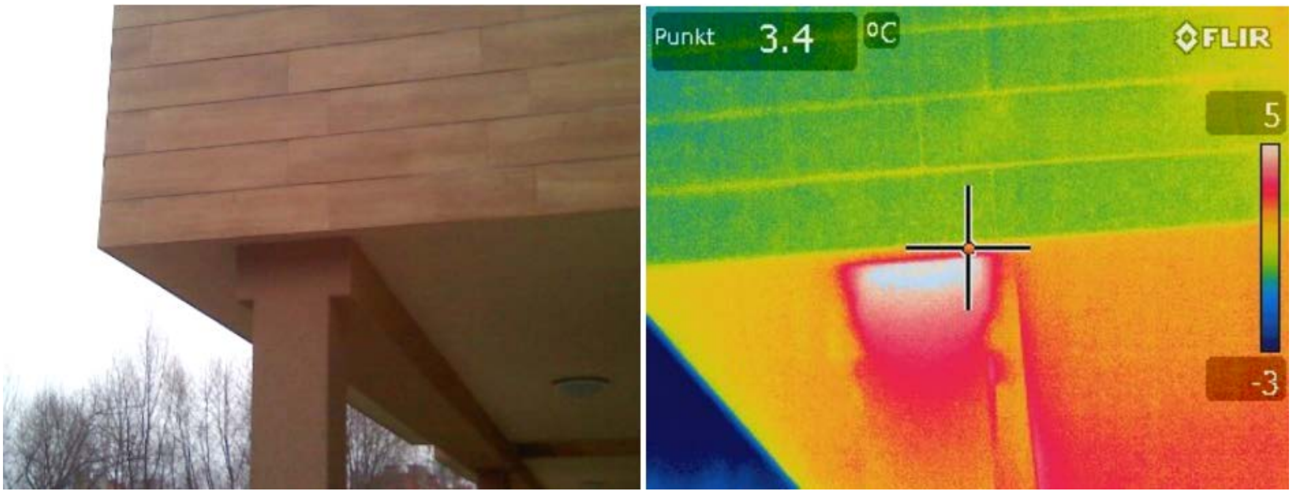
There are numerous elements of approved technical documentation that must be adhered to, to obtain a building permit and, thus, begin a development. Polish construction law defines that non-adherence to approved technical documentation can be significant or insignificant. Regardless, a worsening of the properties of materials or specific zones of a project that were specified in the design cannot be allowed.

When technological changes are made without consultation, there is a danger of creating a thermal bridge as a result of using cheaper materials with lowered thermal insulation parameters (i.e. a higher λ coefficient) for a specific external partition. The lack of a definition of a construction detail can lead to the emergence of a zone of water vapour condensation that is dangerous to the structure, making it possible for a partition to freeze (see Figures 4 and 5 below).

Another danger in construction can be the expiration of certificates and instructions that approve a specific material for use. Unfortunately, ignoring design guidelines to make savings or to alter the appearance of a structure is common. It is preferable to observe that, *it is better to prevent than to cure*, and adhere to this principle on the construction site. Changes that have not been confirmed by the designer and *theoretical* savings can lead to a situation where, in the end, the budget of a project is exceeded. It is generally believed that correcting an error or the effect of negligence costs three times as much as performing the work correctly and in accordance with a design the first time. As architect Frank Gehry pointed out, *I don't know why people hire architects and then tell them what to do*.

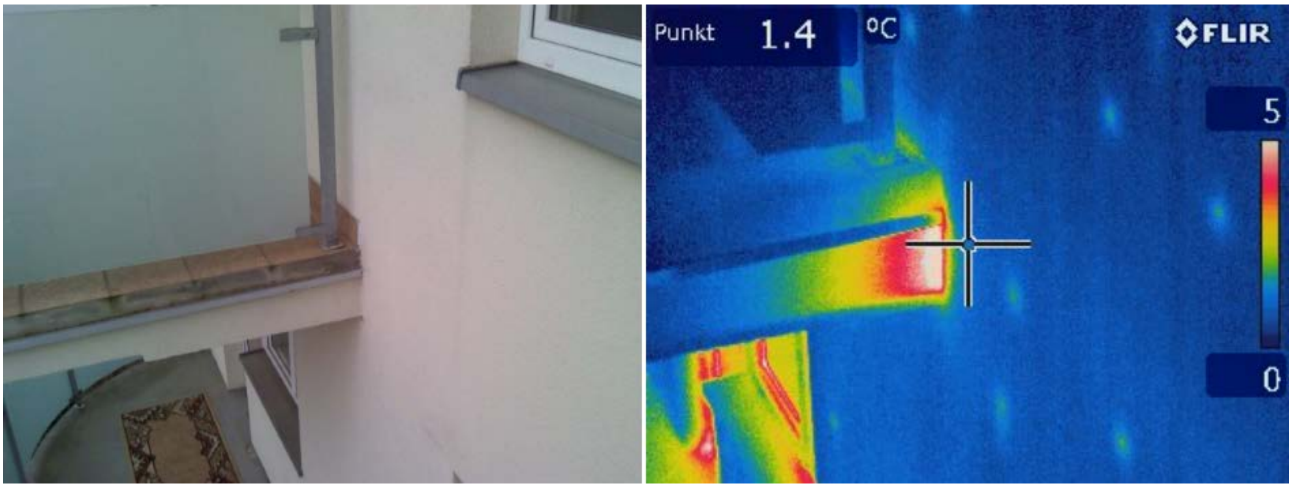
Frank Owen Gehry, born Ephraim Goldberg (28 February1929 in Toronto), was an American architect and industrial designer from a Canadian Polish-Jewish family and one of the main representatives of deconstructivism. He was awarded the Pritzker Architecture Prize in 1989. In 1947 Gehry came to California, where he studied architecture at the University of Southern California, Los Angeles, and then, urban design at Harvard University. Gehry has had his own architectural practice in Los Angeles since 1962. Gehry's buildings have the character of a collage of bent forms with a surface made out of various materials, which do not fit well together in traditional architecture (titanium, concrete, stone, plaster, wire mesh, etc). Gehry also surprises with unconventional colour palettes. His architecture is chiefly orientated towards an external effect, deliberately shocking through contrast with traditional urban space. Slanted walls and waved surfaces are distinct of, and easily associated with, this architect. Gehry's critics point to a meagreness of his interior designs and a banality of functional layouts. He is often accused of being limited to the same repertoire of affected forms.

Introducing changes during the design stage results from the developer and is often caused by a lack of imagination. Oftentimes, it is only a model, physical or virtual, that shows the actual solution to the developer. Unfortunately, they are most often different from what was expected. Another challenge for an architect is the so-called *friends*, who criticise solutions that are better than the ones employed in their own built projects. This is simply gratuitous jealousy, but one that does create doubts. Most problems are encountered on the construction site. Often, acting on the suggestions of contractors, the developer makes changes, justifying them using the argument that …*he who pays the piper calls the tune*. The importance of achieving savings, shortening completion time and making construction easier is usually not made clear. A designer's knowledge and practical experience is not without significance in such a situation, as it provides him or her with the necessary technical and legal arguments.



a) b)

Figure 4: Non-adherence to the principle of insulation continuity in the ground floor area (photographed by the author); a) photograph in the visible spectrum; b) photograph in the infrared spectrum.



a) b)

Figure 5: Non-adherence to the principle of insulation continuity in the area of the balcony floor slab (photographed by the author); a) photograph in the visible spectrum; b) photograph in the infrared spectrum.

CONCLUSIONS

Technical education should make a future engineer or a future architect aware of the consequences arising from material solutions adopted during the conceptual design stage [2]. Approving and handing over a building for occupancy verifies the basic information about the building in terms of height, footprint, as well as the layout of the elements that shape the facades of the building. All matters of non-adherence require the preparation of a replacement design, which means that the initial technical design is invalidated.

Thus, the principle of educating architects should proceed through a number of stages:

1. The initial practical stage: this includes the ability to transform thoughts into graphics and technical drawings. Depending on the stage of a design, this requires familiarity with both construction and machine drawings, as well as determining the details of interior decorations and fittings. The very smallest element of an implementation is important. As Frank Lloyd Wright pointed out, *the space within becomes the reality of the building*. Frank Lloyd Wright (1867-1959) was an American architect, drawing inspiration for his work from nature and using natural materials [3].

2. The initial theoretical stage: this requires a broad understanding of material science (see Figure 6). The construction techniques of the past often appear to be irreplaceable, especially, when work is being performed on historical structures. Regardless, it is necessary to be up-to-date with the latest construction technology. A vision cannot be fully implemented until it is known what can be practically created [4].

3. The advanced practical stage: this is the actual physical participation in the construction of a building, directly on the construction site. Only when *boots are in the mud* do the significant differences between the flawless drawings on an office desk and a construction worker's perception of the building become clear. Without understanding the documentation, the construction worker might destroy the design by, for instance, poorly assembling the waterproofing of the cellar.

4. The advanced theoretical stage: this involves a return to the computer, but this time with an awareness that every line drawn in the design is an actual element of a building, which must be understood and correctly built, in addition to being *compliant with current regulations, principles of technical knowledge and the art of construction* [5].

   This is a fragment of the designer's statement that must be attached to every technical design, viz. *I hereby, after becoming familiarised with the provisions of the Construction Law Act of the 7th of July 1993 (Dz. U. of 2003, iss. 207, pos. 2016 with later amendments), in accordance with art. 20 section 4 pt. 2 of said Act, declare that the technical design for the development project in question has been prepared in accordance with current regulations, the principles of technical knowledge and the art of construction, as well as that the design documentation is complete from the point of view of the aim for which it is to be used. Aware of criminal responsibility for providing a false statement, in accordance with art. 233 of the Penal Code, I confirm with my handwritten signature the truthfulness of this statement* [5].

5. The self-learning stage: this involves combining theory with practice. The dynamic development of construction technologies forces designers to constantly self-develop to keep up-to-date on new materials and construction techniques. Without such knowledge the designer will become uncompetitive in the development marketplace.

a) b)

Figure 6: Significant technological errors (photographed by the author); a) inappropriate selection of materials for the walls of the underground section - fly ash concrete masonry blocks [6]; b) monolithic reinforced concrete wall - mistakes in formwork assembly.

A sad conclusion comes as a summary - even the best vision of an architect can become drowned in a sea of all manner of incompetence. However, as shown in this article, the education of an architect is subject to several specific and well-defined stages. It is most important to be aware that not detecting significant issues could prove disastrous to any project.

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