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THE DIDACTICS OF CONSTRUCTION TECHNICAL DRAWING IN THE AGE OF CAD AND BIM TECHNOLOGIES

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Abstract. The article deals with the problem of the principles of graphic notation in the broadly understood construction drawing, in the context of their teaching in the beginning of first-cycle studies. A review of recommended textbooks and current standards, in confrontation with the software used in design practice, allows to state that textbooks and standards are embedded in the realities of drafting techniques used in the times preceding the development of digitization, while IT tools operate with procedures and marks abstracted from the content of these elaborations. The author identified several of the most significant discrepancies, indicating ways to eliminate them. The problems listed in the article concern, among others modular coordination in design, systems for marking rooms and building parts, defining cross-sections and standardized graphic marks.

Keywords: technical drawing, standardization, CAD, BIM

1 Introduction

The review of didactic materials for teaching construction technical drawing, which are available on the Internet and on the book market [1, 2, 4, 5], as well as of some current Polish Standards in this field [11], shows significant discrepancies between content of them and the properties of software used today in design practice. Standards, and especially textbooks, are embedded in the realities of drafting techniques used in the times preceding the development of digitization and IT tools operate based on procedures and markings distracted from the content of these elaborations. Teaching the basics of technical drawing carried out in the initial period of study based on the above teaching aids loses its sense if in the course of further learning the student is presented with tools that require a significantly different way of working and based on other graphic conventions.

The spread of computer-aided design has changed the nature of the designer's work. On the one hand, CAD programs made his work easier, on the other, the combination of previously separate drafting activities into automated and standardized procedures limited the designer's freedom to choose the form of graphic notation, making him dependent on the will of the software creator. It should be noted that the available software is produced primarily in the USA, which means that it considers the American drawing tradition and the provisions of American standards, other than the ISO standards that are commonly respected in European countries. The change resulting from the implementation of BIM technology is more extensive. The designer writes ideas taken in his mind not directly in the form of drawings, but in the form of a spatial structure composed of virtual equivalents of real building components, and the drawings are obtained automatically as a result of the use of appropriate operations built-in the program.

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2 Respect for the tradition and the use of CAD and BIM technologies

The main difference between the methods of marking building elements and structures in the pre-digital time and at present boils down to the fact that previously a unified 2D mark was assigned to a building element (window, door, bathtub, sink, etc.) and it didn't relate to a particular type of element or device, while in BIM technology, not only a 3D model of equipment element is implemented in the virtual building, but it is usually specific in terms of type, manufacturer, etc. The forms of traditional markings, reproduced to this day in standards and textbooks, were simple, which resulted from the need for independent manual drawing of each occurrence of the mark. The shapes of BIM-compliant models accurately match the shapes of their real counterparts. Relative simplification of graphical representations is obtained by using reducing scales and by choosing a specific level of detailing (low, medium, high) [30]. While learning the basics of technical drawing, students should be made aware of the above circumstances and taught how to present the BIM model so that the form of the generated drawing is as close as possible to the sanctioned tradition.

Further discrepancies between the recommendations of standards and manuals and the properties of commonly used software are derivative of its American origin. Apart from the fact that some of the procedures are inconsistent in terms of the graphic notation being created (e.g. generation in AutoCAD of sectional views in model space and in a layout), the effects of most procedures are clearly subordinated to American standards and traditions [9]. Typical examples are the markings of sections and levels in models and drawings created using Revit software. Figure 1 shows the markings of sectional views, in accordance with the standards [11, 17, 21] (Fig. 1a) and obtained using the Revit program (Fig. 1b), as well as the levels markings, according to the standard [11] (Fig. 1c) and Revit (Fig. 1d). The use of commercial software does not exclude the possibility of carrying out drawings in line with European tradition. Revit has a tool called *Family Editor* that allows to create the own designations, including listed above. Markings created once can be saved in the project template, which could be used later repeatedly.

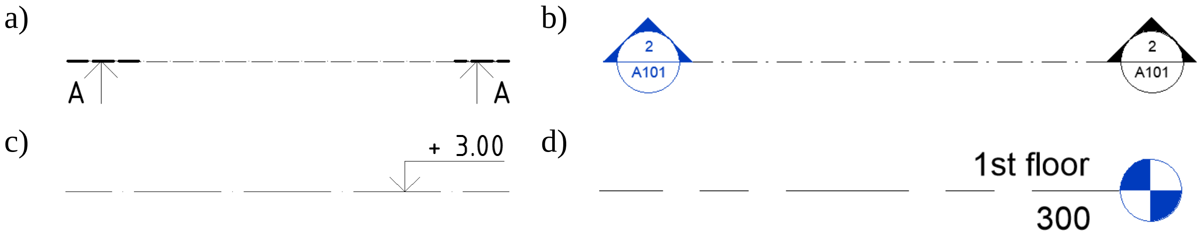

Figure1: The examples of non-compliance of Revit markings with the technical drawing standards: marking of cutting plane according to standards (a) and Revit (b), designation of level according to standards (c) and Revit (d)

3 Strengthening the emphasis on the principles of representing the spatial structure of complex buildings

Teaching the basics of construction drawing is usually supported by examples of fairly simple buildings, usually single-family residential buildings, and in the scope of structural drawing, the emphasis is placed on the working drawings of individual structural elements [1, 2, 5, 6]. According to the author, a teaching subject, such as geometry and engineering graphics or related one, should develop skills in the comprehensive shaping of the space of a building, orientation in it and its description in accordance with the legal regulations and the requirements of most commonly used computer programs.

3.1 Modular coordination

Today, the design of each building is implemented based on a reference system composed of perpendicular planes forming a three-dimensional spatial grid. Projections of these planes on horizontal and vertical viewports define the systems of perpendicular straight lines usually called axes. It is recommended that the distances between the planes forming the spatial grid take into account the values of the basic module and multi-modules [18, 19] and their preferred multiples for vertical [26] and horizontal [27] dimensions. Dimensional coordination based on respecting these values is called modular coordination, and its goal is to provide the ability to erect objects from standardized components without restricting design freedom [23].

Rational design in BIM technology involves the prior establishment of a modular spatial grid, and then determining the location of individual building components in relation to the elements of this grid. The use of the grid not only imposes a different methodology for situating the space of building components, but also has consequences for the way the drawings are dimensioned and the values of the drawing dimensions, as well as for the way of defining the ranges of spaces whose content is presented on individual floor plans or sectional views of the building. Therefore, in the content of teaching the basics of building drawings, the dimensional grid should not be presented as a not significant addition to the drawings, but as a matrix of the spatial structure of the building. Emphasis should be placed on respecting numerical limits regarding the dimensions of individual components and their arrangement relative to each other, which are specified in detailed standards on modular coordination in construction [18, 19, 20, 22, 23, 24, 25, 26, 27, 28].

3.2 Designation systems

Another issue related to orienting the space of a building object is the system for marking buildings, their parts and rooms. This matter is usually treated marginally in textbooks available on the market, although the norms [13, 14, 15] regarding designation systems are one of the few whose use is compulsory in accordance with applicable Polish law [8]. The importance of knowing and respecting designation systems is important because, in accordance with BIM's ideological assumptions, the designations introduced in the design should be retained throughout the lifetime of the building.

4 Redefinition of the sectional view

Two notions of projections defining the internal structure of the object operate in general circulation: section and sectional view. The section shows the outline of the object contained in the so called cutting plane. A sectional view is a projection on a viewport parallel to the cutting plane of the part of the object contained in this plane and located behind it [1, 2, 3, 4, 5, 6, 7, 10]. The terminology is inconclusive, not only because of the distinctness of individual languages, but also traditionally sanctioned differences between the nomenclature used in the machinery and construction branches. Even the standard [17] containing definitions of both terms draws attention to this issue.

The concept of sectional view defined as above corresponds strictly only to the requirements set out for the machine drawing, and in the construction drawing at most with reference to the drawings of individual elements of structures and buildings. Presentation of the spatial structure of entire building or structural system often requires projecting only a certain band of space behind the cutting plane, limited by an additional plane parallel to the cutting plane. This plane will be called the *back clipping plane* (Fig 2a). The postulate of optional limitation of the projected space with the back clipping plane is included in procedures of AutoCAD [29] and Revit [30].

In some situations, the need for clear explanation of the structure of the entire building or a significant part of it creates the need to project also selected elements located in front of the cutting plane or located behind the back clipping plane. Elements located in front of the cutting plane are, for example, suspended ceilings, noted by both the standard [11] and [12], or beams of heights exceeding the height of the cooperating ceiling, referred to in the standard [11]. For the second hand, the objects linked with the one being the subject of the design shown in the drawing, may require the representation as the elements located behind the back clipping plane (Fig. 2a,b,c). As a result, the universal definition of a sectional view requires the introduction of four parallel planes, including in addition to the cutting plane and the back clipping plane also the front clipping plane and distant clipping plane (Fig. 2a). In a situation where all these planes are horizontal, the front clipping plane is named *top clipping plane and the back clipping plane - bottom clipping plane* [30].

Elements located in the bands of space bounded by particular pairs of planes should be marked in different ways. Based on the standard [16], it is assumed that the elements contained in the band between the front clipping plane and the cutting plane are marked with a thick two-point line (line 05.2 according to Table 1 in [16]), and included in the band between the back clipping plane and the distant clipping plane - thin dot line (line 07.1 according to table 1 in [16]). The outline of the object contained in the cutting plane and the elements contained between this plane and the back clipping plane should be marked in accordance with the standard [12]. This standard leaves the freedom to mark the section stroke with a continuous wide or extra wide line, recommending that the line be thicker than the lines used to represent the elements in the view. Thus, the current tradition is sanctioned.

a)

b)

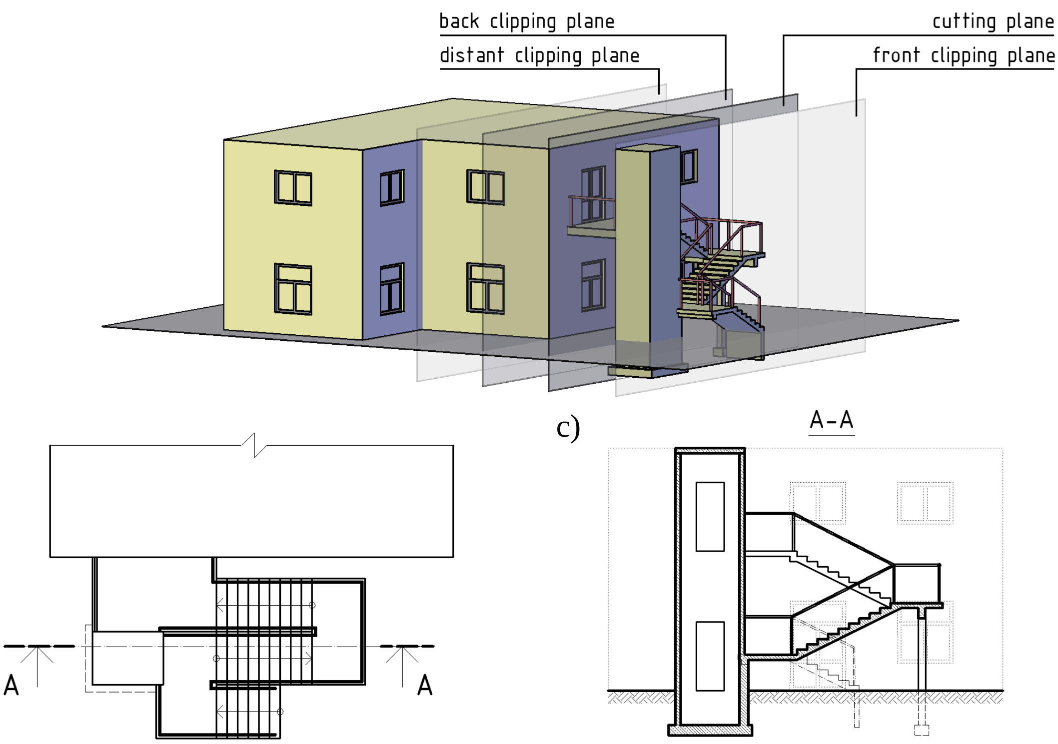

Figure 2. The explanation of redefined concept of sectional view: a) the planes defining the bands of space being the subject of projection in the sectional view, b) position of the cutting plane, c) differentiation of the content of the sectional view by the use of different the drawing lines

5 Conclusion

One of the roles of teaching the basics of technical drawing, usually carried out in the first year of study, is to initiate the formation of engineering competences of students, especially those who are graduates of general education. Responsible teaching of technical drawing plays a big role in forming the so-called *the engineer's ethos*, whose important values should be, among others, rationality of the presented technical solutions, unambiguity and precision of expression, as well as aesthetic sensitivity and care for spatial order. The teaching methodology from the pre-digital era perfectly fulfilled these goals, which is why it is so difficult to part with it. However, if the study plans do not have time to fully interpret the dual approach to creating drawing documentation, firstly, students must not be torn apart by presenting contradictory ways and forms of graphic notation, and secondly, the focus should be on the presentation of contemporary methodology, not on historical perspective.

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DYDAKTYKA RYSUNKU TECHNICZNEGO BUDOWLANEGO W DOBIE TECHNOLOGII CAD I BIM

Artykuł podejmuje problem zasad zapisu graficznego w szeroko rozumianym rysunku budowlanym, w kontekście ich nauczania na początkowych semestrach studiów pierwszego stopnia. Ogląd zalecanych podręczników oraz obowiązujących norm, w konfrontacji z oprogramowaniem stosowanym w praktyce projektowej pozwala konstatować, że podręczniki oraz normy są osadzone w realiach technik kreślarskich stosowanych w czasach sprzed rozwoju cyfryzacji, zaś narzędzia informatyczne operują procedurami oraz oznaczeniami wyabstrahowanymi z treści zawartych w wymienionych opracowaniach. Autor wyodrębnił kilka znaczących rozbieżności, wskazując sposoby ich eliminacji. Wymienione problemy dotyczą m.in. koordynacji modularnej w projektowaniu, systemów oznaczania pomieszczeń i części budynków, definiowania przekroju oraz standaryzowanych oznaczeń graficznych.