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Computer-aided design in the construction industry – BIM technology as a modern design tool

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Abstract: The development of the computer industry has largely contributed to significant progress in design. For several decades, computers have supported designers worldwide. The current computer-aided design systems are a basic tool in any engineering project, from calculations through to complex graphic design. There are many computer-aided programmes designed for the construction industry on the market. So far, the most popular has been CAD i.e. Computer Aided Design, which has supported construction industry designers for years. However, the market in Poland and worldwide is currently being revolutionised by BIM technology. This tool is already shaping the future of construction. The technology not only works well in designing and implementing investments, but thanks to the virtual mapping of an object it also results in efficient management and maintenance. The paper presents the features of CAD and BIM technologies and their influence on modern design-using computer techniques.

Keywords: CAD (Computer Aided Design), 3D building mode, inter-departmental project, collision survey

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Introduction

New and increasingly advanced information technology has had and continues to have a serious impact on many elements of our lives. They have penetrated almost every area of the modern world. They have also proved effective in construction and architectural design.

Design has changed a lot over the last few decades. Fewer and fewer people remember tracing paper, technical pens, photosensitive paper, and challenges connected with handwritten construction documentation. For centuries, architects drew

designs on paper. Designing required the skill of precise, even perfect handling of a pencil, pen or technical pen, as well as great patience when making changes or corrections. Manual preparation of a design was always associated with the great risk of errors.

1. Technology-aided design

The first computer-aided design systems offered an unprecedented convenience to architects. CAD software (Computer Aided Design) became commonplace in the 1990s. It played and still plays the same role as a drawing board and a technical pen did in the past (Stanisławski, 2009).

In the following years, CAD technology moved towards group work and the exchange of drawings. Additionally, thanks to new graphic engines, tools for 3D design are beginning to appear on the market.

Basic CAD systems mostly use geometric data based on the processing of points, straight and curved lines, which can be grouped into blocks, layers or tables. Functions are available supporting dimensioning, precision drawing, scaling of a drawing view, creating objects and hatching. Objects are drawn in the computer exactly the same way as they were drawn on sheets of paper, except that there is no limitation in terms of the plane and everything can be drawn on a 1:1 scale (Montusiewicz, 2011; Pawłowicz, 2016).

As perfect as it is, a CAD drawing is not free from potential errors. Both the old-style tracing paper drawings and computer drawings are based on lines and planes. Although they represent a designed building, it still remains only a collection of single lines in the form and shape of the designed object. A design created on a single plane causes collisions in the drawing, which in most cases are discovered only at the construction stage. Errors in the documentation which require necessary intervention during construction constitutes an additional investment cost and extends the time of completion of a project. CAD still caused problems with recording changes and corrections that occur in almost every design. Drawings created as part of a design are not compatible with each other, and even in the case of minor changes, can pose many problems to designers. Moving a structural wall a few centimetres further requires many hours of correcting a large part of a design. In addition, many elements of a drawing get scattered.

A solution to these problems that CAD fails to provide is BIM (Building Information Modelling) technology. Building Information Modelling is a system resulting from improvements in the CAD programs but created from scratch as a new tool according to new rules (Szruba, 2018). There is a huge qualitative difference between CAD and BIM, which makes exchange of full information between them impossible. For example, it is not possible to fully load information from a BIM model into a CAD system (Tomana 2015; Pawłowicz & Nakielska 2018).

The classic process of creating a design and implementing it requires a huge number of single, unrelated drawings and descriptions that make up construction

documentation. BIM, on the other hand, is a digital representation of the characteristics of a building together with the physical features of the materials used, providing an improved form of construction documentation and an entire construction process (Nalepka, 2017).

In a BIM system, the designer does not use geometric data such as lines, points, and planes, but virtual elements that reflect the actual building components. Building Information Modelling designing allows an investment to be realised within the required deadline, and in many cases accelerates the completion of a project due to the elimination of errors and collisions at the design stage. This makes building an object based on BIM much cheaper than in the case of a project based on 2D CAD documentation (Tomana, 2015).

Another advantage of a BIM system is a significant improvement in the cooperation between all participants of the construction process by being able to work on a three-dimensional, multi-plane and multi-disciplinary model of the investment. This gives investors the opportunity to personalize the interior layout, adjust the final effect to the requirements, and maintain a compromise between the planned effect and the requirements. BIM technology automates the preparation of documentation, which also significantly reduces the amount of work associated with the introduction of changes during design. Even the smallest change is automatically reflected in the final image of the model, along with an update of lists, costs and estimated consumption of construction materials (Sticker, 2017).

If, on the other hand, there is a need to create traditional documentation during a BIM design process, it is obtained automatically on the basis of the current data contained in the designed model. Each part of the documentation generated in this way from a virtual model is consistent with all the other elements of a design. The section is generated automatically in any place of the model chosen by a designer, without the need for additional drawing. The creation of a digital object before actual construction also gives the possibility of a precise analysis to detect and solve emerging collisions and technical problems that may occur at a construction site. A detected collision site is signalled by the program, and information about it is sent, along with a close-up of the collision site, to the relevant discipline designers. Working on an "Internet cloud" model gives individual participants of the design phase the possibility of updating information and changes without having to send emails. Access to a view or edition of the database of the modelled object is regulated by granting appropriate rights to persons participating in the implementation of an object (Adamus, 2012). Therefore, the BIM model makes the work of interdisciplinary teams much easier. Each participant of the investment process can obtain information about a building on an ongoing basis from the updated BIM database. Its advantages can be recognized not only at the stage of design and construction of a building, but also at the later stages of its life. A well-developed model, on which information and changes are applied in real time, enables more effective use, management and administration of a building (Kasznia et al. 2017).

As mentioned earlier, BIM technology enables early detection of design errors by testing and verifying digital building models in terms of functional and energy efficiency, compliance with norms, standards and investment process requirements. Improved tools for creating and modifying 2D views enable automatic generation of drawing documentation from the created building model. The documentation obtained in this way is coordinated and consistent with the tested building model, and the automation of the documentation generation process significantly reduces the time of preparing additional drawings and allows focus on design instead. Building elements such as stairs, balustrades and structural partitions can be modelled more easily and quickly according to their real complexity. Information management tools enable the linking of characteristic parameters to the elements of a building and transferring them to the other stages of the BIM process (Pierzchalski, 2019).

2. Characteristics of CAD and BIM technology

Today, no one considers returning to pen-and-tracking-paper design. This way of preparing documentation is gone forever. Computer-aided design, CAD, is already present in every architectural studio and without it nobody can imagine creating design documentation today. It was easy to move from a tracing paper drawing to a computer drawing using the same tools as a line, point, plane. Unfortunately, the design and manufacturing industry working on CAD systems has for years endured the difficulties resulting from collisions in projects and troublesome changes in the documentation. These difficulties existed in the in-drawing era and still exist despite advanced computer technologies being in place.

Of course, better solutions and technology keep appearing that significantly improve work, reduce collisions and facilitate making changes, but they are based on completely different design parameters, which are in no way connected with traditional design. BIM systems differ significantly from CAD, especially in the following aspects:

- In CAD we deal with drawings made separately. Subsequent drawings are not related to each other, so each correction of one must be manually updated in the others. In BIM technology, all drawings are interconnected and dependent on each other. A change made in one view is automatically applied to the other drawings. This is because all drawings and object views are based on a single digital model (Fig. 1).
- Views and sections of a building made in CAD comprise a set of lines placed on a 2D plane. A building developed by means of BIM technology consists of many three-dimensional parametric objects. It means that all the components have assigned features and information, allowing the determination of e.g. material, cost or physical properties of a component. This is ensured by using ready-made libraries, prepared by the manufacturers of individual building components (Fig. 2).

- The features of CAD-designed objects and their descriptions have to be written manually. In BIM, each element has properties that allow it to be intelligently and automatically adjusted to a design. Thanks to the parameterization of these objects, each description can be generated automatically. This applies especially to automatically inserted labels, which allows the avoidance of various errors, such as the thicknesses of layer structures in a ceiling design (Fig. 3).
- Working in multidisciplinary teams in CAD consists of each participant making his or her own drawings, regardless of the others. This generates errors and collisions between the individual discipline's drawings. A problem is often noticed only at the stage of implementation of a design, which results in the additional cost of making modifications. A model built in BIM technology is developed simultaneously by all discipline's professionals. Each designer has access to the same model, which shows the activities of other participants of the design process. At any time, it is possible to detect the existing collisions and remove them at the design stage (Fig. 4).
- The resulting object in CAD does not fully reflect the building. Only after the construction is completed, full information about the geometry and parameters of an object is obtained. A building model created in BIM technology is a full virtual representation of a real building. Additionally, it is possible to view it virtually at any time at different stages of construction (Fig. 5).

Fig. 1. Virtual model of a building (*own study*)

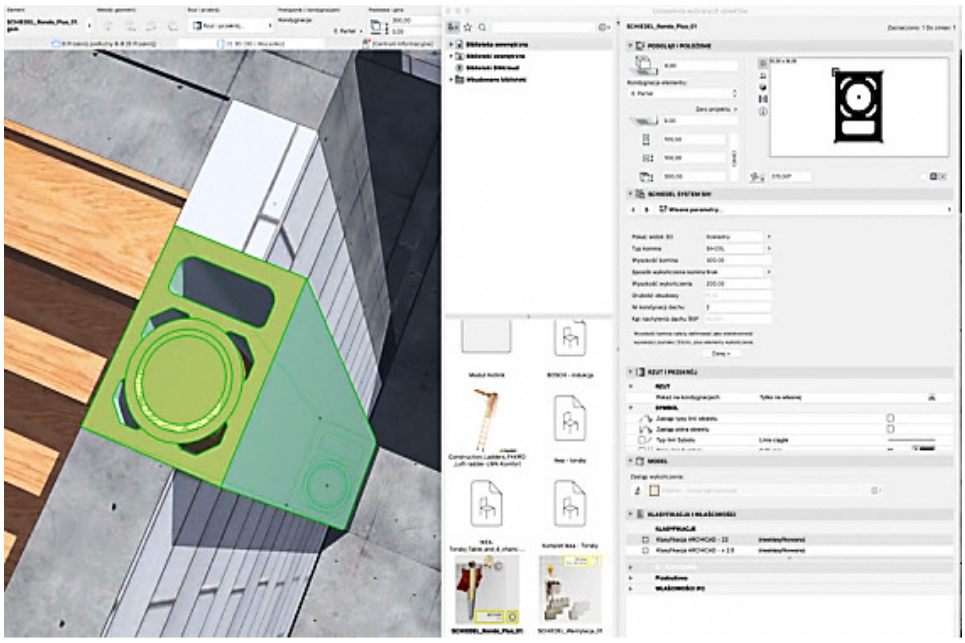

Fig. 2. A chimney element inserted into the project from a library database, with parameters assigned by the manufacturer (*own study*)

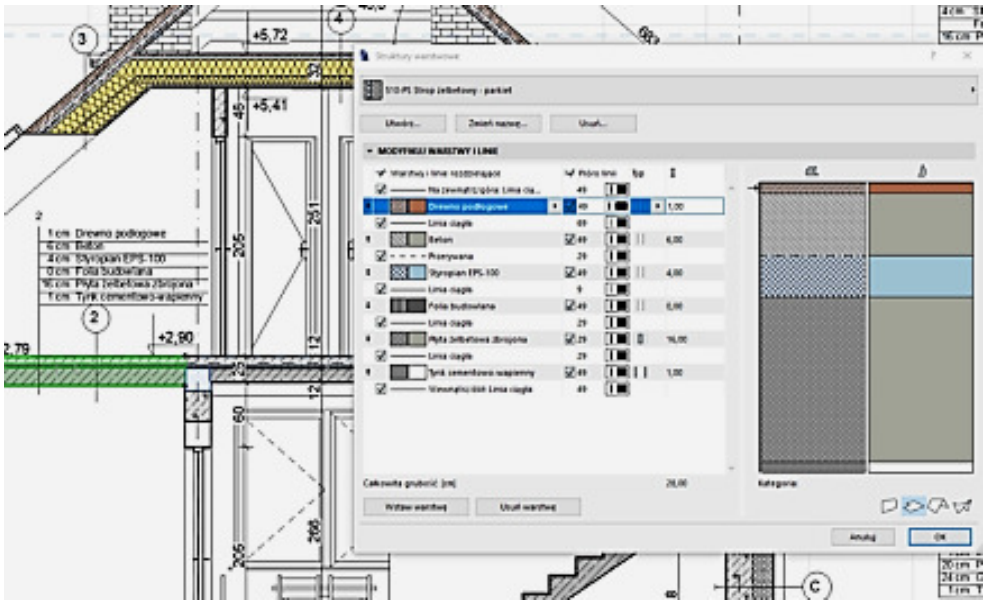

Fig. 3. Ceiling label with layout and thickness of individual layers (*own study*)

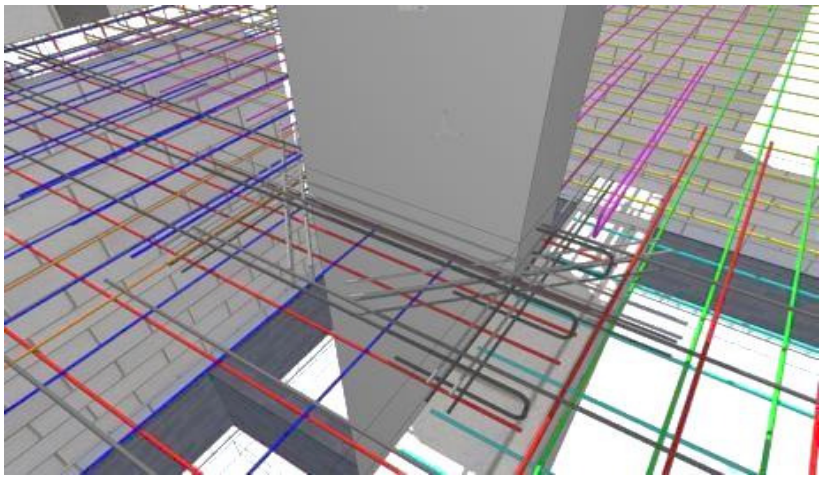

Fig. 4. Visible collision: ceiling reinforcement penetrates the chimney (*own study*)

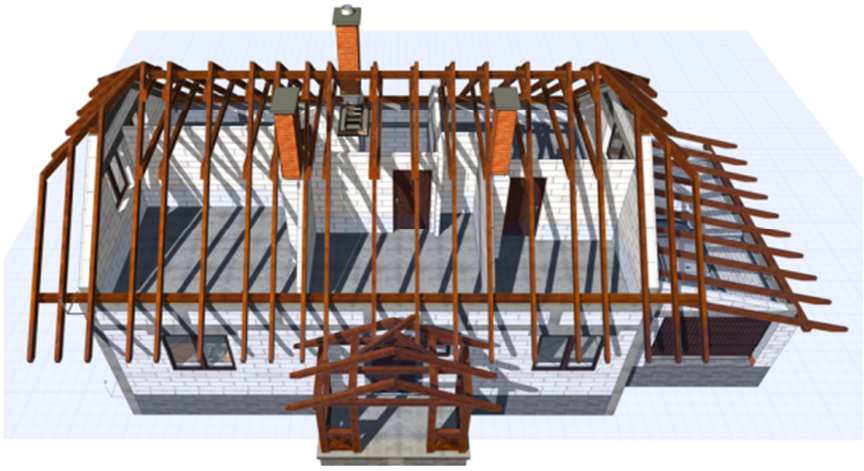

Fig. 5. A core-and-shell building model (*own study*)

3. Summary and conclusions

Computer-aided design is currently the standard in the process of creating construction documentation. Thanks to the digital revolution, which has also changed the construction industry, participants of a construction process have gained a lot of helpful tools. Consequently, computer design is now faster, more efficient and offers more possibilities. CAD systems are now used by all design studios. Unfortunately, designing on one plane and in unrelated drawings are still the cause of many design errors and collisions. These only become apparent at the stage of construction, which results in additional costs and exceeded deadlines. The hope for

solving most of these problems lies in the BIM system, a technology that significantly increases the efficiency of design.

Thanks to the use of BIM in the implementation of an investment, at the design stage, the investor, designers from various disciplines and the contractor actively participate in the design process. They can analyse the application of various technical and functional solutions, accurately estimate costs and construction time. Using BIM technology, it is easy to create various design variants and remove collisions. Changes to a design are made intelligently thanks to the parameterization and automation of work.

The BIM model also facilitates the work of the property administrator, who is able to manage the use and repair of the building from the model level.

More and more participants of the investment process see the benefits of using an integrated design process with the use of the BIM methodology, at the same time hoping that outdated and inefficient design and construction management methods will soon be replaced. The use of BIM in the investment and construction process will increase the efficiency of construction works and put us on the path of innovation in construction.

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