The system of filling the information model of construction structural elements

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Abstract. The article considers the need for information filling of the digital model of the building object. The effectiveness of laser scanning for the real display of the state of building structures and their adequacy to the design data was noted. The effectiveness of laser scanning for the formation of a cloud of spatial points of objects for the further formation of a three-dimensional digital model was noted. Examples of laser scanning of building objects and subsequent reproduction using software of volumetric digital elements from the obtained point cloud are given. It is proposed to consider the filling system of the information model on the example of the developed technology of installation of the structural coating of light metal structures. On the basis of the developed installation technological equipment, control indicators, features of the installation technology, structural features of the building object are determined, which allows entering such data for consideration in the monitoring system of the installation process. All this together makes it possible to develop a

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generalized database of both the object as a whole and its components, which will take into account the compliance of the manufactured structure with the design data, the preservation of its properties before the installation process, during installation during operation, strengthening, and disposal.

Keywords. Product life cycle, laser scanning, cloud of points result, 3D digital model construction element, construction technology, craneless installation, information model, mechanized equipment.

INTRODUCTION

Recently, more and more attention is paid to the analysis of the life cycle of products, their digital support [1]. The same trend is observed in the construction industry in the context of considering the informational construction model.

Building information modeling (BIM) is a process of collective creation and use of information about building objects, which forms the basis for all decisions throughout their life cycle (from planning to design, issuing working documentation, construction, operation and disposal). At the heart of BIM is a three-dimensional information model, on the basis of which the work of the investor, the customer, the executors of construction works, and the operating organization is organized [1].

Continuous support of BIM - the basis of object life cycle management (PLM) - the need to fill the information model of the source system at various stages.

Depending on its complexity, several hundred people work on the project in a single information model, as a rule, working on many areas of the project. Each of them can daily change the basic and create new information about the system and its components, for which a separate communication of mutual work is organized. As long as this communication system is not available, individual data may be lost or distorted, which leads to inconsistency in terms of the stages of the object's life cycle.

Due to internal communication errors and its routine, up to 90% of projects are completed behind schedule, and individual project participants spend up to 28 hours per week searching for information and personal communication with each other [4].

THE PURPOSE OF THE WORK

The purpose of the work is creating the system of filling the information model of construction structural elements.

From the point of view of construction, it is possible to single out individual stages of the life cycle of a building object, but for efficiency, it is necessary that the information model is equally accessible and adequately reproduced - an ecological digital system is created. The task of such a system is to provide the possibility of obtaining various digital data about the building system and its components in various forms: from the most simplified to complete, and the possibility of its further use in the information support of the object [3, 4].

At the creating new modern construction objects, in most cases, the construction stages are filled with digital data whenever possible: from the technical task to disposal. This is true for newly created construction objects. However, the situation with existing buildings and structures is somewhat more complicated. At the same time, it is necessary to create new digital models using the interaction capabilities of GIS [5] and CAD [6] systems.

A similar program of interaction is also envisaged in case of creation of new structural elements of buildings, technological equipment, improvement of technology of construction processes.

Building structures differ in their shape, size, materials, purpose, method of installation, etc. Information about the geometric parameters of building structures is the main toolkit of a builder, therefore, when analyzing the existing building system as a whole and a separate structure, it is necessary to carry out their geometric analysis. For this, the most common methods are obtaining a cloud of points of the building object and their subsequent CAD modeling.

The most common methods of obtaining point clouds are the use of photogrammetry and laser scanning technologies.

Laser scanning is the most modern technology for obtaining a spatial point cloud of an object or individual structures. Laser scanners are classified by type: stationary ground, mobile, hand-held, etc. Such technical characteristics as distance, speed and accuracy of scanning are also important [4]. In fig. 1 presents the results of scanning a fragment of the subway line in Kyiv with a laser scanner.

Requirements regarding the conformity of geometric parameters of building structures are established by certain regulatory documents [7] (Table 1). Ranges of permissible deviations and control methods are indicated.

However, the methodology proposed by regulatory documents in modern conditions does not provide the full amount of information for Building Information Model. Therefore, the use of laser scanning to form a cloud of points and 3D modeling of structures will provide an opportunity to supplement the information model.

When analyzing the requirements for permissible deviations of the geometric parameters of reinforced concrete structures, we see that the deviations are in the mm range. Therefore, when choosing the type of laser scanner, preference should be given to stationary ground scanners that meet the accuracy specified in the regulations.

Handheld laser scanners are the simplest and most convenient option for solving the problems of building point clouds of small rooms [8,9].

Specifications:

• Measurement speed – 420000 points/sec;

• Relative accuracy of scanning - 20 mm;

• The range of measured distances is 0,5 - up to 25 m.

Advantages: ease of use; relatively low cost.

Disadvantages: low scanning accuracy due to lack of controlled movement, impractical use for large objects.

Stationary ground laser scanners are the most accurate and efficient option.

Specifications:

• Measurement speed – 500000 points/sec;

• Relative accuracy of scanning - 2 mm;

• The range of measured distances is 0,5 - up to 80 m.

Advantages: ease of use; hight scanning accuracy, .

Disadvantages: hight cost, increased requirements for the hardware part of data processing.

Table 1. Example of normative requirements regarding the geometry of building elements

Parameters	***Size***	***Control***
1 Deviation of the lines of the cross-section planes from the vertical or the design slope over the entire height of the structures for: - foundations	20 mm	Measuring, each structural element, work log
- walls and columns supporting monolithic coverings and ceilings	15 mm	
- walls and columns supporting prefabricated beam structures	10 mm	
- walls of buildings and structures erected in sliding formwork, in the absence of intermediate floors	1/500 of the building height, but not more than 100 mm	Measuring, all walls and lines of their intersection, journal of works
-walls of buildings and structures erected in sliding formwork, in the presence of intermediate floors	1/1000 of the height of the structure, but not more than 50 mm	
2 Deviation of horizontal planes along the entire length of the area being corrected	20 mm	Measuring, at least five measurements every 50-100 m, log of works
3 Local irregularities of the concrete surface when checking with a two-meter rail, except for supporting surfaces	5 mm	The same
4 Length or span of elements	± 20 mm	Measuring, each element, work log
5 The size of the cross section of the elements	+6 mm; -3 mm	The same
There are Markings of surfaces and embedded products that serve as supports for steel or prefabricated reinforced concrete columns and other prefabricated elements	-5 mm	Measuring, each support element, executive scheme
7 Slope of the support surfaces of the foundations when supporting steel columns without pouring	0.0007	The same every foundation, executive scheme
8 Location of anchor bolts: - in the plan inside the contour of the support	5 mm	The same for each foundation bolt, executive scheme

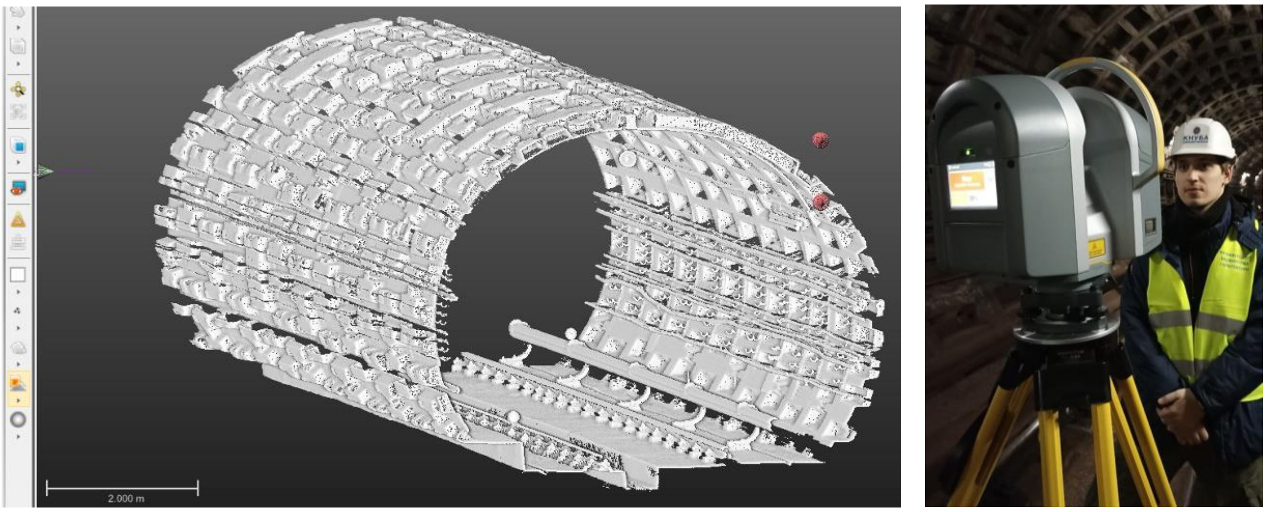

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Figure 1. Scanning a fragment of the subway line in Kyiv by the laser scanner: a - the cloud of points result; b – using the laser scanner by Kyiv National University of Construction and Architecture specialist.

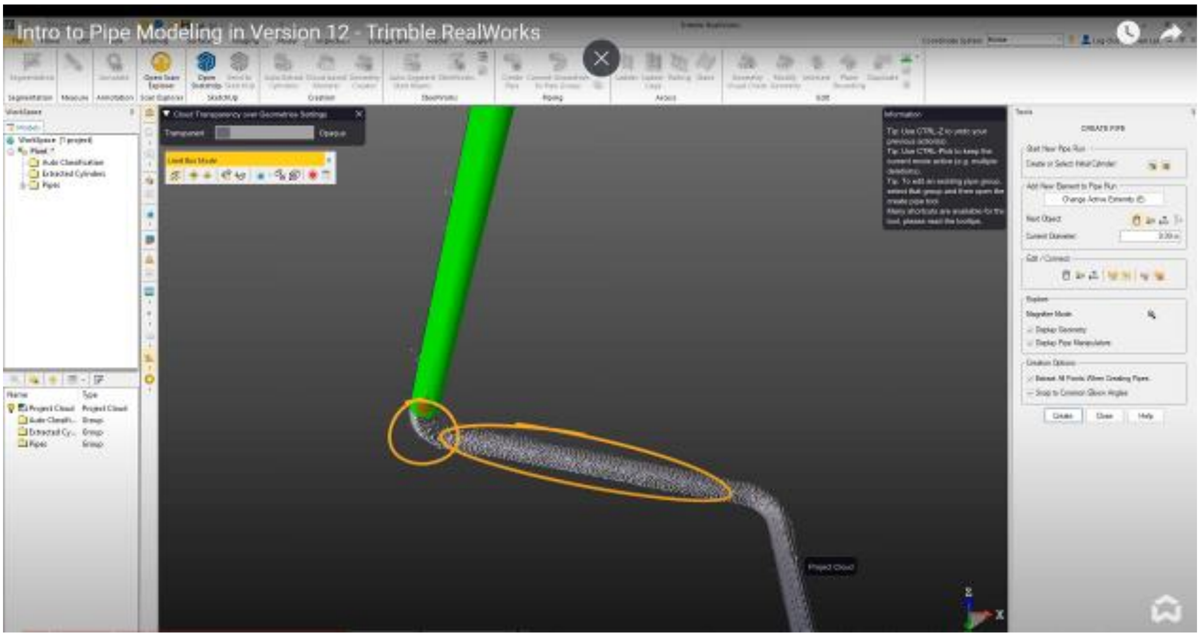

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Figure 2. An example of rendering three-dimensional objects from a cloud of points using software.

- in a plan outside the contour of the support	10 mm	
- by height	+20 mm	
9 The difference in height at the junction of two adjacent surfaces	3 mm	The same every joint, executive scheme

After processing the scan, the cloud of points can be transformed using special software into a CAD object (Fig. 2) [10].

It is interesting to use geodetic technical means in the creation of new constructive solutions, as well as new technological equipment for performing construction and installation operations.

Methods of installation of building structures are considered in the work [11]

Let's consider the process of filling the information model of the building object during the mounting of the structural covering by using technological equipment in the form of a technological lifting module (Fig. 3) [12].

In the work [13, 14] considered the specifics of designing light metal structures for structural covering with blocks of 15x24 m in size. In particular, the installation technology of such a structure was developed and the use of a new construction of a technological lifting module was proposed.

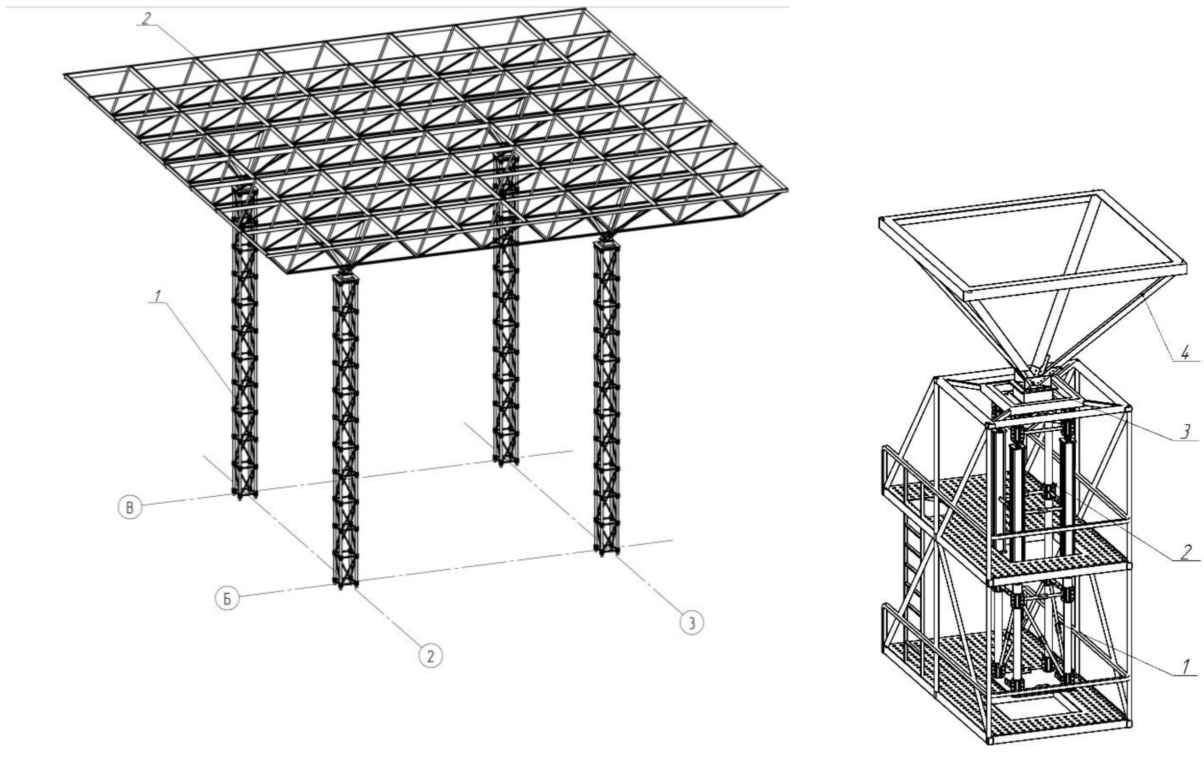

Figure 3. Building construction with a light metal frame: *a* – frontal view of construction: column; 1 – column: 2 – structure cover block; 2 - coating; *b* – technological lifting module: 1 – column tier; 2 – cargo lifting module; 3 – column head; 4 - support node.

Structural blocks of coatings are designed and manufactured in plan.

The field of application of covering block structures is characterized by the need for their quick installation, ease of maintenance, and the possibility of quick dismantling.

Taking into account the possible sizes of the 24x24 covering blocks, you can get building options with the dimensions in the plan, according to the number of blocks. In our opinion, the minimum effective is the number of 3x4 blocks with the arrangement of columns.

In the case of the use of the technological lifting module, the installation of the structural block of the covering together with the crane equipment takes place immediately on the support nodes, which are installed on the technological lifting module.

When the height of the building is up to 18 m, the number of sections of the column in height reaches 11 pieces, when installing the first tier of the column at 0.0.

According to the selected parameters of the structural block, we will get the following characteristics of it:

• the weight of the metal structure of the 24x24 structural block is about 12 tons;

• coverage area 576 m^2;

• covering height 2,1 m (with supporting nodes 4,2 m);

• the height of the column is 13,8 m;

• column weight 1,5 t;

• the number of tiers is 11 pcs.;

• the number of pipe elements of the column is 44 pcs.

Installation of the column tier is as follows.

For one block of structural covering, it is necessary to provide such a number of lifting modules that will ensure the stability of the structure and will correspond to the structural scheme of the building (Fig. 4). Consider a system with 4 sets of modules. First, it is necessary to carry out their initial installation in the places of supports, to install the 1st tier of columns. It is also necessary to ensure the constant availability of power for the module drive system as well as the installation accuracy control system.

The control system of mounting process includes receiving devices; high-precision electronic robotic tacheometers; prisms and

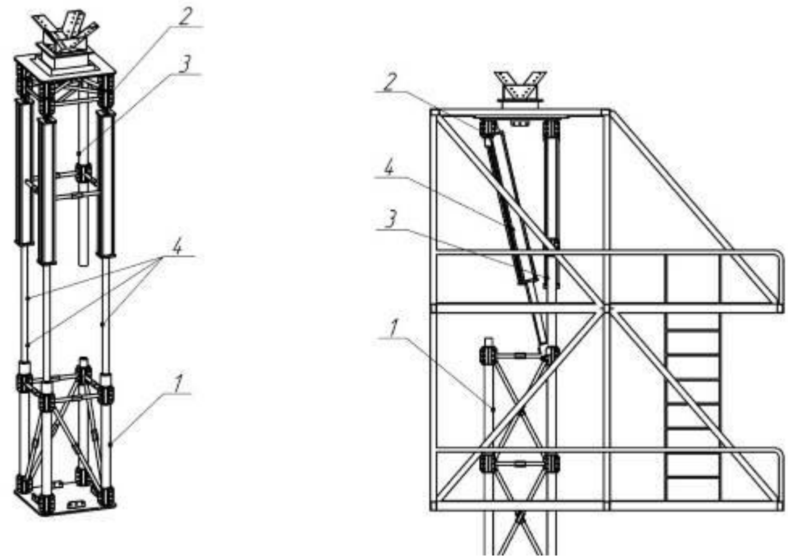

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Figure 4. The sequence of lifting (the frame with supports is conditionally not shown): 1 – the mounted tier of the column; 2 – the technological module; 3 – permanent support of the module; 4 – leaning on a column; a – synchronous extension of the rods of 3 hydraulic cylinders; b – installation of the last tier of the column.

marks mounted on the structures of the arch, stiffening beam, and around them to determine the design position of the stiffening beam and its change; communication and computer equipment, as well as software for managing the complex.

The proposed design of the covering block has at its base runs in the form of channels, connected to each other by corners of different sizes. The support of the structural block takes place at a distance of 3 m from the overall axes and forms a free zone inside with the size of 6x6, 12x12, 12x18, 18x18 m. Loads are concentrated in the support node and transferred to the support cup of the column.

The column is a prefabricated structure consisting of 4 pipe elements with a length of 1000 mm, the distance between which in the axes is 700 mm. Pipe elements are connected to each other by couplings, through which the column is aligned with the help of rods and its components are fixed (Fig. 5) [14, 15].

After the modeling process, the information system is filled with additional data. The geometry, shape and weight of structures will determine the specifics of technological operations during installation. In a certain way, the natural frequencies of oscillations can influence the choice of mechanized technological equipment, taking into account installation control errors. Total deviations directly affect the geodetic control error, safety limits, etc.

Separately, it should be noted that compliance with design data in real conditions is ensured by discrete execution of geodetic surveys. At the same time, the methods and means will be determined in accordance with the required accuracy, the required number of measurements, and hardware capabilities.

It is obvious that for new construction objects, the design features of which involve the elemental nature of the structure, the application of real scanning of the structure throughout its entire life cycle is promising. This allows, for example, to identify the structure on the object, based on its digital identifier, by which it is possible to apply the batch, material, deviation of the geometry at the production stage, defects detected during operation, reinforcement, etc.

Conclusions:

- Digital support of construction objects during the life cycle is an effective means of communication between all project participants, which allows for the efficient use of time resources, optimization of mutual work and determination of optimal ways of digitalization of project data;

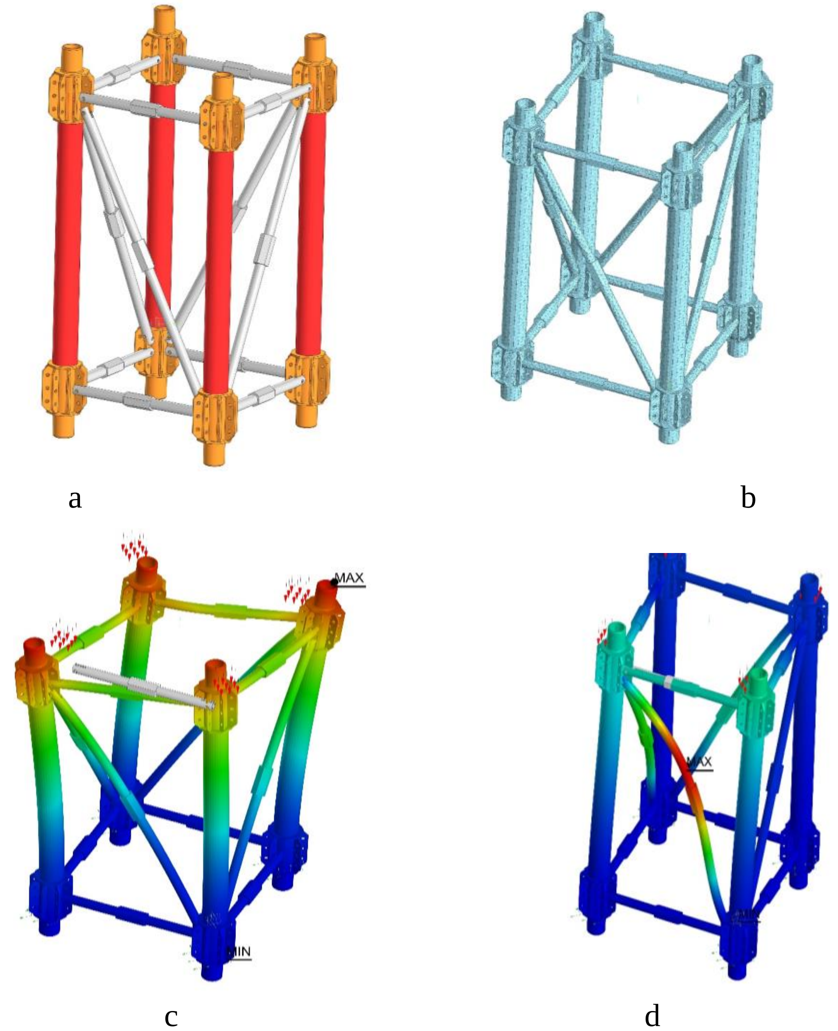

Figure 5. Block of the structural column tier: *a* – CAD model; *b* – finite element scheme; c – visual representation of the total movements; d – visual representation of the nature of deformations from self-oscillations.

- Volumetric scanning is a modern means of determining the adequacy of real construction objects with design data, as well as a promising means of monitoring the execution of construction processes and the state of structures;
- Scanning methods and tools depend on the specifics of the technical task and the technical capabilities of the performer;
- GIS and CAD systems complement each other depending on the set goals, methods of work execution, as well as the stage of the construction object's life cycle.
- The system of filling the information model of construction structural elements is a live system that is filled and modified depending on the technical task, the specifics of the object under study and the technical capabilities of the owner of this system.

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Система наповнення інформаційної моделі конструктивних елементів конструкції

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Анотація. У статті розглядається необхідність інформаційного наповнення цифрової моделі об'єкта будівництва. Відзначено ефективність лазерного сканування для реального відображення стану будівельних конструкцій та їх адекватність проектним даним. Відзначено ефективність лазерного сканування для формування хмари просторових точок об'єктів для подальшого формування тривимірної цифрової моделі. Наведено приклади лазерного сканування будівельних об'єктів і подальшого відтворення програмним забезпеченням об'ємних цифрових елементів з отриманої хмари точок. Пропонується розглянути систему наповнення інформаційної моделі на прикладі розробленої технології монтажу конструкційного покриття легких металоконструкцій. На основі розробленого монтажного технологічного обладнання визначаються контрольні показники, особливості технології монтажу, конструктивні особливості будівельного об'єкта, що дозволяє вносити такі дані для врахування в систему моніторингу процесу монтажу. Все це разом дає можливість

розробити узагальнену базу як об'єкта в цілому, так і його складових, яка буде враховувати відповідність виготовленої конструкції проектним даним, збереження її властивостей до процесу монтажу, під час монтажу. під час експлуатації, зміцнення та утилізації.

Ключові слова: життєвий цикл продукту, лазерне сканування, результат хмари точок, елемент побудови 3D цифрової моделі, технологія будівництва, базкранові способи монтажу, інформаційна модель, механізоване оснащення