Expanding the capabilities of the ARCHICAD software package for effective solution of construction design tasks

A V Dolzhenko\(^1\), A V Grebenik\(^2\), M A Sedashova\(^1\), and D S Rudenskyi\(^1\)

\(^1\)Department of Construction Management and Real Estate, Belgorod State Technological University named after V G Shukhov, Kostyukov St, 46, Belgorod, 308012, Russia

\(^2\)Department of Automation and Informatization, Belgorod State Technological University named after V G Shukhov, Kostyukov St, 46, Belgorod, 308012, Russia

E-mail: davidenkopolly@mail.ru

Abstract. Effective management of real estate complexes, which determines the minimum cost of ownership of constructed and operated objects, implies at the present stage the active introduction of information modeling technologies into the project life cycle. At the same time, in all the variety of modeling software and modeling formats offered by the national and foreign markets, those that have advanced controllability and adaptability to the changing conditions of the design or actual construction stages are the most effective for the purposes of managing the capital intensity of a non-movable asset. The ARCHICAD software package, which is a recognized leader in architectural modeling software, contains the necessary standard and additional tools for creating parameterized objects - elements of a real estate object that have the required properties, significantly accelerating and simplifying the work on adapting the model and optimizing space-planning solutions created on its basis. The authors created a universal parameterizing library feature of wall panel of precast technology in private residential construction, which implements a modular approach to parametric modeling using encapsulation basic library features to upgrade effectively the panel, to implement the specification of resources, visualize technology, including the virtual reality environment, providing the necessary visibility when training for line personnel of the construction site and technical quality control of construction products. The estimation to reduce the complexity and growth performance of work implementation of the proposed approach when designing a wall barrier of low-rise residential buildings.

1. Introduction

Effective management of the life cycle of an immovable object, which helps to minimize the cost of ownership, is based, among other things, on the technologies of rational design and constructive optimization of the made design technical decisions. Information modeling is a promising direction that is actively developing, contributes to improving the quality and speed of design. In the market of BIM applications, several key companies provide special software to various target groups of design and construction activities. Among the leaders of BIM applications in terms of intensity and efficiency of use is ARCHICAD. With an intuitive interface, algorithmic design capabilities and automatic generation of resource documentation, high-quality visualization tools and high performance, the ability to effectively form complex geometrically and parametrically elements, ARCHICAD has earned the well-deserved respect and preference of more than 1.5 million users, mainly among architects. At the
same time, the market of design services and informatization of the design process of building structures is covered by the program to a lesser extent than potentially possible. This is due to the orientation of the full-time capabilities and tools of the program to the tasks of the architect, while information support for solving the tasks of the designer can be performed by freelance software tools, the key of which is programming in the GDL language and using formulas for object properties.

2. Materials and methods
Due to the active development of BIM design, one of the main features of which is the construction of a parameterized digital model of a real object, an important place in the designer’s work is occupied by the use of GDL objects and, directly, GDL programming. GDL (Geometric Description Language) is a programming language integrated into the ARCHICAD environment. They can use it to create library elements, that is, to describe three-dimensional 3D objects, as well as their 2D designations. GDL objects can contain various information: 2d drawing/symbol of the object and its 3D geometry, information about the product and its characteristics, parameters, structure and construction of the product, coating, etc. [1].

In practice, GDL allows creating parameterized unique constructs, modifying, transmitting and using them repeatedly in different projects. This applies both to the basic parts of the building, such as walls, doors and windows, and to unique elements that have never been seen before. Objects created through GDL programming can serve several purposes: executing user queries; creating a standard object library; creating a manufacturer’s object library based on specifications; and customizing and improving objects presented in ARCHICAD. The concept of the library part of GDL programming includes the formation of a pool of object parameters with a user interface and input data control elements, writing scripts for spatial and flat representation (sections, facades, plans); managing output data for building resource lists and specifications. In the final release of the ARCHICAD software package at the time of writing, the developers implemented a convenient and effective visual editor of the GDL programming environment PARAM-O [2] (Fig. 1).

![Visual editor of GDL programming environment PARAM-O](image)

**Figure 1.** Visual editor of GDL programming environment PARAM-O as part of the ARCHICAD regular additions.

3. Results and discussion
Information modeling based on the use of GDL objects as an integral part of complex technical and technological systems is a growing application in all sectors of building design, from reinforced concrete to create items of tooling and equipment of ancillary industries. Thus, in particular, parametric modeling in ARCHICAD significantly increases the efficiency of modular design of elements and assemblies of modular construction technologies, in which a certain set of initial structural elements cor-
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responds to a variable set of final space-planning solutions that are implemented within the framework of a certain construction standard. To assess the prospects for the widespread use of ARCHICAD parametric modeling tools in solving a large number of current problems of modern construction practice, the authors performed parametric models of individual elements of building structures and auxiliary equipment, conducted studies of changes in the labor intensity and speed of performing typical technological operations of modern design activities related to sketch construction, structural analysis, optimization of technical solutions and drawing up elements of design and estimate documentation for individual real estate objects and small stores. At the same time, parameterized information models of structural and technological elements themselves became prototypes for the formation of a vertical nesting structure that implements a consistent approach to creating families of elements based on a limited number of typed unified basic elements that have scientific and practical novelty [3].

One of the modern innovative production technologies in the field of low-rise housing construction is a series of precast-monolithic wall elements based on the use of plastic-tube concrete (PTC) developed at the Engineering and Construction Institute of BSTU named after V.G. Shukhov. The structural elements of this technology are external and internal layers made of oriented excelsior board (OEB), combined through special intermediary elements with plastic pipes filled with heavy concrete of the design class, installed inside the shield with a certain step [4, 5]. Filling the space between the PTC racks is carried out with light concrete. The next layer of the wall panel is provided with a slab insulation, external and internal finishing [6, 7] (Fig. 2).

![Figure 2. General view of the GDL wall panel model: 1 – intermediary elements; 2 – polyethylene pipe; 3 – filling the panel with light concrete; 4 – monolithic belt for connecting to the top panel; 5 – finishing layer; 6 – insulation; 7 – OEB.]

Figure 2. General view of the GDL wall panel model: 1 – intermediary elements; 2 – polyethylene pipe; 3 – filling the panel with light concrete; 4 – monolithic belt for connecting to the top panel; 5 – finishing layer; 6 – insulation; 7 – OEB.

Figure 3. Model of a single-store residential building made of standard GDL objects of wall panels.

The basic encapsulated elements of the wall panel are facing layers of variable thickness, an intermediary element that serves as a vertical panel switch, and a PTC rack. Rational design of the walls of individual residential buildings carried out in the proposed technology, based on a wide range of sizes and geometric parameters of the panel, optimal for a single climatic or economic conditions of the construction of the building, and individualization of the structure of wall panels in accordance with the results of the structural analysis of its actual situation and work load in part of the wall fencing. The specified tools of rational design were implemented in the creation of a universal parametrizing library element of a wall fence, which allows varying the parameters in a wide range and providing modeling of a wall fence of any shape in plan and load-bearing capacity. The panel information model is a parameterizing object that provides a variation of the following parameters (Fig. 4):

- length of panel;
- height of panel;
- type and rotation of the intermediate element for the side panel adjunction;
- number and diameter of polyethylene pipes;
- height and concrete class of the monolithic belt;
- thickness and material of insulation;
- thickness and material of the finishing layer;
- filling material of polyethylene pipes and the space between them.

Figure 4. Varying the parameters of the information model of the wall panel in order to optimize the made design decisions: 

a) — changing the height and length of the panel;

b) — changing the thickness of the layers;

c) — changing the type of intermediary elements, the number and diameter of polyethylene pipes.

The parameterized model of the wall panel, which implements the principles of vertical nesting of basic elements created by standard GDL primitives (CPRISM_, CYLIND, BRICK), forming complex structural elements of a wide degree of variability of technical parameters, was performed on the basis of the object encapsulation tool available in the GDL environment, implemented by the CALL function (fig. 5).

CALL "RACK" PARAMETERS cod1=2, D1=D11, Bt=Bt1, Ht=V-Hp, m2=mt11

Figure 5. An example of using the CALL function that implements object encapsulation in the GDL environment. Parameters transmitted to the encapsulated base object “Rack”: cod1 — element group code, D1 – pipe outer diameter, Bt - pipe thickness, Ht – pipe height, m2 – pipe material.

The cyclical formation of model elements was ensured by using the loop (FOR) and conditional transition (IF) operators, while the interface provides the user with a choice from a set of unified basic primitives associated with logical and analytical dependencies with general and particular design parameters of the panel is implemented by the PARAMETERS operator and the corresponding section of the GDL programming environment. The user is given the opportunity to change the parameters of the wall panel in a wide range of pre-set discrete values of the geometric dimensions and shape of the basic elements composing the panel. The used preset series of parameter values, implemented in the object own description section in a single place and description format, allow changing easily and updating the incoming information, updating it according to the actual design and market situation in the proposed construction area, and reading the source data from an external text file that allows using in the future the connection of the object to the information bases of resource classifiers used in the federal state information system for pricing in construction [9].

Using GDL objects allows displaying quickly and conveniently the specification of the finished object that meets the current or most effective design solution, which confirms its effectiveness with comparative resource intensity. In the PARAMETERS section of the GDL environment, it is allowed to use a variety of mathematical expressions, including cyclic and iterative ones, that provide calculation of all the specification characteristics required for an accurate assessment of the natural resource intensity and cost of creating an object — the number of discrete elements, linear dimensions, areas, volumes, including those separated by the used coatings and materials (Table 1).

Table 1. Specification characteristics of the natural resource intensity of the wall panel information model, defined as part of the GDL script of the object.

| Name | For panel | For the entire vol- |
|------|-----------|--------------------|
|      |           |                    |
A practical example of the use of a universal parameterized library element of a wall panel based on the use of plastic-tube concrete in the design of a low-rise residential building is shown in fig. 2. An information model of a typical building for this technology, containing walls designed for implementation in the proposed prefabricated-monolithic version, is performed at the stage of primary sketching using a family of wall panels that implement row, corner and connecting structural functions [10]. At the same time, even at the sketching stage, an exceptionally accurate and reliable resource statement is automatically generated, which allows determining the total costs associated with the potential implementation of the information model in natural construction terms [11]. An example of a resource specification for the walls of a building obtained at all stages of design using parameterized elements is presented in Table 2. The resulting resource sheet can be documented at the current stage of sketching in order to further compare it with the space-planning and technical solution, which is more rational, in the opinion of the designer. A comparative analysis of resource efficiency indicators achieved on iterations of space-planning and technical solutions of the walls of the building under consideration from the point of view of improving the internal structure of the panel and reducing the cost of forming the external wall contour of the walls of the building is presented in Figure 3. The authors’ studies of the potential for optimizing the complexity of making changes to the project (design iterations 2+) and the full-scale resource intensity of the model allowed estimating a decrease in the complexity of making changes to the information model using parametric objects up to 8 times compared to manual model changes, and in resource intensity — up to 20% compared to the initial basic iteration of structural and space-planning solutions.

Table 2. Specification of a single-store residential building.

| Name                        | Monolithic belt | Type 1 row panel | Type 2 row panel | Type 1 corner panel | Type 2 corner panel | Total |
|-----------------------------|-----------------|------------------|------------------|---------------------|---------------------|-------|
| Number                      | 7               | 14               | 53               | 8                   | 24                  | 106   |
| Number of connectors        | -               | 4                | 4                | 4                   | 4                   | 396   |
| Pipe length, m              | -               | 1.60             | 1.20             | 1.60                | 1.20                | 127.60|
| The OEB area, sq. m.         | -               | 2.25             | 1.75             | 2.26                | 1.76                | 184.57|
| Exterior finishing area, sq. m. | -       | 1.13             | 0.88             | 1.31                | 1.02                | 97.42 |
| Interior finishing area, sq. m. | -        | 1.13             | 0.88             | 1.06                | 0.82                | 90.62 |
| Area of insulation, sq. m.  | -               | 1.13             | 0.88             | 1.31                | 1.00                | 96.70 |
| Volume of concrete of the monolithic belt, m³ | 0.02     | 0.02             | 0.02             | 0.02                | 0.02                | 2.12  |
| Volume of concrete filling panels, m³ | -        | 0.10             | 0.07             | 0.10                | 0.08                | 7.83  |
| Volume of concrete filling pipes, m³ | -        | 0.02             | 0.01             | 0.02                | 0.01                | 1.21  |
Figure 6. The demonstrated increase in the efficiency of project activities using parameterized elements of building information models: on the left — the increase in resource efficiency of the accepted space-planning and structural solutions of the building by iterations of model improvement; on the right — the comparative complexity of making changes to the information model in the process of iterative optimization of space-planning and structural solutions of the building.

4. Summary

An information model of a building compiled using parameterizing objects corresponding to individual structural units, elements or units of equipment and tooling, developed, for example, in the GDL parametric programming language or in the PARAM-O visual parametric design environment for the ARCHICAD software package, allows not only to expand significantly the variability of the assembled models and its relevance to the general technical requirements set out in the design specification, but also significantly increase the overall resource efficiency of design solutions due to their space-planning and constructive iterative optimization. Automatically generated resource specifications, the composition and structure of which determine the tracked parameters of the simulated objects, set by the standard tools of the programming environment, are the tool that allows optimization in the conditions of dynamic tracking of indicators of natural resource intensity and cost of the collected model. The authors recognize the method of vertical encapsulation as a rational algorithm for designing parametric models, in which a certain set of basic primitives corresponds to an almost unlimited number of variations of the resulting finished models, based on their variable use, modified by the user based on subjective preferences or on the basis of structural analysis of elements in their actual position in the information model of the building. The resulting models not only contribute to the full implementation in practice of the principles of rational design of building structures, which, for example, is important when using funds from the state budget. However, they also help to implement technological optimization of the future construction process — visually monitor collisions, carry out a variant assessment of resource intensity, form the necessary design estimates and logistics documentation. In addition, the information model has a significant visualization potential for use in the educational and exhibition media environment, where they are implemented as part of training complexes for mastering technical disciplines of construction orientation, improving the skills of personnel of linear and assembly plants in technical expositions, demonstrating the technologies under consideration using virtual and augmented reality technologies. Thus, the expanded use of standard tools of information modeling programs with the inclusion of parametric elements, aimed at applying software to the successful solution of construction design and project problems, allows implementing effectively the key task of information modeling in construction (BIM) — improving the resource efficiency of a construction project by optimizing its information model, which plays a decisive role in improving the efficiency of man-
agement of property real estate complexes at the stages of implementation of investment and construction projects.

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