

Graph-analytic model of parameters of unified construction products on the requirements of environmental safety

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Abstract. The methodology concept of building parametric series of unified building products is presented. The purpose of the work is to create a method that would enable consideration of environmental safety requirements at the stage of design of the size range of the building products line. Method simplicity is based on the assumption of linear correlation of building products use parameters and required environmental parameters. Existing lifecycle assessment methods are intended for the analysis of one-off products rather than a set (line) of similar unified products. The problem is that the known product lifecycle assessment methods and line product configuration management methods yield mutually exclusive results. This work proposes the data presentation method that combines graphic construction of a parametric series of unified products and graphic construction of environmental requirements to products and their manufacturing and operation techniques. The work uses the known map imposition method as an environmental assessment method. Imposing a layer with graphic information about interrelated design and operational parameters of a product on a layer of information on acceptable exposure of these products manufacture and operation processes helps the product designer choose parameters of the unified product that meet environmental requirements from a host of options.

1. Introduction

The methodology concept of building parametric series of unified building products is presented. The proposed method of graphoanalytical construction helps estimate options and choose the best parameters for the line of unified building products from the parametric series with regard to environmental safety requirements. Method simplicity is based on the assumption of linear correlation of building products use parameters and required environmental parameters.

Existing lifecycle assessment methods are intended for the analysis of one-off products rather than a set (line) of similar unified products. When the known method is used, the task of choosing by the number of standard sizes in the line and parameters of each unified building is not solved for each range from the same line of product types. The problem is that some known methods are used to optimize product environmental parameters and other known methods are used to optimize line product unification parameters. This work proposes the method that combines graphic construction of a parametric series of unified products and graphic construction of environmental requirements to products and their manufacturing and operation techniques, which helps find efficient solutions with regard to both criteria:

- environmental safety, and
- economic feasibility.

Presently, the building sector is going through a boom of “green” construction, for which the scientific mission of “Unified building products configuration management with regard to environmental requirements” is being solved. The most important task among those that the building sector faces is quality improvement through the unification of building products that meet environmental requirements. The efficiency of construction operations may be considerably enhanced subject to the successful solution of this problem. When considering the reasons behind inconsistency of the methods of unified building products configuration management and environmental assessment methods, in particular, building product lifecycle assessment, it is



obvious that this inconsistency needs to be eliminated by creating a new method “Unified building products configuration management with regard to environmental requirements” that would integrate conflicting results.

Thus, the analysis conducted confirms the relevance of the subject: environmental safety of construction as a factor of information graphoanalytical modeling of product parameters.

The purpose of the work is to create a method that would enable consideration of environmental safety requirements at the stage of design of the size range of the building products line.

Study object – configuration management methods and lifecycle assessment of building products.

Study subject – method “Unified building products configuration management with regard to environmental requirements (method ecological unification - MEU)”.

The expediency of this subject matter is due to computerization of unified building products design processes and appearance of new opportunities for building information modeling (BIM technology).

The necessity and relevance of the proposed method “MEU” are justified by the rapid development of “green” construction technologies. Research in green technology is relevant and actual. The proposed method “MEU” is targeted at obtaining newest scientific results to back up the development of nature-like technology and biopositive building products, biopositive building materials and biopositive building components. Introduction of the new method “MEU” into scientific use or social practice will foster the solution of the theoretical problem of “green” construction standardization and many practical tasks related to building product quality improvement.

2. Materials and Methods

Methods used: product configuration management methods, product lifecycle assessment methods – valid since they have been proved by the international standardization practice.

Configuration management method – a managerial technique related to the development, release, and lifecycle (LC) support of complex products made in multiple options, including in line with particular environmental requirements. This technique is commonly used abroad, which is evidenced by multiple regulatory documents [1, 2].

Configuration: structure of a product proposed for development, a product under development or existing product that features operational, functional and physical attributes (properties, characteristics) that meet established requirements and are reflected in various information models that correspond to this product LC stages [2].

Configuration Management: managerial technique intended to ensure and maintain conformity of product operational, functional and physical attributes (properties, characteristics) with established requirements (including environmental requirements) when creating and transforming product models throughout its LC [2]. This technique implies the following operations:

- configuration identification;
- configuration control;
- configuration status accounting;
- configuration verification (audit).

Product lifecycle assessment methods in terms of international standards – corporate environmental management system ensures the settlement of ecological and economic issues through the allocation of resources, distribution of duties and continuous assessment of the methods, procedures, and processes in use. Environmental management as a school implies the development and study of a set of methods for the effective solution of joint economic and environmental issues.

The aim of environmental management is to minimize the adverse environmental impact of production activities, attain a high level of environmental safety of production and consumption of products and services. These aims must be consistent with the purposes of assurance of the company’s current and long-term competitive power.

The environmental management system has to be continuous and be coordinated with activities in other disciplines, for example, production, finance, quality, labor protection and general safety management.

3. Results

The method “MEU” has been elaborated. Building parametric series implies: choice of the main, primary and recommended parameters; determination of parameter variation limits; justification of the series denominator choice [3].

The following must be studied for new designs of the building products [8], to be used in environmentally and energy efficient buildings when building parametric series: demand for building products with output

parameters in line with heat protection parameters of existing buildings; possibility to meet this demand with the maximum use of field-proven building components, assemblies and units.

Demand for building products is determined by collecting their required parameters for all standard sizes of various buildings and by building the required parameter region based on the data obtained (Ω_n). The region method is commonly used to create series of transmission mechanisms of various construction machines [3].

Let us consider the application of this method when building parametric series of the building products that meet green construction requirements.

In general, Ω_n is determined by a set of particular parameters and features characterized by the process and functional purpose, correspondingly. Thus, in terms of the process purpose, this set may include the following parameters of building products: linear size and specific mass values, strength values and heat conductivity, air and/or fluid filtration performance, heat transfer control range, etc. In terms of their functional purpose, building products, for example, building blocks may be classified as a filter or dust arrester, heat or cold accumulator, ventilated wall or lift slab, inflatable front, radon protection, etc. Thus, general Ω_n for each functional feature is divided into a number of specials, either of which is a function of many process features, i.e. each type of building blocks has a partial region with required parameters, the building stages of which are shown in Figures 1 and 2 [4, 6]. Here Ω_n is an area of required parameters, M_q are the points characterizing the parameters of the product in accordance with environmental requirements; R_s is the denominator of the series for the additional coordinate axis of the parameters, q_i ; q_j are the coordinates in the plane of construction of a multi-coordinate field; K_{ij} - the point corresponding to the parameters of the product.

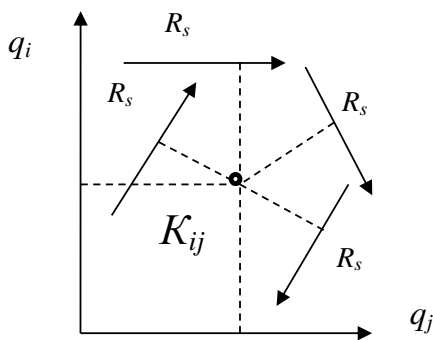


Figure 1. Graphoanalytical construction of a parametric series for products taking into account ecological requirements.

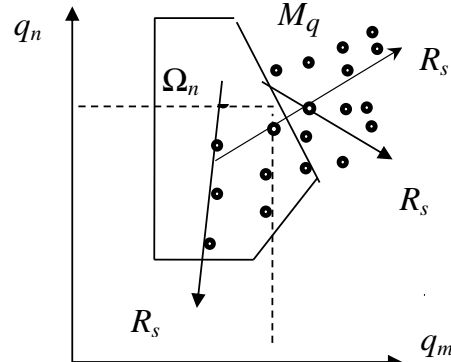


Figure 2. Graphoanalytical construction of a parametric series for products taking into account environmental requirements.

Analytically, the region of required design and operational parameters for building blocks may be expressed as follows [3, 5]:

$$q_i \in \Omega_n; (1),$$

where Ω_n is a set of required parameters for the building product type by a certain functional feature;

n is a number of points that meet required q_i parameters that describe a building product, for example, a certain type of building blocks with parameters varying in the following range:

$$q_{min} \leq q_i \leq q_{max};$$

Graphically, Ω_n may be presented as a part of the plane confined by extreme value isolines of required parameters (Figure 1).

The blocking contour of region Ω_n normally consists of three to five parameters (see Figure 2) that are accepted as primary series parameters with the main parameter chosen from among them. The parameters, the borders of which come closest to blocking contour borders are accepted as recommended series parameters.

A design chart with a parameter isoline grid is built in the following order (see Figure 1):

- q_n and q_m parameters that, according to the developer, may be included as primary parameters, are chosen as coordinate axes from q_i parameters;
- parameter isolines are drawn at regular intervals on coordinate axes; in line with series of preferred numbers, these parameters are assigned q'_n and q'_m values;

- values of other q_i parameters are determined based on known functions for the points of intersection of coordinate axes isolines (K_{ij}), while the points with same-name and single-valued parameters are joined with isolines; next, additional axes of q_s parameters are plotted.

The region of required Ω_n parameters is built by plotting parameter values of building blocks of existing wall structures on the design chart grid.

Figure 2 shows M_{mm} points plotted on the q_n and q_m coordinate field. The total number of M_{mm} plot points is equal to the number of building block types and each M_{mm} point is characterized by a set of required parameters from Ω_n region. Mean values of the parameters, for which no functional relations to the parameters forming the design chart grid are known, are determined in each square (see Figure 2) formed by isolines. Statistically average parameters may be mass, durability, cost of building blocks, etc. The number of mass-produced building blocks with close parameters is added. For each square, this number will be equal to the sum of the released building blocks that hit this square. Points of statistically average values of the parameters in the center of the squares are joined with isolines. Once isolines of parameter boundary values have been identified, there is a blocking contour that confines Ω_n region. Borders of this region correspond to the extreme values of required parameters and represent sections of the relevant isolines.

Boundary values need to be determined by calculating confidence limits with a hit probability of ~95% of all possible building blocks. For this calculation, a probability distribution law needs to be found for the value of each parameter using mathematical statistics methods.

The design chart field is plotted with M_q points (see Figure 2) that correspond to the parameters of unified series of the building blocks released by the enterprise. Next, q_s axes of inherent parameters describing building blocks are plotted (see Figure 3). Analytically, Ω_m of a building block is expressed by a formula similar to (1).

The number of inherent parameters and their boundary values are determined by the building block type. Graphically, Ω_m region may be presented as a part of the plane confined by the isolines of efficient inherent extreme values of building block parameters. Normally, the blocking contour of Ω_m region does not lie in the blocking contour of Ω_n region (see figure 2). Ω_m region may have multiple contours as there are different types of building blocks capable of performing the same function.

Possibility to meet demand is defined by existing unified series of building products that may perform the required function. Accounting implies comparing Ω_n region of required parameters with regions of environmentally safe use of product Ω_m .

A building product with the best environmental indicators, the blocking contour of which overlays Ω_n region of required parameters as much as possible is chosen as a base model for the unified series. One of the primary parameters of the building product that functionally relates primary parameters of building products of the existing unified series to the primary parameters of Ω_m safe use region has to be accepted as the main parameter of this building product. The series denominator for R_q main parameter is assigned in line with standard values of R_s series of preferred numbers.

4. Discussion

Product designers must ensure compliance with ecological standardization and regulation requirements. International and national standards of the Russian Federation are intended to attain the environmental safety objective at all stages of the product lifecycle. Attainment of the product configuration management objective is addressed in authors' words and normalized methods. When developing design and production documents for the manufacture of building products, developers must take into account environmental impacts according to Russian laws.

The problem is that when standardized building products are designed, it is necessary to present and take into account data on acceptable limits of environmental impacts declared in technical regulations and statutes [1, 2] for the configuration management of products at all their lifecycle stages.

There is a host of normative legal acts in the Russian Federation that regulate relations in ecological standardization and regulation. In Russian environmental laws, environmental quality standardization determines the system of environmental standards and norms, their establishment criteria, and authorities in charge of the development and approval of these norms. Laws set out requirements to sanitary and hygienic rate standardization in habitat protection. The legal framework of ecological standardization is established by the Russian Law "On standardization".

Unification of building products released requires a reduction in the number of standard sizes in the single-type product line. This task needs to be settled with building parametric series for the line of newly designed building products. The typical construction series under design is arranged and approved by features with

existing unified series of building structures of various elements of buildings, structures, and facilities with regard to environmental safety requirements.

The standard method takes into account environmental safety requirements only for a one-off product. When a line of multiple standard sizes is created, these requirements at lifecycle stages must be individually calculated for each standard size. However, environmental impact changes not only with the varying product size in the series line but also with increasing production that varies in line with the growth in batch production thanks to the configuration of the unified product series.

The method proposed allows us to use the “slide rule” principle [3] in modern computer graphics for calculations. The map imposition method [4 - 7] is used as an environmental and product configuration management method. Imposing a layer with graphic information about interrelated product parameters on a layer of information on acceptable exposure of these products manufacture and operation processes helps display a raw version of unified product parameters on the developer’s PC screen.

Concept novelty of the proposed method “MEU” lies in the fact that the authors have for the first time managed to develop the method that allows us to solve the problem of inconsistency and uncertainty of the results of analysis and configuration and lifecycle assessment of a building product that earlier could not be solved in combination and that normally had to be solved separately. The authors have proposed the method different in that, for the first time, there is a possibility of concurrent visual comparison of the results of analysis of configuration and environmental parameters of building products.

- This method “MEU” is, as a matter of fact, the first comprehensive scientific analysis of building products in terms of their unification ability and environmental safety.
- Procedures of data generation for the presentation of options of preferred parametric series of products with set environmental properties in information space have been developed.
- Scientific novelty of the study lies in the fact that the concept of the method of building parametric series of the unified building products that meet environmental safety requirements has been elaborated.

5. Conclusion

The method proposed gives an insight into the steps that the developer of unified products has to take in order to consider the adverse environmental factors inherent in the product production and operation techniques at the design stage. The method proposed supplements lifecycle assessment method procedures.

The proposed method of graphoanalytical construction helps present and choose a design and operational parameters for the line of unified building products of the range of sizes with regard to environmental safety requirements.

The method “MEU” is proposed for the first time; it provides new insight into correlation of positive and negative properties and attributes of building products under study when developing the structure and technology of a building product as part of a constructively unified set of similar products in the single-type line.

Certain theoretical value of this research is the fact that analysis is aimed at “green” standardization, nature-like technologies, biopositive structures, and materials. We should note that theoretical aspects of the method may be used in product standardization and unification in building and construction material industry.

Scientific (theoretical) value of the method is the author’s contribution in the development of scientific notations of building product configuration management as related to the environmental safety of construction and city economy; it discloses the essence and development mechanisms of construction greening. The method is used as the basis for further research in “green” standards.

- The materials and summaries presented in the work may be of use to designers and manufacturing technicians of construction operations.
- The method proposed may be used as the basis when elaborating training aids and special courses at building universities.
- Work materials have been used when teaching the course “Environmental safety of construction and municipal economy” at NIU MGSU and may be used to teach the course “Environmental standardization and building product quality management” to graduate students in country’s other higher educational institutions.

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