

## Reduced Concrete Method in Feasibility Studies of Water Supply and Sewage Structures

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### ABSTRACT

The concept of reduced concrete is considered. A methodology for calculating technical and economic indicators in the construction of water supply and sewage facilities is proposed. The advantages and disadvantages of the proposed method are considered. Based on the significant advantages of the method over traditional ones used in design, the scope of possible application of the proposed method is outlined. It is shown that its use in the development of feasibility studies allows for significant savings in time and money.

*Keywords: reduced concrete, feasibility study, methodology, water supply and sewage facilities, публікація, technical and economic indicators.*

### 1. INTRODUCTION

One of the important components in the design of water supply and sewage facilities is determining of technical and economic indicators. In many cases, the design of large and complex facilities requires a preliminary feasibility study to select the optimal design solutions. In accordance with the requirements of the State Building Code A.2.2-3:2014, a feasibility study is developed for engineering and transport infrastructure facilities that require technical and economic justification of the decisions made, as well as the determination of possible construction options and the feasibility of their implementation [1].

One approach to comparing alternative design options is to use the reduced concrete (or consolidated cost) method, which allows to standardize costs of different nature in one base year and compare options based on the minimum reduced costs [2].

### 2. REQUIREMENTS FOR WATER SUPPLY AND DRAINAGE FACILITIES

Modern requirements for water supply and drainage facilities are not limited to technical ones. The structure must not only ensure the efficient and accurate performance of its functional purpose and be durable, but also meet the criterion of economy, that is, be cheap to build and operate [3].

One of the tasks of feasibility studies is calculating the cost of building a structure. In the context of a crisis in the economy, the instability of the national currency and, accordingly, the instability of prices for the materials and work performed, this task turns out to be difficult [4].

When arranging structures, the following general principles must be observed:

- each structure must be functioning in the best possible way and not interfere with the operation of other structures;
- the cost of the structure must be minimal, taking into account annual operating costs;
- the design of structures and their arrangement must take into account the conditions for organizing and performing work and ensure its construction in the shortest possible time;
- it must create a harmonious architectural ensemble.

The importance of fulfilling the feasibility studies for water supply and wastewater facilities is due to their features [5], such as:

- long service life – facilities operate for decades, so repair costs, corrosion losses, environmental impact, etc. are important;
- various types of expenses – costs for materials, excavation, pumping equipment, treatment facilities, networks, energy consumption, maintenance, etc;
- time heterogeneity of expenses – some investments occur at the beginning, others – after years during replacement or overhaul;
- the need to compare alternatives – different network routes, different types of materials (concrete, reinforced concrete elements, polymer pipes), different water purification or pumping technology.

Thus, the reduced concrete method becomes a useful tool for objectifying the choice [6].

### 3. THE ESSENCE OF THE METHOD

The term “reduced concrete” in this context does not refer to the strength or chemical composition of the concrete itself, but is a conventional definition of the approach when all capital and operating costs associated with a concrete structure (or its variants) are reduced to the equivalent of the cost expression in one base year. That is:

- capital investment for the construction of a concrete structure
- operating costs (repair, depreciation, maintenance);
- costs for materials, transportation, installation all are reduced taking into account the time factor (discounting, reduction factors) to one base moment;

Variants are compared in which the technical indicators (strength, durability, hydraulic performance) satisfy the requirements, and the minimum reduced cost indicates the effective variant.

The method is based on the introduction the reduction factors that characterize the relative costs of performing various types of work compared to placing 1 m<sup>3</sup> of ordinary structural concrete. For example, 1 ton of reinforcement or 1 m<sup>2</sup> of formwork are converted into an “equivalent” volume of concrete.

The following algorithm for applying the method can be proposed:

- list the components of the option (Q<sub>i</sub>: m<sup>3</sup> of concrete and reinforcement; m<sup>2</sup> of formwork; m<sup>3</sup> of removed soil, etc.);
- take the reduction factors k<sub>i</sub> for each case (in "m<sup>3</sup> of concrete per unit i" from local prices);
- calculate  $V_{pr} = \sum k_i \cdot Q_i$  and choose the option with the minimum  $V_{pr}$ ;

- additionally check the strength/crack resistance/operational reliability (standard checks remain mandatory).

Thus, the method can act as a simplified economic criterion that allows weeding out less profitable solutions at the early stages of design.

The method can be used for the feasibility study of the following structures:

- potable water tanks and chambers;
- pumping stations and sewer collectors;
- trays, channels, retaining walls;
- wastewater treatment plants.

The calculation includes:

- volume of concrete of different classes;
- mass of reinforcement;
- area of formwork;
- earthworks;
- additional structural elements (waterproofing, protective coatings).

After determining the reduced volume, a mandatory verification of the options is performed according to the current standards of strength, crack resistance, and reliability [7].

The general indicator for the construction variant is proposed to be defined as:

$$V_{red} = \sum_{i=1}^n Q_i \cdot k_i \text{ (M}^3\text{)},$$

where:  $Q_i$  - the amount of material ( $m^3$  of concrete, tons of reinforcement,  $m^2$  of formwork, etc.);  $k_i$  the reduction factor for this type of material.

The variant with a lower value of  $V_{red}$  is considered more economically feasible at the preliminary stage.

It is possible to propose the values of the reduction factors given in Table 1.

Table 1 Reduction factors for different types of material

| Type of work/material               | Units | Reduction factor, $m^3$ concrete-equiv. |
|-------------------------------------|-------|---|
| Structural concrete                 | $m^3$ | 1.0                                     |
| Reinforced concrete                 | T     | 8 – 12                                  |
| Inventory formwork                  | $m^2$ | 0.3 – 0.5                               |
| Earthworks (excavation, embankment) | $m^3$ | 0.2 – 0.4                               |
| Waterproofing                       | $m^2$ | 0.1 – 0.2                               |
| Metal structures (auxiliary)        | T     | 10 – 15                                 |

Note: The factors values are approximate and should be specified based on local cost estimates and the actual cost of the work.

Among the advantages of using the reduced concrete method, the following can be distinguished:

- reduced concrete takes into account factors that affect strength, thereby providing more accurate calculations;
- the accuracy of determining the required amount of different materials when using the reduced concrete method allows you to save money on the construction of a hydraulic structure;
- taking into account various factors helps reduce the risk of problems with the strength of a hydraulic structure.

Among the disadvantages of using the method are:

- calculating the required volume of reduced concrete is a complex task, since it is necessary to take into account various factors;

- to apply the method, it is necessary to solve specialized tasks in the field of structural mechanics, which can be quite complex.

Recommendation for calculations can be the next:

- the method can be used as a preliminary filter between options at the level of the draft feasibility study (with transparent local reduction coefficients);
- the next step is to proceed to a full cost comparison and/or life cycle analysis (including energy, repairs, downtime).

#### 4. CONCLUSIONS

The reduced concrete method is a useful engineering tool for preliminary comparison of water supply and sewerage facility options. It allows for a quick assessment of the economic feasibility of solutions by reducing costs to a single criterion. At the same time, for the final choice, it is necessary to apply full-fledged technical and economic calculations in accordance with modern regulatory requirements and international practice.

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