Share of the volume of work types and financial costs according to the stages of construction of reinforced concrete monolithic buildings

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Share of the volume of work types and financial costs according to the stages of construction of reinforced concrete monolithic buildings

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Abstract. The aim of the paper is to evaluate the technological and economic demands on the construction of multi-storey reinforced concrete monolithic buildings for administrative purposes incorporating the stages of construction, technological stages and selected partial construction processes.

The entry criteria for objects that are included in monitoring and evaluation are their identical location, used technologies, mechanization, built-in materials and their purpose.

The purpose of the paper is to prepare tables for the professional and academic public for a rough idea of the proportional representation of time and financial consumption in the construction of this type of object, for selected stages of construction, technological stages and selected partial construction processes.

1. Introduction
The aim of this paper is to evaluate the technical and economic requirements for the construction of multi-storey monolithic reinforced concrete buildings for administrative purposes, divided into stages of construction, stage processes and selected construction sub-processes.

A subsidiary focus of the paper is the creation of financial indicators within the methodology of construction planning for building construction.

It will be possible to use the indicators listed below to provide a quick and basic informative estimate of the financial costs of reinforced concrete structures in the building industry. They may also see application as a tool providing aid and support in the production of plans for construction work or during pre-production business planning.

These indicators are necessary for rapid and correct decision-making in the field of construction planning. They can be used not only in design activities but also in supplier planning and for study purposes.

The creation of a system summary enables the application of theoretical methodology in a practical and illustrative form that can be used for construction planning activities throughout the preparation of an investment plan.

2. The state-of-the-art
At the end of the last century, large building companies developed their own user-friendly databases of financial expenses for individual types of structures and buildings, divided into construction stages. These databases helped the companies make quick decisions when creating new investment plans. At
present, there is no known publicly available work or publication that directly deals with the financial volume of work divided into stages of construction, stage processes and selected subsidiary construction processes for the mentioned use in construction planning.

The currently known investigated issues are dealt with using calculation software products (e.g. Build Power or Kros) which handle finances as part of their data (price) base using technical/economic indicators.

When dealing with the given issues, the investigator must prepare for the acquisition of data and their correct evaluation not only theoretically but also through being a direct participant in realized construction projects. This will enable the correct inclusion of the required delivery and assembly aspects of the relevant investigated parts of a given issue.

3. Methodology for the achievement of results
The fundamental prerequisite for the gaining of useful results is the correct theoretical division and subsequent application of the obtained data. Within the given topic, defined parts (intermediates) that arise chronologically are determined during the construction planning of buildings [1].

These parts are known as stages of construction, which are composed of technical stages. A technical stage is structurally and production-wise a comprehensive part of the building or structure (i.e. a set of structures – not a process). A stage process is an aggregate of subsidiary construction processes whose product is a technical stage. A construction stage process is an aggregate of stage processes whose product is a stage of construction. A stage of construction is thus a part of a building which is comprehensive as far as production is concerned, i.e. composed of several technical stages that are related technically or in terms of purpose [2].

The individual stages of construction (complete parts of the structure) and stage products are clearly defined by characteristics and are divided into sub-units that will be the main indicators in this paper. It is clear from the facts stated above that the indicators of the individual technical stages will then be grouped into stages of construction as follows:

1.) substructure
   ground work (and demolition), foundations, substructure;
2.) superstructure
   superstructure, roofing;
3.) interior works
   partition walls, piping and wiring, application of interior plasters and floor underlays;
4.) finishing works
   construction of floors, completion of surfaces and equipment, completion of piping, wiring and interior works, external modifications.

As a stage process, quality control and handover are not strictly assigned to one specific stage of construction as they can be carried out within all four comprehensive parts of the stages of construction.

Another requirement that should be met in order to achieve relevant results is the determination of the input parameters of the samples from which the data will be obtained. The criteria that the samples (buildings) must have in common are: the location of the building, the purpose of the use of the structure, the supporting structural system, the use of materials (including products and semi-finished products), and building services [3].

The data are taken from specific realized samples (buildings) with the following parameters: the location is in the South Moravian region of the Czech Republic; the purpose is the operation of an administrative building with rental space; the supporting structure is a combined load-bearing system based on deep foundations (pilots) with basements and above-ground floors; the materials are monolithic reinforced concrete with a modular façade and plasterboard structures; and there is a complete array of building services, including measuring and regulation systems along with backup diesel generators. For the relevant determination of the price of the building, it is necessary to place the buildings in a built-up area with a direct connection to utility networks. If the building is not in a built-up area, utility costs will be higher than shown below.
In addition to the input parameters mentioned above, the data used for the determination of indicators also fulfilled the following conditions: the owner and operator of the building are one and the same, and there is a certification programme for the building, designer and contractor. The enclosed space is 63 000 m³ ± 3%.

The operational design of the building is structured as a base building for the subsequent creation of fit-outs for open offices with outdoor landscaping.

The participation of the investigator in the further acquisition of data at the given structures should be direct and active, ideally from the position of being a member of the technical preparation or construction management staff working for the contractor, or a project manager or technical supervisor working for the builder. Thanks to this, the investigator will not only have access to financial data but will also be able to work with them and evaluate them.

4. Results

Table 1. Percentage share in the total costs of each stage of construction.

| No. | Stage of construction | Percentage [%] |
|-----|-----------------------|----------------|
| 1.  | Substructure          | 15.05          |
| 2.  | Superstructure        | 31.30          |
| 3.  | Interior work         | 15.38          |
| 4.  | Finishing works       | 38.27          |
| Total|                       | 100.00         |

Table 2. Percentage share in the total costs of the individual technical stages of construction.

| No. | Stage processes of building construction | Percentage [%] |
|-----|------------------------------------------|----------------|
| 1.  | Ground work and demolition               | 1.15           |
| 2.  | Foundations                               | 4.01           |
| 3.  | Substructure                              | 9.71           |
| 4.  | Superstructure                            | 29.32          |
| 5.  | Roofing                                  | 1.92           |
| 6.  | Execution of partitions, piping and wiring| 13.75          |
| 7.  | Execution of interior plasters and floor underlays | 1.51 |
| 8.  | Construction of floors, completion of surfaces and equipment | 11.97 |
| 9.  | Completion of piping, wiring and interior work | 22.81 |
| 10. | Exterior finishes                        | 3.46           |
| Total|                                         | 99.59          |

Table 3. Percentage share in the total costs of utility network stage processes.

| No. | Utility network stage processes | Percentage [%] |
|-----|---------------------------------|----------------|
| 1.  | Ground work                     | 0.20           |
| 2.  | Structural work                 | 0.06           |
| 3.  | The construction itself         | 0.13           |
| 4.  | Finishing works                 | 0.03           |
| Total|                                | 0.41           |
Table 4. Percentage share in the total costs of subsidiary construction processes and professions.

| No. | Selected subsidiary construction processes and professions | Percentage [%] |
|-----|----------------------------------------------------------|----------------|
| 1.  | formwork                                                 | 3.44           |
| 2.  | demoulding                                               | 1.30           |
| 3.  | reinforcement                                             | 6.85           |
| 4.  | concreting                                                | 6.24           |
| 5.  | tower cranes                                             | 1.01           |
| 6.  | masonry                                                  | 0.60           |
| 7.  | modular facades                                          | 18.28          |
| 8.  | internal fillings of openings                           | 1.83           |
| 9.  | plasterboard structures                                  | 0.90           |
| 10. | wiring work                                              | 9.41           |
| 11. | sanitary installation                                    | 3.11           |
| 12. | air handling units                                       | 6.54           |
| 13. | cooling of the building                                  | 4.87           |
| 14. | heating of the building                                  | 2.17           |
|     | Total                                                    | **66.55**      |

5. Discussion

Based on the obtained and processed data on the financial volumes of the samples used (structures), the following percentages were determined for the stages of construction and stage processes.

The total financial volume of the construction project is one hundred percent. Each stage of construction and stage process attains a specific number of percent which determines its level of cost as part of the construction process.

It is clear from the results that the chronology (order) of the technical construction processes is not the same as the order of costs from the most expensive to the cheapest, or vice versa.

To illustrate the results from the evaluated data, the total price of building construction is used, e.g. 500 million Czech crowns, alongside the total price in EUR at an assumed exchange rate of 25.50 CZK/EUR. These financial details have been chosen randomly to show the variable and practical use of the investigated issues.

If we maintain the sequence of the technical construction methodology, the cost levels according to the stages of construction and stage processes are as follows:

Table 5. Example cost levels of the stages of construction.

| No. | Stage of construction | amount        |          |          |
|-----|-----------------------|---------------|----------|----------|
|     |                       | [%]           | [CZK]    | [EUR]    |
| 1.  | Substructure          | 15.05         | 75,250,000,- | 2,950,980.39 |
| 2.  | Superstructure        | 31.30         | 156,500,000,- | 6,137,254.90 |
| 3.  | Interior work         | 15.38         | 76,900,000,- | 3,015,686.27 |
| 4.  | Finishing works       | 38.27         | 191,350,000,- | 7,503,921.57 |
|     | Total                 | **100.00**    | **500,000,000,-** | **19,607,843.14** |
The involvement of tower cranes is 1.01% (5,050,000,- CZK).

Table 6. Example cost levels of the stage processes of the building.

| No. | Stage productions of the building | amount [CZK] | [EUR] |
|-----|-----------------------------------|--------------|-------|
| 1.  | Ground work and demolition        | 5,750,000,-  | 225,490,20 |
| 2.  | Foundations                       | 20,050,000,- | 786,274,51 |
| 3.  | Substructure                      | 48,550,000,- | 1,903,921,57 |
| 4.  | Superstructure                    | 146,600,000,- | 5,749,019,61 |
| 5.  | Roofing                           | 9,600,000,-  | 376,470,59 |
| 6.  | Execution of partitions, piping and wiring | 68,750,000,- | 2,696,078,43 |
| 7.  | Execution of interior plasters and floor underlays | 7,550,000,- | 296,078,43 |
| 8.  | Construction of floor, completion of surfaces and equipment | 59,850,000,- | 2,347,058,82 |
| 9.  | Completion of piping, wiring and interior work | 114,050,000,- | 4,472,549,02 |
| 10. | Exterior finishes                 | 17,300,000,- | 678,431,37 |
| **Total** |                                  | **498,050,000,-** | **19,531,372,55** |

Table 7. Example cost levels of utility network stage processes.

| No. | Utility network stage processes | amount [CZK] | [EUR] |
|-----|---------------------------------|--------------|-------|
| 1.  | Ground work                     | 1,000,000,-  | 39,215,69 |
| 2.  | Structural work                  | 300,000,-    | 11,764,71 |
| 3.  | The construction itself          | 650,000,-    | 25,490,20 |
| 4.  | Finishing works                  | 150,000,-    | 5,882,35 |
| **Total** |                                  | **2,100,000,-** | **82,352,94** |

During the investigation of the given issues, several obstacles may occur which limit the collection and evaluation of data.

It is mainly a long-term activity which enables the gradual evaluation of even a small number of samples (structures), these mainly being financially demanding buildings costing in the order of hundreds of millions of Czech crowns.

The obtained results show that the described methodology can be used to estimate the financial demands of buildings.

If more samples were obtained and evaluated not only from a specific town and its surroundings but also from specific parts of the Czech Republic, the European Union and the world, percentage shares in total costs could be determined for regions, states and continents.

6. Conclusion

Based on the obtained results, it can be said that the values for each stage of construction are for the substructure 15.05%, superstructure 31.30%, interior work 15.38% and finishing works 38.27%.

The shares in the total costs of the technical stages of construction of the following are: ground work and demolition 1.15%, foundations 4.01%, substructure 9.71%, superstructure 29.32%, roofing 1.92%, execution of partitions, piping and wiring 13.75%, execution of interior plasters and floor underlays 1.51%, construction of floors, completion of surfaces and equipment 11.97%, completion of wiring installations and interior work 22.81%, exterior finishes 3.46%.

For utility networks, the percentage shares in the total costs are divided thus: ground work 0.20%, structural work 0.06%, the structures themselves 0.13% and finishing works 0.03%.

It can be said with regard to construction processes and professions that the percentage share in total costs of monolithic reinforced concrete structures in relation to the whole construction process is 17.83%, which is 89,150,000,- CZK. The involvement of tower cranes is 1.01% (5,050,000,- CZK),
masonry 0.6% (3,000,000,- CZK), modular façades 18.28% (91,400,000,- CZK), interior fillings of openings 1.83% (9,150,000,- CZK), plasterboard structures 0.90% (4,000,000,- CZK), building services 16.69% (83,450,000,- CZK) and wiring work 9.41% (47,050,000,- CZK).

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