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COST STRUCTURE FOR RESIDENTIAL BUILDINGS WITH REINFORCED CONCRETE STRUCTURAL SYSTEM

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Determining the participation of each type of works in the total construction costs for the building is a useful issue, particularly in the early stage of the project. Therefore, data has been collected for fifteen residential buildings built in Macedonia. Buildings have reinforced-concrete structures, one underground level and four to seven levels above the ground. The participation of each type of works in the total construction costs for each building was calculated. Their average participation is: earth works 3,02 %, concrete and reinforced-concrete works – 41,55 %, masonry works – 10,84 %, roofing works – 2,44 %, plastering – 14,67 %, painting – 0,76 %, floor works – 12,95 %, insulation works – 4,22 %, doors and windows – 9,55 %. Although the values presented are approximate, they can be used to roughly predict costs of each type of work for residential buildings with reinforced concrete structure.

Keywords: costs, cost structure, construction works, residential buildings, reinforced-concrete structural system.

1. INTRODUCTION

The accuracy in the estimation of construction costs, as well as the project budget; always have an influence on the building construction and the project participants' work [1]. Therefore, knowing the building cost structure is a useful for all project participants, although its determination is a complex procedure. Hence, it is an imperative to determine the participation of each type of works in the total construction costs for the building with satisfactory accuracy [2].

Globally, building costs are determined by many factors whose influence depends on a set

of circumstances, such as conditions of the building location and its' surrounding, the impact on the environment, market conditions, the investor's wishes and needs (including the luxury of the building), the pricing methodology applied by each of the participants in the construction project, etc. [3-5]. Furthermore, costs are influenced by the type of contract signed between the project participants, the sustainability rating of the building, the references and reputation of the project participant, the method used for cost forecast, the expertise and experience of the personnel who calculate the costs, software application etc. [6-10].

The building costs are also impacted by the complexity and duration of the construction process, which usually lasts for months or years. During that period, usually there are changes in the costs of materials, human resources and energy, which directly affect the construction costs [11, 12]. Furthermore, there are other circumstances related to the total costs, such as: influences on the cash flow; financial activities faced by project participants; influences on profit percentage; delay of construction; delay of incomes; interruption of the construction process; supply of materials, machines, equipment and other resources; usage of recycled materials; the quality of performed preparatory work; software used; management of the construction site, etc. [13-17]. In addition, in construction practice, each of the project participants has their own interests regarding the costs and price of the building.

The factors that influence the costs of the buildings have been investigated by many researchers and participants in the construction processes worldwide, from various aspects [18]. One of the aspects is a research on the factors that determine the costs of a building. Laksono investigated project implementation time, depth of the foundation, number of floors and floor area as independent variables for the multiple linear regression of stepwise method [19]. The contracted value of the project for the building was a dependent variable. Results showed that project time implementation, number of floors and floor areas are factors that have significant influence on building cost.

A guide for detailed estimation of construction costs, based on the estimation by category of works is given in [20]. Similarly, an analysis of the cost structure of construction works is presented in [21]. Authors use the model based on the cost estimation of works.

El-Kholy et al. applied Monte Carlo Simulation for prediction of the simulated cost contingency [22]. For building designs are developed artificial neural network and regression based models to predict simulated cost contingency for steel reinforcement. The research results pointed that the artificial neural network models are more powerful than regression based models in the theoretical modelling of simulated cost contingency.

Design optimization is necessary for each building. Therefore, computational tools play an important role in order to maximize the cost efficiency and the sustainability of the structures. In that sense, [23] presents several iterations for reinforced concrete building layout and develops optimization model that integrates Building information modelling (BIM) with computer programing and structural design. BIM is also used in [24] to present a conceptual cost-estimation model when structural analysis and design are BIM-based.

Data for residential buildings built with reinforced concrete, but damaged due to the earthquake, are analyzed by Del Vecchio et al. [25]. Using computer tools and actual costs for repairing the buildings, authors made probabilistic loss assessments. It was obtained that there are some economic losses in building designs due to their seismic design. Another study [26], analyzed the quantity of structural materials and their estimation for reinforced concrete buildings designed for seismic effects. The conclusion was that the parametric quantity modelling is useful for cost estimation purposes. In that sense, for Indonesia, where earthquakes are often, Suhendi et al. analyzed several types of residential buildings [27]. They noted that for residential buildings the structural costs are average of 34.20% of the total costs.

Related to the construction costs there are useful guides, reports and baselines. They usually give indicative data and guidelines for construction costs, since many factors should be taken into account, according to the specific case [28]. However, the amount of total costs for the building, as a value, do not indicate how the construction costs were distributed and the price was obtained. In that relation, although the estimate cannot be accurate, the benefit of knowing the percentage participation [%] of cost for each type of work in the total construction costs is of great importance, particularly in decisions making processes related to the buildings. There are opportunities to arrange the costs in forms that will be suitable for further use, regardless of the costs variability over time. One such possibility is

determining the cost structure, i.e. determination of the percentage share of the costs of various types of works in the total construction cost.

In RN Macedonia, there is no official data for the costs structure for buildings, nor official methodology and software for costs estimation. Furthermore, it is very difficult to obtain such data from construction companies. Therefore, the aim of this paper is to investigate the cost structure of residential buildings. The focus is on residential buildings with reinforced concrete structural system, as the largest number of constructed buildings for collective housing in RN Macedonia.

2. RESEARCH METHOD

Using interview research method, data have been collected from contractors for fifteen residential buildings built in South-West region of RN Macedonia, in the cities Ohrid and Struga. Buildings are built in the last decade, including all their phases, from their initial period. Their structural system is a reinforced concrete skeleton system built using wooden formwork. Buildings have one underground level and four to seven up-ground levels. Reinforced concrete skeleton systems include vertical columns and walls, as well as horizontal beams in both directions, with various dimensions according to the static calculation. The floor structured are designed as massive reinforced concrete slabs. The basement walls are reinforced concrete, while the facade walls are masonry, with ceramic blocks and energy efficiency facade. Partition walls between the apartments are masonry work of ceramic blocks with appropriate thermal insulation, while the partitions in the apartments are built of plasterboards. The roof structure is timber class 2, with roofing of plasticized ribbed sheet, on a wooden panelling, insulated with mineral wool, protected with a vapour barrier [29].

As mentioned above, there is no official model for costs breakdown and presentation as costs structure in RN Macedonia. Consequently, the contractor and other project participant use their own cost calculation methodology and the selected model for the breakdown of the total building costs and their grouping depends of the contractor's own methodology. Therefore, the buildings' collected data were additionally arranged and grouped in order to be enabled the usage of the same cost structure for all buildings.

3. RESULTS AND DISCUSSION

Nine different groups of works were taken into account in the costs structure of the construction works. That are costs, which have the greatest influence in defining the overall cost for building construction. The nine groups of considered works are earth works, concrete and reinforced-concrete works, masonry works, roofing works, plastering, painting, floor works, insulation works, doors and windows. Their participation in the total building costs was calculated for each building, as well as their average participation (in %) for all buildings.

The costs for preparatory works for each construction site (offices, warehouses, security, water for the construction site, etc.) were not taken into account; they are calculated as a special group of costs that are not analyzed in this paper. The costs of the location are not included, as well.

The results of the performed analysis for each building separately are given in the Table 1. Furthermore, the average value (in percentage [%]) participation of each type of work in the total construction costs was calculated for each building, separately.

Regarding Table 1, the following can be concluded:

- Earth works participate with 2,55-3,60 [%], average 3,02 [%],
- Concrete and Reinforced-concrete works participate with 38,11-44,30 [%], average 41,55 [%],
- Masonry works participate with 9,40-12,28 [%], average 10,84 [%],
- Roofing works participate with 1,93-4,00 [%], average 2,44 [%],
- Plastering participate with 12,38-21,73 [%], average 14,67 [%],
- Painting participate with 0,38-1,02 [%], average 0,76 [%],
- Floor works participate with 10,92-15,10 [%], average 12,95 [%],
- Insulation works participate with 2,47-6,10 [%], average 4,22 [%],
- Doors and windows participate with 8,65-11,38 [%], average 9,55 [%].

The obtained results support the research outputs of Martinec et al. who noted that concrete and reinforced-concrete works has the highest participation in the total costs for buildings with reinforced concrete structure [21]. This is also supported by the research results of Suhendi et al. [27]. As mentioned

above, their research indicates that for residential buildings the concrete structure costs are average of 34.20% of the total costs.

It should be noted that the accuracy of the cost estimation, particularly from the contractor's point of view, depends on a large number of parameters. Some of them are the type of the contract, the quality of the project documentation, applied methods (models) for cost estimation, the personnel in charge of implementing the procedure for estimating costs, the methodology and software used and other factors. Therefore, the presented values are approximate and can be used for roughly prediction of costs for each type of building construction works for residential buildings with reinforced concrete structural system when the building project budget is known.

For the future research is suggested to collect more data and to compare it with the data for constructed residential buildings in other cities and regions in RN Macedonia and, also with the other types of buildings.

Table 1. Construction works participation in total costs for residential buildings

No.	Building gross area [m^2]	Earth works [%]	Concrete and reinforced concrete works [%]	Masonry works [%]	Roofing works [%]	Plastering [%]	Painting [%]	Floor works [%]	Insulation works [%]	Doors and windows [%]
1	3.000,00	2.57	43.63	12.01	1.97	14.99	0.45	11.33	2.82	10.21
2	4.241,40	2.55	42.87	11.46	2.45	13.68	0.42	12.58	3.07	10.91
3	1.617,75	2.57	38.11	9.86	4.00	21.73	0.38	11.27	2.47	9.65
4	2.234.40	3.40	43.10	12.11	1.98	15.26	0.46	10.92	2.57	10.20
5	3.734,37	3.60	42.40	12.28	1.93	15.67	0.49	11.94	2.82	8.87
6	3.282,55	3.05	38.49	11.59	2.03	14.48	0.95	12.56	5.92	10.93
7	3.359,16	3.08	38.89	11.71	2.01	14.31	0.94	12.41	5.85	10.80
8	3.143,50	3.16	38.30	11.64	2.05	14.08	0.94	12.74	5.85	11.38
9	1.826,08	2.89	42.50	9.40	2.20	12.75	0.98	14.52	6.10	8.65
10	1.624,86	3.10	41.46	9.70	2.30	12.38	1.02	15.10	5.80	9.00
11	1586,68	2.90	40.20	9.85	3.35	12.60	1.00	15.10	5.65	9.35
12	2585,30	3.10	41.50	10.15	2.20	15.60	0.90	14.55	2.80	9.15
13	1.326,54	2.95	44.30	10.20	2.80	15.40	1.00	11.50	5.10	6.80
14	935,80	3.00	45.70	9.80	3.30	13.40	0.90	13.65	3.10	7.10
15	2.825,30	3.35	41.80	10.80	2.10	13.70	0.60	14.10	3.40	10.20
Average		3.02	41.55	10.84	2.44	14.67	0.76	12.95	4.22	9.55

5. CONCLUSIONS

Buildings must meet numerous requirements related to relevant regulations, but also from the project participants and future users of the buildings. All this affects construction costs. Therefore, knowing the costs of each type of building work is of particular interest to all project participants.

Cost estimation is an extremely difficult and demanding task, especially in the early phase of the project realization due to the many unknowns in relation to the factors that influence the construction. Accurate cost estimation is not possible. However, the accuracy of cost estimation has an influence on the project realization and project participants' work. The costs presented in this paper are calculated by the contractors of the residential buildings, based on the project documentation for the constructed buildings. Therefore, the values presented are only an indication of how much each type of the building construction work will "roughly" cost. Besides that, the presented values can be used for roughly prediction of costs for works for residential buildings with reinforced concrete structure

The process of development of the cost review is complex and responsible, but it is of great help in all phases of design implementation. Therefore, it is very important to use the experience gained from designs realized up to the moment of the cost estimation. Thus, although the research is focused on building construction in Macedonian context, it can be used as an experience for similar research around the world.

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