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# COMPARISON STUDY BETWEEN A CONCRETE FRAME STRUCTURE AND A MASONRY STRUCTURE FOR A FIVE-STOREY BUILDING

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***Abstract***

*The current study focuses on the structure cost and the energy efficiency for a five-storey building located in Timisoara, Romania. A cost comparison and the energy demand between two types of structures was concluded, namely a concrete structure and a masonry structure. The study focuses only on the building's structure because the building's finishes and the installation are the same for both cases. Regarding the energy efficiency, the difference appears for the exterior walls, in the first case, for the concrete structure building the walls are realized with autoclaved cellular concrete (ACC) and in the second case for the masonry structure the exterior walls are realized with brick masonry. The walls insulation is the same in both cases.*

***Key words:*** *cost comparison, frame structure, masonry structure.*

## INTRODUCTION

The current study focuses on the decision factors when choosing a structural solution for a building. The analyzed building has five floors, which is the maxim number of floors for a masonry structure building in Romania, according to the National Normative. The two factors are the economic factor and the energy efficiency factor, which are combined in a life cycle cost analysis.

There are two structural cases chosen for this study, the first one, using reinforced concrete frames, and the second one using a masonry structure. In the case when the structure is realized using reinforced concrete, the design is made using beams and columns. A more cost-efficient design would be using flat slabs and columns, but considering the irregularity of the building this solution is not considered because of the seismic instability (Sahab et al., 2005). In the case when the structure is realized with masonry, a cost-reduction solution for the building, would be the reduction of the wall thickness, but this would reduce the shear strength of the building, and in terms of efficiency this would not be beneficial (Min Jiang, 2020).

The concrete class used in both cases of the study is C25. A higher class would increase significant the building cost, and the reduction of the element would be subtle (Khan I.K. & Abbas H., 2011).

In each case, the structural conformation is attentively designed, so that the building does not collapse, in the first case, and secondly, in case of a seismic impact, the damages should be subtle. The cost would be overwhelming if the building suffers a big damage (Roque et al., 2021).

In terms of sustainability, a more suitable material would be timber. But in Romania, because of the high deforestation and the low level of regenerating the forests, this solution is not suitable (Ahmed Shafayet & Arocho Ingrid, 2021).

Regarding energy efficiency, the major difference between the chosen solutions, is the material used for the exterior walls. In the first case the walls are realized of autoclaved cellular concrete (ACC) and in the second case the walls are realized using bricks with gaps. Considering the two types of exterior walls used, even though the ACC has a higher thermal resistance than bricks with gaps, the masonry walls with bricks have a higher thermal inertia, that offers a better interior comfort (Uroš, M. et al., 2023).

The life cycle cost analysis consists of the initial investment, the future cost for a chosen period. The actualization factor and the waste value at the end of the analyzed period. The initial investment deducted, may differ to the real cost of the building with 2-4%, as shown in a study. This difference is due to the loss of concrete during the implementation phase, which may be even higher depending on the experience of the builder (Kanit Recep et al., 2007). The cost is affected by factors like the construction level, the coordination ability between different type of work, the preparation rate and assembly rate (Linkevicius, E. et al., 2023).

An important role in the life cycle cost analysis is assigned to the location of the building, pricing may vary depending on the location. All the financial parameters may differ, including material price, manufacturer price and energy price (Samani P. et al., 2015).

The LCC analysis is suitable for every investment to determine the profitability of the project. The cost-effectiveness is an important matter, especially nowadays in a crisis period, and a small reduction counts even more for a large surface building (Mwafy A. et al., 2015).

## MATERIALS AND METHODS

The analyzed building is in the design phase now, and it will be in the city of Timisoara, Romania. The building developer wants to get the best cost-efficiency for the building, so a study is required. The building has five floors, and it is a collective building with 20 apartments, and it has no basement.

There are two solutions considered. The first one is by using reinforced concrete frames for the structure, and the walls are realized with autoclaved cellular concrete (ACC). The second solution is chosen to be with masonry walls for the structure, and the walls are realized using bricks with gaps. The building is designed in both cases using the Romanian normative, especially the normative for building design in seismic zones, P100-1/2013.

The comparison between the two solutions follows the life cycle cost of the building. For realizing the life cycle cost analysis, it is required the cost of the building, but it is considered only the cost of the structure, the cost for the rest of the building is not considered, because it is the same for both cases, regarding the thermal insulation, the finish, and installations. Another element required for the life cycle cost analysis is the energy cost for the building.

The building cost is realized using the prices on the current market, and by using medium quality materials, used in most cases.

The energy cost for the building is determined using the current prices for the used energy (gas, electricity) and multiplying it with the energy demand deduced using the energetic stationary method. For this study a local program is used.

The life cycle cost is determined by using an excel program developed by the research team, that considers, the initial cost, the annual cost, the actualization factor and the waste value at the end of the analysis period.

**Structural solutions**

In the first case when using reinforced concrete frames, the main elements are the beams and the columns. The beams have the cross-section dimension 30x60 cm, and there are two types of columns, one with the cross-section dimension 40x40 cm, and the other one with variable cross-section, having the dimension 50x50 cm at the ground floor, and the dimension for the rest of the floors is 40 x 40 cm (Figure 1).

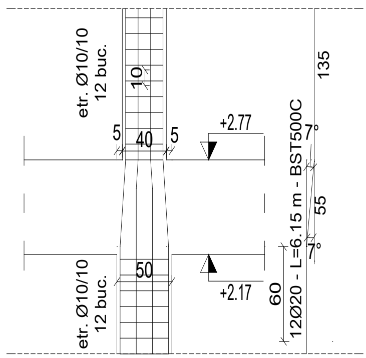


Figure 1. Vertical section of the beam with variable dimensions

The foundation of the building is realised using isolated foundations for each column, and coupling beams, elements that stiffen the foundation.

The roof for both cases is realised using wooden frames.

In the second case when using masonry walls for the structure, the thickness of the walls remains the same as in the first case, the difference is the material used, instead of ACC it is used bricks with gaps. Instead of the beams used in the first case, there are used smaller beams on each wall that have only 25 cm heigh. (Figure 2). Instead of the columns used in the first case, there are used smaller columns at the intersection of the walls (Figure 3). The beams and columns used in the second case have only the role to link the walls to each other, and not structural role.

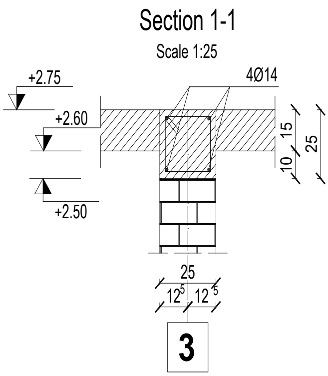


Figure 2. Beam on top of the wall

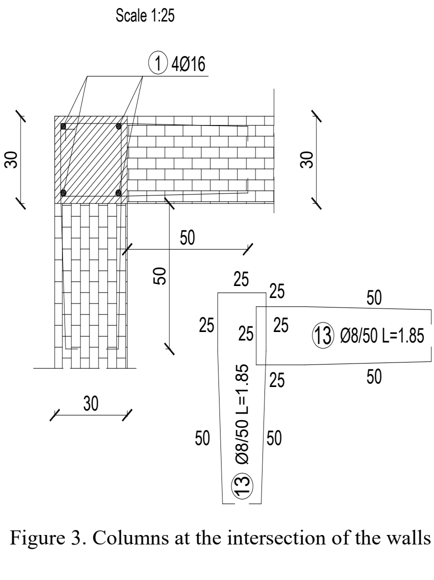


Figure 3. Columns at the intersection of the walls

## RESULTS AND DISCUSSIONS

### Building cost

The building cost is the initial cost for the life cycle cost analysis, but it is taken into consideration only the cost for the structure of the building, without finish and installation. This choice is because, the only difference when calculating the cost, is the type of structure. The total cost consists of the material price, the workforce, and the transportation. Also, VAT is included in the sum, and it is 19% for Romania. Table 1 displays the results for the total structure cost in the two considered cases.

Table 1. The cost differences between the two cases

| Case | Total cost (including V.A.T) [euro] | Price / built square meter [euro/sqm] | Price / useful square meter [euro/sqm] |
|---|---|---|---|
| I | 484448.36 | 347 | 384.21 |
| II | 450854.43 | 322.93 | 357.57 |

As shown, the initial cost is 7% higher for the first case, when the structure is realised with reinforced concrete frames. The difference may not be significant, but it can be a decision-making factor when choosing the solution. The surface is the same for both cases, so an important element when comparing the two solutions is the price per square meter, which is a very important indicator when developing a high surface building.

### Energy demand

The building envelope differs only for the exterior walls. For this element the different layer is the masonry, which in the first case consist of ACC and in the second case consists of bricks with gaps. The thermal conductivity for ACC is 0.1 W/mK and for bricks with gaps it is 0.207 W/mK. The lower the thermal conductivity is, the higher is the value of the thermal resistance. The thermal insulation for the exterior wall is the same in both cases, and it consist of 10 cm of expanded polystyrene. The thermal insulation of the slab under the roof is insulated using 15 cm of mineral wool and the ground slab is insulated using 10 cm of extruded polystyrene. The installation is the same for both cases. The heating is realised using local heating units that use gas as fuel, the same system being used for domestic hot water preparation. The cooling is not considered, and the ventilation is done naturally.

Internal gains are considered, from the building's residents. The building is occupied 24 hours per day. The stationary method considers a constant occupancy for the specified period. The energy demand is determined using the stationary energetic method, using the monthly method, according to the Romanian Methodology Mc 001-2006.

The envelope area of each element is presented in Table 2. The exterior walls represent over 50% of the building's envelope, so it has a high intake.

Table 2. Envelope elements surface

| Element | Surface | Unit |
|---|---|---|
| Ground slab | 252.4 | m² |
| Slab under roof | 252.4 | m² |
| North wall | 139.42 | m² |
| West wall | 226.47 | m² |
| East wall | 224.77 | m² |
| South wall | 139.42 | m² |
| North window/door | 19.66 | m² |
| West window/door | 66.01 | m² |
| East window/door | 67.71 | m² |
| South Window/wall | 19.66 | m² |
| Volume | 2895.03 | m³ |

The data described is used for obtaining the energy demand for heating, domestic hot water, lightning, and the total energy consumption. The data obtained for the two cases is shown in Table 3.

The consumption of domestic hot water and lightning remain the same in both cases because the envelope affects only the heating consumption.

Table 3. Energy demand

| | Case I | Case II | Measuring unit |
|---|---|---|---|
| Heating | 80,6 | 81,5 | kWh/m²year |
| Domestic hot water | 28,8 | 28,8 | kWh/m²year |
| Lightning | 2,6 | 2,6 | kWh/m²year |
| Total energy consumption | 112,0 | 112,9 | kWh/m²year |

**Life cycle cost**

Life cycle cost is an economical method used to determine the cost efficiency of an investment. The method is useful for higher investments.

The global cost for the analysed period contains data regarding the initial investment cost, the maintenance cost, the actualisation factor, and the waste value of the investment at the end of the analysed period. The maintenance cost contains the energy prices, consisting of natural gas and electricity. The prices considered were 0.067 Euro/Kw for natural gas and 0.16 Euro/kW for electricity, being the current energy prices in Romania.

For realising the calculus, and excel program was used developed by the research team. The results are presented in Figure 4 and show the investment cost over the chosen period, which in this case was chosen to be 20 years, even if the period for a radical rehabilitation is higher. The period was chosen considering the building as an investment.

The life cycle cost chart is presented in Figure 4. The chart shows that when using the case 1 structure, with a higher initial cost, the investment is not recovered in a 20-year period. This situation is because the difference between the energy consumptions is insignificant and using AAC walls does not bring such a big benefit.

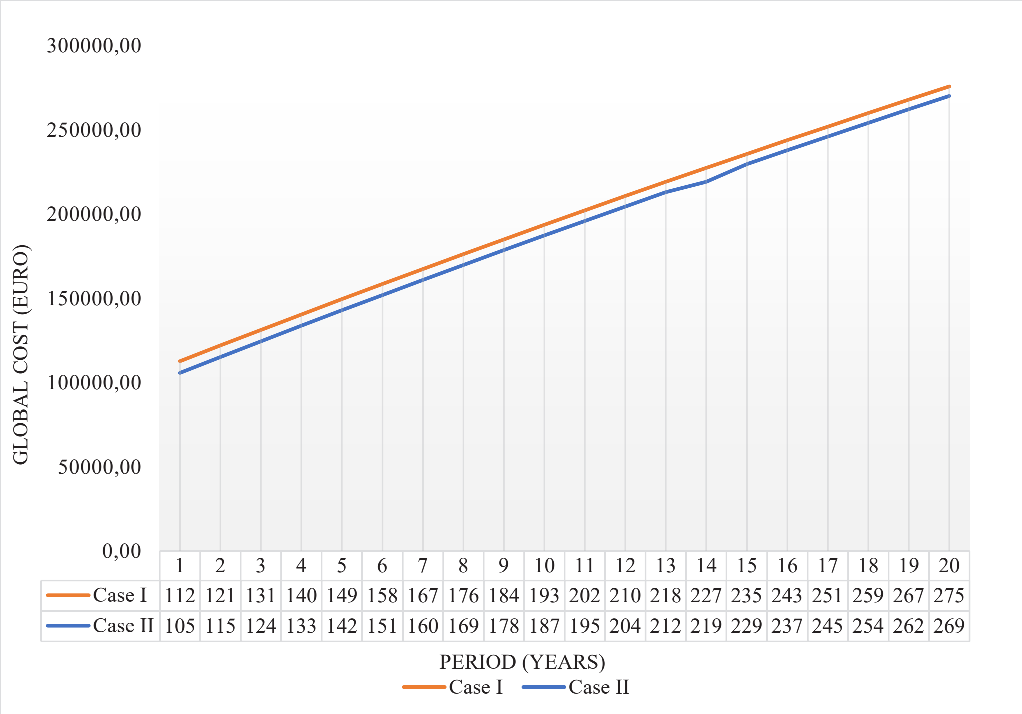


Figure 4. Life cycle cost analysis

## CONCLUSIONS

Considering the price increases in all sectors, the spendings should be reduced for every investment.
The life cycle cost presents a viable tool for determining which investment is useful and profitable.
The study presents a cost comparison between two structural solutions for a residential building, the first one is by using reinforced concrete frames for the structure, and the walls are realized with autoclaved cellular concrete (ACC) and the second solution is by using masonry walls for the structure, and the walls are realized using bricks with gaps.
The study shows that when choosing a reinforced concrete frame structure, the cost is significantly higher that a masonry wall structure and the investment does not pay off after a 20-year period.
The study is realized for a four-floor building, which is the maximum number of floors for the chosen zone in Romania, according to the national Normative.
When designing a higher building, in Timisoara, a reinforced concrete structure is necessary.

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## REFERENCES

Ahmed, S., Arocho, I. (2021). Analysis of cost comparison and effects of change orders during construction: Study of a mass timber and a concrete building project. *Journal of Building Engineering, 33.* 101856.

Kanit, R., Ozkan, O., Gunduz, M. (2007). Cost assessment of concrete and steel types for office buildings: An exploratory study. *Building and Environment, 42*(9). 3404–3409.

Khan I.K., Abbas H. (2011). Static and dynamic response of cost-effective unreinforced brick masonry buildings. doi: 10.1016/s1644-9665(12)60087-9.

Linkevicius, E., Žemaitis, P., Aleinikovas, M. (2023). Sustainability Impacts of Wood- and Concrete-Based Frame Buildings. *Sustainability, 15.* 1560. https://doi.org/10.3390/su15021560.

Min Jiang. Building cost control of assembly construction project using analytic hierarchy process. (2020). 5th International Conference on Smart Grid and Electrical Automation (ICSGEA)

Mwafy A., Hussain N., El-Sawy K. (2015). Seismic performance and cost-effectiveness of high-rise buildings with increasing concrete strength. 2015-03-04. doi: 10.1002/tal.1165.

Roque, E., Vicente, R., Almeida, Ricardo M.S.F., Ferreira, Victor M. (2021). Energy Romeu consumption in intermittently heated residential buildings: Light Steel Framing vs hollow brick masonry constructive system. *Journal of Building Engineering,* 43, 103024.

Sahab M.G., Ashour A.F., Toropov V.V. (2005). Cost optimisation of reinforced concrete flat slab buildings. *Engineering Structures, 27.* 313–322.

Samani P., Gregory J., Leal V., Mendes A., Correia N. (2018). Lifecycle cost analysis of prefabricated composite and masonry buildings: Comparative study. 2018-12-28. doi: 10.1061/(ASCE)AE.1943-5568.0000288.

Uroš, M.; Demšic, M., Banicek, M., Pilipovic, A. (2023). Seismic Retrofitting of Dual Structural Systems-A Case Study of an Educational Building in Croatia. *Buildings, 13.* 292. https://doi.org/10.3390/buildings13020292