

# COMPARISON OF COSTS OF BRICK CONSTRUCTION AND CONCRETE STRUCTURE BASED ON FUNCTIONAL UNITS

Soheyl Sazedj

*University of Évora, Department of Rural Engineering, Évora, Portugal*  
[sazedj@uevora.pt](mailto:sazedj@uevora.pt)

António J. Morais

*Architecture Faculty – Technical University of Lisbon, Department of Technology, Lisbon, Portugal*  
[ajmorais@fa.utl.pt](mailto:ajmorais@fa.utl.pt)

Said Jalali

*University of Minho, School of Engineering, Guimarães, Portugal*  
[said@civil.uminho.pt](mailto:said@civil.uminho.pt)

**ABSTRACT:** In the context of economic sustainability of building construction, it is an issue to decide which constructive solution is more reasonable without losing quality. This study is about the comparison of the costs of construction of structural walls; conventional reticulated reinforced concrete structure filled with ceramic blocks versus unreinforced masonry with ceramic blocks. Functional units are defined as inner and outer walls to enable a further specification of the costs in order to perform a more detailed comparison without having designed a specific architecture. The results show a lower cost of unreinforced masonry construction, especially in the case of small buildings, whether for home or public services.

## 1 INTRODUCTION

To decide which constructive solution for a structure is more economical, regardless of the architectural form, requires information and indicators that help to find economically sustainable solutions. An instrument recommended by ISO 14040, that regulates internationally the environmental assessment and life cycle of products, is the comparison of functional units. The standard requires that for the functional units must be created equal conditions in relation to all aspects of concern that may have an impact on the scientific comparison.

For this specific case, comparing conventional reticulated reinforced concrete structure and unreinforced brick walls both with ceramic blocks, this means that the units must have the same function regarding stability, thermal and acoustic behavior.

To compare the two constructive solutions, exterior and interior walls are defined as functional units, with spans of 4, 6 and 7 meters and a ceiling height of 2.7 meters. The comparison is carried out between the functional units of the same span.

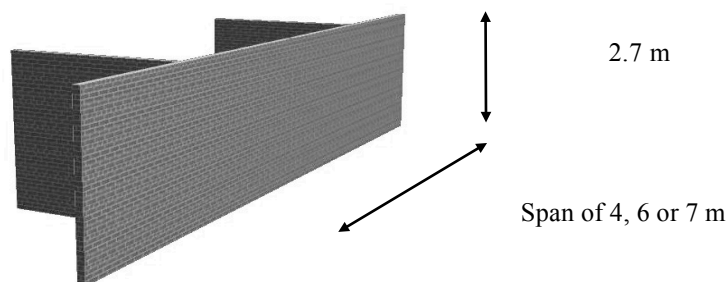


Figure 1. Brick wall as functional unity

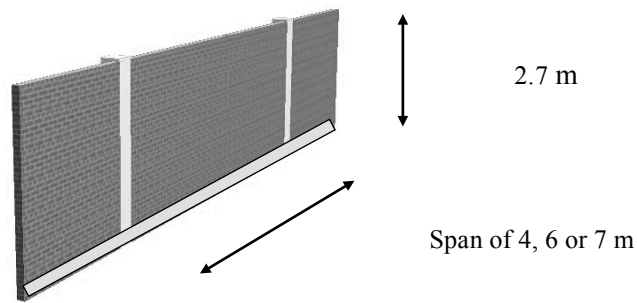


Figure 2. Wall of conventional reticulated reinforced concrete building filled with ceramic blocks as functional unit

## 2 CONDITIONS

The functional unit in conventional construction (CC) consists of side pillars and brick walls in between. The pillars are counted as half, as the pillar also serves for the wall that continues. The beams are considered in regard of the span. Therefore, the beam has a height of 40 cm, 60 cm and 70 cm depending on the span range of 4 m, 6 m and 7 m. As the slab is considered equal in both solutions, in case of CC the slab height of 20 cm is reduced from the beams for the quantification of the materials. For each level is just considered the lower beam as the upper beam serves for the upper level. In case of the masonry solution (M) the functional units consist simply of brickwork without columns and beams with equal dimensions of the CC solution.

The functional units are treated uncoated considering that in both solutions the coating will be the same to safeguard the same quality, concluding that the price of the structure is of interest. For the same reason the slabs are also equal for both constructive solutions. To avoid loss of quality on the thermal and acoustical behavior, the masonry units are considered without reinforcement. According to the National Laboratory of Civil Engineering of Portugal, for safety reasons and the weak seismic behavior of masonry, it is advised not to construct masonry buildings more than 3 or 4 floors. Suitably this comparison is limited to all the aforementioned conditions.

Regarding the thermal behavior, a simplified model of calculation is used to compare the medium heat transfer coefficient in connection with the surface area of the functional units. In both construction cases, CC and M, the walls are considered with 3 layers, from the inner to the outer side a 29 cm thermal brick, 1 cm of air and 3 cm of insulation with a thermal conductivity of 0.033 W/mK. In case of CC, the surface is divided in brick and concrete zone, whereby the concrete zone, 30 cm pillars, has no layer of air. So both walls are geometrically equal and have a thickness of 33 cm without coating. For the CC unite the medium value of the heat transfer coefficient must be considered, contrary to the M unite where the surface is equal and the coefficient can be determined directly. The comparison of the heat transfer coefficients shows that in case of CC the value is 0.456 W/m<sup>2</sup>K and in case of M 0.422 W/m<sup>2</sup>K. As the difference is very small, it can be concluded that both cases are very similar; as equality is technically impossible adequate heat insulation is used.

Two different scenarios are considered. In the first scenario the functional units are considered for the construction of a building with 3 or 4 floors and in the second setting the building has only one or two floors. It is noted that for both scenarios the beams have the same dimensions, since the design is independent of the height of the building. The beams are designed with an overload of 5 kN/m<sup>2</sup>, which permits the use of the building for public services.

In the first scenario the choice of the materials is guided by a study on the comparison of the conventional structures and unreinforced masonry (Sazedj, 2012). According to this study, to satisfy Eurocode 6, thermal bricks are used with a width of 29 cm for the outer walls and a resistant clinker brick, 11 cm wide, for the inner walls. This configuration ensures the static and dynamic stability, while satisfying the needs of the thermal and acoustic comfort, compatible with a reticulated structure of reinforced concrete. The exterior walls of the conventional construction have 29 cm width using the same thermal bricks equal to the masonry structure guar-

anteeing the same thermal quality. Therefore the pillars with 30 cm width are well designed for constructive reasons. As, previously mentioned, the comparison concerns a construction with a maximum of 4 levels, the design of the pillars with 30 cm meets also the required resistance and there is no need to consider a larger section for the lower floors. The functional units of the interior walls in case of conventional construction consist of lateral pillars, 30 cm width as mentioned, and a normal brick of 11 cm width.

In the second scenario in case of masonry the above mentioned structural requirements in relation to the inner walls do not exist, since the height is limited to two floors, interior walls can be built with sufficient stiffness using the common ceramic bricks used in the conventional construction. Table 1 lists the materials used in the functional units in both scenarios.

Table 1. Used construction material

MATERIAL	DIMENSIONS (mm)	DENSITY (kg/m <sup>3</sup> )
Normal brick	290x106x189	700
Clinker brick	237x115x70	1300
Thermal brick	294x289x189	1300

### 3 COMPARISON OF THE RESULTS

The cost is calculated according to the functional units, referring to the structure, including costs of materials, concrete, brick and mortar, and labor, considering one worker and a servant. The foundation is not considered since the foundation template is equal to either conventional construction or masonry.

#### 3.1 Scenario 1

Table 2 shows the costs for the construction of the functional units for the first scenario. Variation is estimated as  $\text{Variation} = \text{CC} - \text{M}$ . Hence, the sign minus indicates lower costs for Masonry option.

Table 2, Comparison of costs for scenario 1

Functional units	Exterior wall			Interior wall		
	CC	M	Variation	CC	M	Variation
4 m	537.72	418.18	-22 %	278.66	237.60	-15 %
6 m	841.01	627.26	-25 %	486.06	356.40	-27 %
7 m	1011.00	731.81	-28 %	619.72	415.80	-33 %

For the functional units of exterior walls can be seen that the masonry construction is more economic for spans studied and cost reduction increases with increasing span. Cost reduction varies with openings 4 to 7 m settling for 22 to 28%. This is due to the change in the height of the beams, which increases with increasing span. The span changes two meters, from 4 to 6 m, and then one meter, from 6m to 7 m, however the cost variation is 3% for both intervals.

In the case of interior walls the tendency is more marked as the span range increases. There is a cost reduction from 15% to 33% as the span increases from 4 m to 7 m. The variation appears more linear than in the case of the exterior walls although there are only three data.

The detailed costs for construction materials and labor are shown in the Tables 3 and 4.

Table 3, Comparison of material costs for scenario 1 (euro)

Functional units	Exterior			Interior		
	CC	M	Variation	CC	M	Variation
4 m	419.82	290.41	-31 %	201.66	163.51	-19 %
6 m	664.23	435.62	-34 %	358.79	245.27	-32 %
7 m	805.76	508.22	-37 %	464.75	286.15	-38 %

Table 4, Comparison of labor costs for scenario 1 (euro)

Functional units	Exterior			Interior		
	CC	M	Variation	CC	M	Variation
4 m	117.89	127.76	8 %	77.00	74.09	-4 %
6 m	176.78	191.65	8 %	127.26	111.13	-13 %
7 m	205.25	223.59	9 %	154.97	129.65	-16 %

The trend in the cost of materials is in accordance with the total costs. The materials costs have a higher weight than the labor costs. It appears that the labor costs in structural masonry are slightly higher in the execution of the exterior walls and slightly lower in the execution of the interior walls due to partial occupation of spaces for reinforced concrete beams.

### 3.2 Scenario 2

Table 5 shows the constructions costs of the functional units in the second scenario.

Table 5, Comparison of the total costs of the functional units for scenario 1 (euro)

Functional units	Exterior			Interior		
	CC	M	Variation	CC	M	Variation
4 m	537.72	418.18	-22 %	278.66	107.14	-62 %
6 m	841.01	627.26	-25 %	486.06	160.70	-67 %
7 m	1011.00	731.81	-28 %	619.72	187.49	-70 %

In the second scenario the costs remain the same for the outer walls, while for the interior walls costs become much more favorable for masonry construction. This means that small buildings up to two levels may benefit more from ceramic masonry, with a remarkable reduction of the costs of the interior walls 62 to 70% as the span increases from 4 to 7 m due to less necessity of structural stability in comparison to the first scenario.

The detailed costs for construction material and labor are shown in the Tables 6 and 7.

Table 6, Comparison of material costs for scenario 2 (euro)

Functional units	Exterior			Interior		
	CC	M	Variation	CC	M	Variation
4 m	419.82	290.41	-31 %	201.66	33.05	-84 %
6 m	664.23	435.62	-34 %	358.79	49.57	-86 %
7 m	805.76	508.22	-37 %	464.75	57.83	-88 %

Table 7, Comparison of labor costs for scenario 2 (euro)

Functional units	Exterior			Interior		
	CC	M	Variation	CC	M	Variation
4 m	117.89	127.76	+8 %	77.00	74.09	-4 %
6 m	176.78	191.65	+8 %	127.26	111.13	-13 %
7 m	205.25	223.59	+9 %	154.97	129.65	-16 %

In this scenario it becomes clear that the second scenario is more beneficial in the construction of the interior walls regardless of the outer walls as they must evidently have the same costs either in scenario 1 or 2. The interior walls in case of conventional construction turn to be more expensive because of the concrete used for the pillars and beams.

## 4 CONCLUSION

This study compares the costs of exterior and interior walls of conventional construction, reticu-

lated reinforced concrete structure and unreinforced masonry both with ceramic blocks. Functional units are defined with the same functional and physical criteria, structural, thermal and acoustic performance for walls with spans of 4 m, 6 m and 7 m. The results show that in small buildings, up to two floors and spans up to 7 meters, the material costs can be reduced. Cost reduction is obtained for the outer walls at least 22%, while for the interior walls at least 62%. The results are applicable in residential and public buildings, such as health centers or centers of administration. The labor cost is slightly higher, indicating the more intense application of manpower. In the high unemployment societies, such as Portugal at the time being, this can result in higher rates of employment.

## 5 REFERENCES

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