

SUSTAINABILITY AND FUNCTIONAL ASSESSMENT OF A MIXED BUILDING TECHNOLOGY SOLUTION

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ABSTRACT

Most of the new construction solutions arise from the feeling that something should be done in order to answer current society concerns: reduction of energy consumption, minimization of pollution, etc.

The aim of this paper is to evaluate the potentialities of a MBT – “Mixed Building Technology” solution. This solution was evaluated under the thermal, acoustic and natural lightning performance, and economical/environmental analysis.

Key words: MBT buildings, construction costs, environmental impact, thermal performance, acoustic performance, visual comfort

1 Introduction

Construction industry is one of the most important Portuguese economical sectors, but it still relies too much on traditional construction methods and unskilled handwork, being characterised by an excessive use of natural resources and energy. This implies a great environmental impact that could easily be reduced.

The construction industry and the buildings sector, contributes to the degradation of the environment through the dilapidation of natural resources (is responsible for the consumption of 25% of wood and 40% of aggregates), energy consumption (40% of the energy annually spent), atmospheric pollution and residues production (1).

Nowadays, society problems such as the growth in the world population, the amount of waste produced every year and the collapse of the natural resources, make us realize that our present way of life, including how and what we build, may not be sustainable in the future.

It is in the design phase that the sustainable building concepts should be applied, through the implementation of a strategic combined action that makes possible the reduction of the environmental impact through a judicious selection of materials, technologies and construction methods to be used.

Nowadays, research in this domain led to the use of lightweight and composite materials in the building construction. This new architectural perspective is known as MBT – “Mixed Building Technology”. MBT buildings are characterised by the use of lightweight and highly insulated envelope walls and punctual heavyweight materials for structural and energy reasons (e.g. thermal storage). In order to analyse the Mixed Building Technology potential, a case study is presented, where the performance of a MBT building is assessed and compared with the performance of an identical conventional building. The comparison of these two constructive solutions integrates:

- The satisfaction of two important functional demands: the thermal and the acoustic comfort;
- The natural lighting comfort and potentialities;
- The economical and environmental analysis.

2 Buildings Characterization

2.1 Geometry

To show the Mixed Building Technology potential it was selected a building enlarged according to a MBT strategy: an office building belonging to the Portuguese Electricity Company (EDP), located in Coimbra - Portugal. Figure 1 shows the frontal and the lateral view of the studied building.



Fig. 1 - Front and lateral view of the building

It must be pointed out that only the last floor of this building is a new construction and has been built according to a MBT strategy. The first two floors kept the original constructive characteristics during a rehabilitation process. The internal layout of the MBT floor (case in study) is an open space. In order to assess its potential, the characteristics of this room have been compared with the characteristics of a virtual one with the same geometry, but designed in a traditional constructive way in what concerns the structure, walls, windows and roof, i.e. adopting an architectural solution similar to the one used in the rehabilitated area. Figure 2 shows the schematic plan of the MBT and of the conventional buildings.

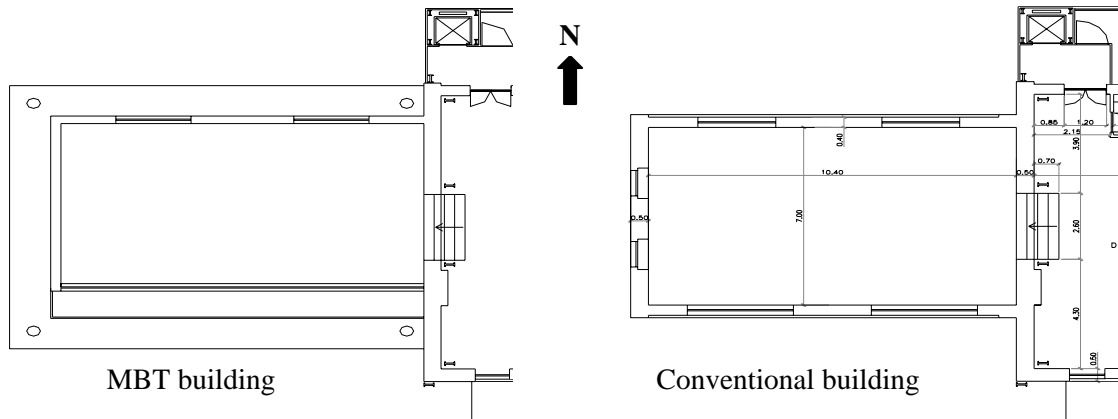


Fig. 2: Schematic plan of the MBT and of the conventional buildings

2.2 Constructive Characteristics of the MBT Building

The structure of the MBT room is made of laminated steel profiles, with HEA profiles used as pillars and IPE profiles as beams. The structural plan of pavement and covering slabs are equal. The technology used for the exterior walls is based on lightweight sandwich panels, consisting on a painted fibre glass reinforced render layer, a 5 cm thick layer of EPS (expanded polystyrene) fixed to a plywood panel, a 25 cm thick mineral wool layer and, on its interior surface, two 13 mm thick plasterboard leaves. The floor is a 12 cm thick lightweight steel reinforced concrete slab, made with lost metallic formwork plates. The floor covering is made of square plywood plates with linoleum coating, placed 10 cm above the slab in order to allow electric and network cables pass through. The roof consists on a lightweight concrete slab, made of a 6 cm thick concrete layer over lost metallic formwork plates. Above the support element is placed a 5 cm thick layer of XPS (extruded polystyrene) and two waterproof bituminous sheets, with an exterior protecting finishing. Under the slab there is a 13 mm thick plasterboard suspended ceiling. Table 1 lists the characteristics of the MBT building constructive elements.

TABLE 1 - Characteristics of the MBT building opaque envelope

	Area (m ²)	Mass (kg/m ²)	Overall conductance (W/m ² .K)
North wall	44.71	100	0.20
East/West wall	34.34	100	0.20
South wall	5.61	100	0.20
Floor	74.12	180	0.90
Roof	74.12	180	0.65

The windows have a double glaze (6+12+6mm) with low-leakage metallic frame. In the North facade the glass is clear on both sides and in the South façade the inside layer glass is clear and the outside layer is brown reflective. The solar protection of the windows is achieved with a pergola made with blades placed over the roof, as Figure 1 shows, and is complemented with an internal roller screen. Table 2 lists the major characteristics of the MBT building windows and shading devices.

TABLE 2 - Characteristics of the MBT building windows

Windows	Area (m ²)	Mass (kg/m ²)	Overall conductance (W/m ² .K)	Solar fraction (%)	
				Without roller screen	With roller screen
North	10.34	30	3.30	0.75	0.25
South	49.44	30	3.30	0.49	0.25

2.3 Constructive Characteristics of the Conventional Building

The conventional room geometry and constructive technologies were defined taking into account the rehabilitation strategy followed in the other two floors. The resistant structure of this solution is a steel reinforced concrete beams and pillars system. The exterior walls are double leaf (15+11 cm) hollow brick walls with a 2 cm thick layer of mineral wool placed in the air gap. The floor and the roof slabs are a 25 cm thick pre-strengthen beams and ceramic moulding blocks slab. The pendant of the roof is made of another pre-strengthen beams and ceramic moulding blocks slab, constituting a non-ventilated attic. The thermal insulation of the roof is a 4 cm thick mineral wool layer placed over the horizontal slab and the waterproofing of the set is guaranteed by ceramic roofing tiles on the tilted slab. The floor and ceiling finishing are made of wood and plaster board, respectively. These characteristics can be seen in Table 3.

TABLE 3 - Characteristics of the conventional building exterior walls, floor and roof

	Area (m ²)	Mass (kg/m ²)	Overall conductance (W/m ² .K)
North wall	44.71	371	0.85
East/West wall	31.34	371	0.85
South wall	40.65	371	0.85
Floor	74.12	290	1.00
Roof	74.12	290	0.90

The windows have double glaze (6+12+6 mm) with traditional aluminium frame. The glass is clear on both sides in all the facades. Table 4 lists the characteristics of the conventional building windows.

TABLE 4 - Characteristics of the conventional building windows

	Area (m ²)	Mass (kg/m ²)	Overall conductance (W/m ² .K)	Solar fraction (%)
North windows	10.34	30	4.20	0.75
East/West Windows	3.00	30	4.20	0.75
South windows	14.40	30	4.20	0.75

3 Thermal Performance Evaluation

3.1 Thermal Evaluation Method

The assessment of the thermal performance of both buildings was based on the evaluation of their energy consumption (2). For this, the energy needed to heat or to cool the air inside the buildings had to be determined. This quantification was based on the thermal load concept defined as the calorific power required to be supplied to (in winter) or to be removed from a space (in summer) so that the comfort conditions, such as the temperature (18°C in the heating season and 25°C in the cooling season) and the relative humidity, remain constant (3, 4).

The thermal load is obtained considering four separate components:

- Heat exchange by conduction through the opaque envelope - roofs, floors and walls;
- Heat exchange by solar radiation and by conduction through glazed areas;
- Heat exchange associated with the indoor air renewal - forced ventilation, natural ventilation or by infiltration;
- Heat released by internal heat sources, such as equipment, lighting and occupants.

The considered climatic data was the one correspondent to sequences of typical winter and summer days corresponding to the building's location: zone I2 for winter and zone V2 for summer according to the Portuguese legislation (3). The reference data for these zones considers an average heating degrees-day, in an 18°C base, of 800°C/year, in winter, and an exterior design temperature of 32°C for summer with a temperature amplitude of 13°C (5).

3.2 Thermal Evaluation Results and Comments

Table 5 summarizes the heating and cooling needs, partial and total values, estimated for the two analysed buildings.

TABLE 5 - *Building thermal performance*

	MBT Solution	Conventional Solution	MBT / Conventional
Heating Needs [kWh/year]			
- Opaque Exterior Envelope	1250	3185	↓ 61%
- Glazing	3788	2237	69%
- Air Renewal	2323	2323	0%
Useful Solar Gains [kWh/year]	3900	3514	11%
HN [kWh/year]	3461	4231	↓ 18%
Cooling Needs [kWh/year]			
- Opaque Exterior Envelope	327	484	↓ 32%
- Glazing	Without roller screen	1491	117%
	With roller screen		11 %
CN [kWh/year]	Without roller screen	1975	80%
	With roller screen		0%
HN + CN [kWh/year]	Without roller screen	6206	13%
	With roller screen		↓ 12%

This study shows that along a typical year, the overall energy needs in the MBT solution are 13% higher than in the conventional solution. This is due to its worst performance in summer caused by an exaggerated window area and by the absence of proper shading devices. If some interior roller screens are activated, the overall performance improves and, at the end, the MBT solution presents a better performance with energy needs 12% lower. It should be pointed out that in winter the MBT solution has a better performance since the heating needs are 18% lower than the ones of the conventional solution due to a better thermal insulation level of the building's opaque envelope, which makes possible a significant reduction on the heat losses through the building skin.

4 Acoustic Performance Evaluation

The assessment of the acoustic performance of any building should be done through the evaluation of each building element's noise insulation level. As the existing numerical estimation methods are not accurate enough to assess building acoustics (6), the acoustic performance of the MBT building was experimentally evaluated and compared with the acoustic insulation values obtained in earlier experimental studies performed by the Building Physics Laboratory of the University of Minho for several traditional constructive solutions.

4.1 Acoustic Evaluation Method

The acoustic MBT measurements were done according to the ISO 140 Standards, parts IV, V and VII (7), and the ISO 717 Standards, parts 1 and 2 (8).

The airborne sound insulation was measured by placing a sound source in one side of the element and measuring the sound pressure levels in this room and in the other side of the element, on a 1/3-octave band. The sound pressure levels were spatially averaged. With these values, the noise insulation of facades measured “in situ”, R_{45} , and the noise insulation of a partition element measured “in situ”, R' , were calculated according to the international standard EN ISO 140-IV and V procedures.

To measure the impact sound insulation, a standard impact was given to the floor, with a tapping machine, and the sound pressure levels, also on a 1/3-octave band, were measured in the receiving room. These sound pressure levels were also spatially averaged. With these values, the impact sound insulation of floors measured “in situ”, L'_n , was calculated according to the international standard EN ISO 140/VII procedures.

The EN ISO 717-1, 2 describes a rating method that fits a standard reference curve to the measured sound reduction index curve (R' and L'_n). The resulting values are the weighted sound reduction index (R'_w) and weighted normalized impact sound pressure level index ($L'_{n,w}$).

4.2 Acoustic Evaluation Results and Comments

The facades noise insulation (R_{45}), the floor weighted sound reduction index (R'_w) and the floor weighted normalized impact sound pressure level index ($L'_{n,w}$), for the MBT building are summarized in Table 6.

TABLE 6 - Buildings Acoustic Performance

Element type	R'_w (dB)	$L'_{n,w}$ (dB)	R_{45} (dB)
MBT Solution	Measured		
South facade (90% glass + 10% opaque)	-	-	30
East/West facade (0% glass + 100% opaque)	-	-	50
North facade (19% glass + 81% opaque)	-	-	40
Floor	53	70	-
Conventional Solution	Experimental Database		
South facade (26% glass + 74% opaque)	-	-	33
East/West facade (9% glass + 91% opaque)	-	-	35
North facade (19% glass + 81% opaque)	-	-	34
Floor	48	77	-

The study carried out allowed the conclusion that in almost all cases the MBT solution has a better acoustic performance than the conventional one due to the better quality of the glazing and to the higher level of insulation of the exterior wall. However, the MBT south facade possess a noise insulation index lower than the conventional solution due to its large area of fenestration. In spite of the higher mass of the conventional building floor, the floor finishing and the suspended ceiling, with small stiffness, backed with mineral wool quilts, make possible to obtain a better airborne sound insulation and impact sound insulation of the MBT building floor.

5 Natural Lighting Evaluation

The daylight availability in buildings is measured using the average daylight factor concept, which is a comparison between two illuminance measures. The illuminance, measured in lux, is the degree of concentration of light striking a surface. The daylight factor at a given point inside a room is defined as the illuminance at that point expressed as a percentage of the simultaneous horizontal illuminance under an unobstructed overcast sky. According to the “CIE - Commission

Internationale de l'Eclairage" (9) recommendations, for comfortable natural lighting conditions, the daylight factor should be between 3 and 5%. An average daylight factor greater than 5% will generally give the impression of generous day lighting while an average below about 2% would be judged gloomy and electric lights would be switched on as soon as an occupant enters the room. The ISO 8995 (10) recommends that the average illuminance values, for comfortable lighting work conditions, should be between 500 and 1000 lux.

5.1 Natural Light Evaluation Methods

The daylight availability was assessed in real work conditions and by computational simulation. Measurements of illuminance in the MBT building were carried out with the objective of evaluating "in situ" illuminance levels in an average day and collect data for calibration and validation of the simulation code to be used to predict the natural lighting availability inside both buildings (MBT and Conventional).

The illuminance measurements were carried out in May in accordance with the DIN Standards (11) and the CIE specifications (9). This became an adequate season to undertake the measurements since in this period there is some equivalence between clear skies, partially cloudy skies, and total cloudy skies. It was considered the amount of light striking a horizontal surface 75cm above the floor level in order to reproduce the working plane conditions. Due to frequent variations of sky conditions along the day, the measurements were carried out at different points of the room and at different hours of the day in order to adequately characterize the space. In these measurement campaigns, 45 points were considered in each room in a 1.20x1.20 m grid, distanced 0.60 m from the walls and windows. Illuminance measurements were carried out for the three positions of the roller screen: opened (O), half closed (HC) and closed (C). Measurements of horizontal external and internal illuminance were made simultaneously.

Computational simulations using Relux software (12) were made for both constructive solutions, by inserting architectural coordinates, exact location of building and orientation. The calibration of the computational model was done considering the values of the measured average illuminances in the MBT building with the roller screen in the 3 mentioned positions.

5.2 Natural Lighting Evaluation Results and Comments

With the indoors and outdoors measured values of illuminance, the average daylight factors (DF) were calculated. The average daylight factor obtained with the roller screen opened was 15.2%, which can be considered as a very high level of day lighting. For the other two positions of the roller screens (half closed and closed), the obtained DF values were 7.9 and 1.6%, respectively.

The computational model calibration process consisted in the adjustment of the values to be used for the solar radiation, the glazing transmittance and the interior surfaces reflectance. Table 7 lists the results of the simulation after the calibration.

TABLE 7 - Comparison between Simulation and Experimental Results

	Illuminance (lux)		
	Roller screen positions		
	Opened	Half closed	Closed
Simulation results	2 123	1 111	234
Experimental results	2 142	1 114	224
Simulation error	-19	-3	10

5.2.1 Results from Computational Simulation

The simulations made with the Relux software (12) used the climatic data supplied by the Daylight and Solar Radiance database Satel-Light (13) and permitted the attainment of the natural lighting space distribution in the room. Figures 3 and 4 show the space maps of the pseudo colour illuminances and the isolux curves for MBT and Conventional rooms. These maps were done for the climatic conditions of a typical middle spring day with the roller screen opened. As it can be seen, the MBT solution leads to a more uniform daylight distribution than the conventional solution.

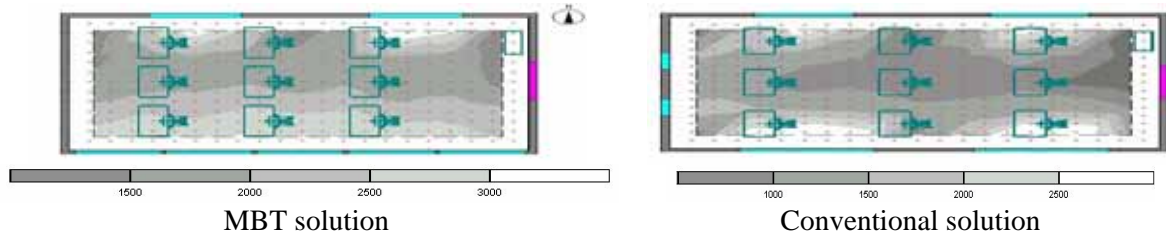


Fig. 3 - Pseudo colour illuminances for MBT and Conventional rooms.

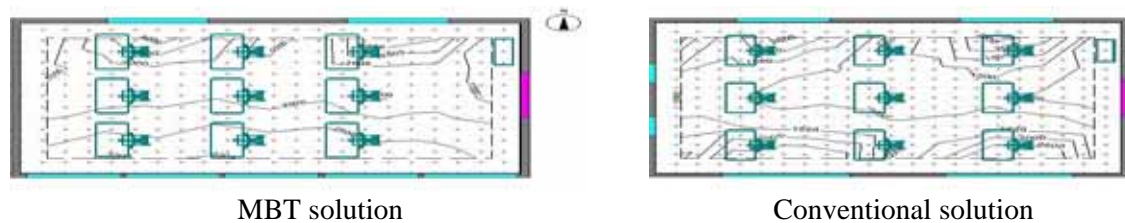


Fig. 4 - Isolux curves for MBT and Conventional rooms.

An extended number of simulations have been carried out for different climatic conditions and for different positions of the shading device. The results showed that in winter the Conventional building has to have the roller screen always opened in order to guarantee an illuminance level between 500 and 1000 lux. In this case, the Conventional building needs artificial lighting a few minutes after 15h00m while in the MBT building the artificial lighting is only necessary after 16h00m. During summer when the natural lighting potential is higher, both the MBT and the Conventional buildings need to have the roller screen always half closed in order to prevent an excess of lighting and of course the overheating solar radiation effect. In summer, if the roller screen is not always half closed, the risk of space overheating will become much more important in the MBT solution than in the Conventional one (14). For the intermediate climatic conditions which correspond to spring and autumn seasons, also both the MBT and the Conventional buildings need to have the roller screen always half closed in order to prevent an excess of lighting. In this case, the Conventional building eventually will need artificial lighting only at the end of the day while in the MBT the artificial lighting will not be necessary. Table 8 summarizes the solar control exposure that should be adopted in order to achieve illuminance levels along the year between 500 and 1000 lux for typical climatic conditions.

TABLE 8 - Comparison of MBT and Conventional Solutions Results

Average Illuminance	MBT			Conventional		
	Dec. (O)	Jun. (HC)	Mar./Sep. (HC)	Dec. (O)	Jun. (HC)	Mar./Sep. (HC)
lux	815	1021	736	507	624	449

O - Opened roller screen

HC - Half Closed roller screen

C - Closed roller screen

6 Comparative Analysis of the Constructive Costs

The global budget of a building depends on each activity quantity and on its unitary price which comes from the composition of the directly imputable costs with the indirect costs. In Portugal, the Construction Industry doesn't rely much on standard products which means that each construction presents specific costs depending on the used technologies, available workmanship, equipment and atmospheric and physical conditions of the site. Thus, for a more realistic estimation of the unitary prices, it was decided to consult the prices of some Portuguese companies. This document presents the average values resulting from this survey.

It can be verified that the cost of the MBT solution is approximately 70% higher than the cost of the conventional solution. Table 9 shows that the use of a MBT metallic structure is 329% more expensive than the use of a conventional solution of reinforced concrete pillars and beams. This huge difference between prices is due to a lack of tradition in constructing with metallic structures and, in part, due to the lack of specialized workmanship. The small number of companies specialized in metallic structure technology also increases its cost and reduces its competitiveness. All these facts make conventional construction still much more competitive.

TABLE 9 - Budget Comparison of the Two Solutions

Element	MBT Solution (€)	Conventional Solution (€)	$\frac{MBT - Convent}{Convent}$ (%)
Structure	19 625	4 578	329
Roof	6 493	7 288	-11
Pavement	4 762	5 156	-8
Walls	8 257	7 636	8
Windows	7 427	2 674	178
Estimated cost	46 564	27 334	70
Estimated cost/m ²	606	375	61

However, it is necessary not to forget that while the conventional solution process has no significant residual value, since great part of its elements cannot be reused or recycled, in MBT solution, the structure can easily be sold for posterior re-use or recycling.

7 Comparative Analysis of the Environmental Impact

The amount of energy needed to produce materials, their assembly in construction site, maintenance and demolition, can vary from 6 to 20% of the total energy consumed during the useful life of a building, depending, among others, on the constructive technologies used, the number of users, the climate and the degree of comfort demanded by the occupants. About 80% of this value corresponds to the materials Primary Energy Consumption (PEC), which means the energy resources spent for its production, including the energy directly related to the extraction of raw materials, their processing and the energy needed for their transport (15). The remaining 20% includes the energy consumed in the transport of the transformed materials to the construction site, the energy consumed during the building construction and the consumed energy during the dismantling and demolition processes.

7.1 Raw Materials Quantification and Primary Energy Consumption Assessment

The MBT constructive solution just need 38% of the mass needed by the conventional one, what turns this solution much more sustainable by the natural resources preservation point of view.

TABLE 10 - Construction Mass and Primary Energy Consumption (PEC) of the Solutions (15)

Material	MBT	Conventional	MBT	Conventional
	Mass (Ton)		PEC (MWh)	
Steel (100% recycled)	-	1.121	-	3.105
Steel (20% recycled)	11.787	-	114.570	-
Extruded polystyrene (XPS)	0.230	-	6.432	-
Concrete	32.088	76.893	10.589	25.375
Clay (hollow brick)	-	42.759	-	21.380
Clay (roof tiles)	-	7.522	-	6.093
Asphalt shingle	0.192	-	0.780	-
Gypsum	2.762	1.79	2.900	1.880
Laminated timber	1.400	0.709	1.512	0.766
Mineral Wool	0.578	0.111	3.324	0.638
Mortar (cement)	3.237	10.245	1.716	5.430
Aluminium (30% recycled)	0.146	0.056	6.482	2.486
Glass	1.578	0.973	8.064	4.972
Total	54.001	142.170	156.369	72.125

Analyzing the materials total Primary Energy Consumption, it can be seen that the execution of the MBT solution consumes approximately twice the energy needed to the execution of the conventional one. This difference is justified by the great amount of energy consumed in the steel production, as can be seen in Table 10. However, the PEC energy consumed on these elements could be considered zero, because the steel used in the pillars and beams of the MBT solution may be reused on another building. Assuming that the amount of steel used in the slabs is approximately equal to 18% of the total steel used, the energy really consumed in the steel elements is 20.623MWh. Thus, the energy really spent on the MBT solution is 62.422MWh and on the conventional solution is 72.125 MWh, which reverse the obtained values.

7.2 Environmental Impact of the Constructive Solutions

The waste materials from the construction industry constitute a significant portion of the total amount of waste produced. Currently, in the European context, the construction is responsible for about 30% of all the produced residues. The amount of these residues and their eventual re-use or recycling depends essentially on the type of material and on the construction techniques used, apart from the construction company organization, the specifications of the project and the professional qualification of the workers (16). It is important to stress that it is during the project phase, that all the intervenient will have to assure the recycling or future re-use of residues resulting from demolition.

One of the most important waste productions occurs during the construction phase of the building. In this phase are produced about 10% of the total volume of residues produced (16). MBT technologies are characterized by a great industrialization of the constructive process, allowing a significant reduction of the residues. The almost total formwork dismissal in the MBT construction, apart from diminishing the construction period, prevents the waste of material resources and energy resources associated to the operations of assembly, dismount, cleanness and arrangement. With the lost formwork it is avoided the use of moulding oil, which during the formwork cleaning process is released to the environment, with extremely pernicious effects.

Another important aspect in the evaluation of the environmental impact is the noise production. The possibility of using lighter forms of transportation in the MBT construction, the almost absence use of concrete, and the less time spent in construction, expresses a significant reduction on the emitted sonorous energy.

During the construction and demolition phases of a construction, the concern is not only with the production of residues but also with the production of pollutant gases. These gases result basically from the fossil fuel combustion during the materials/elements transportation. Assuming that the form of transportation used is a diesel truck, it is observed that the average amount of pollutant gases emitted per km for a MBT solution is about 38% of the amount emitted by the conventional solution, as Table 12 shows.

TABLE 12 - Pollutant Gas Emissions during Materials Transport on both Solutions (15).

Gas	Quant. Produced (g/ton km)	MBT solution (kg/km)	Conventional solution (kg/km)
CO ₂	120	6.480	17.060
SO ₂	0.1	0.005	14.217
NO _x	1.9	0.103	0.147
	Total	6.588	17.221

8 Conclusions

This study has shown that although in winter the MBT solution has a better thermal performance than the conventional one due to its heavier insulation, in summer, the MBT behaviour is very penalising in the cooling energy requirements, resulting in greater overall energy needs. This poor performance is due to the huge area of windows with inadequate shading control devices and also to the lack of thermal inertia. To correct the performance of the MBT building, the solar exposure strategy must be revised.

From the study carried out, it was possible to conclude that in almost all the studied cases, the MBT solution has better acoustic performance than the conventional one, in spite of having less mass. The very good quality of the glazing and windows frames and the higher level of acoustic absorbent material placed inside the building elements allow this good acoustic performance.

From the natural lighting evaluation carried out it was verified that in summer, the excess of lighting in the MBT and in the conventional buildings, can be solved with a cheap efficient shading system. A simple roller screen system will filter the excesses, and it is not expected the use of artificial illumination during normal working hours. In winter, MBT solution provides more light till later hours. This fact will have a great impact, not only in terms of energy consumption, but also in terms of the improvement of the working and health conditions. In the conventional solution, the use of artificial illumination will be surely necessary, especially at the end of the afternoon and at the early morning, to maintain illuminance levels between 500 and 1000 lux. In spring and in autumn, both solutions need to have the roller screen always half closed in order to prevent an excess of lighting. In this case, the conventional building eventually will need artificial lighting only at the end of the day while in the MBT the artificial lighting will not be necessary.

In the MBT solution, constructive costs are significantly higher than in the conventional one, what can be justified by the weak implementation of the highly industrialized building technologies in Portugal. However, in what concerns the environmental impact the MBT solution is better since it needs a less amount of materials to be used. On the other hand, the MBT solution presents greater potentialities, by reusing its elements, after the building dismantling. This fact allows the partial recovery of the initial investment and rationalization on the use of natural resources. Despite the fact of being more expensive, the option for MBT

solutions is one of the possibilities to explore in future in order to turn the Portuguese construction industry more sustainable.

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