RTCM's Role in Green Building and the Green Economy

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Abstract. The building sector is ranked second in the world after transportation in terms of energy consumption, mainly distributed in air conditioning and heating, these expenses generate more and more high energy bills that encourage all the countries on a global scale find radical solutions.

To be able to its global counterparts, Morocco has recently launched the Moroccan Construction Thermal Regulation "RTCM". This regulation was launched by the National Agency for the Development of Renewable Energies and Energy Efficiency (ADEREE) and it showed according to simulation studies by TRNSYS software a great efficiency in the final economy of energy related particularly to air conditioning and heating despite the extra cost that will be added to the final price of the investment. This extra cost is shown to be the lowest in the category of luxury housing, which shows the interest of its application in this category of housing.

In this respect, the present article mainly examines the results of an energy simulation of a building according to the requirements of the RTCM and its impact on the gain and the energy bill. This simulation has shown its effectiveness despite a surcharge that remains surmountable for all climatic zones and some categories of buildings, hence the interest of making more known the RTCM among professionals in the field through surveys and surveys, to know the degree of its application in Moroccan constructions, the obstacles to overcome and the proposals to be studied so that the RTCM is a practical means of assistance for the simulation of energy-efficient buildings and so that it will be more applied in the buildings of tomorrow.

In addition, we will propose insulating construction materials based on previous literatures that will be adapted for residential and tertiary buildings in each climatic zone.

Keywords: RTCM · Green building · Energy efficiency · Green economy · Insulating materials

1 Introduction

The objective announced by the Moroccan Government is to achieve a primary energy saving of around 12% to 15% by 2020 [1] through the implementation of an energy efficiency plan in the different regions. economic sectors. Among the energy efficiency

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plans, the elaboration of the Construction Thermal Regulation in Morocco (RTCM) which aims essentially to improve thermal performance by reducing the heating and air conditioning needs of buildings, by improving the comfort of non-residential buildings. air-conditioning and the reduction of the power of the heating and air-conditioning equipment to be installed;

Compliance with RTCM requirements in the housing sector allows for final energy savings of around 22 kWh/m^2/year and a significant reduction in CO2 gas emissions [1–3], variable according to climatic zoning. These savings generate substantial gains estimated on average at 18 Dh/m^2/year [1], compared to the usual energy bill of the final consumer.

On the other hand, the constraints related to the application of this regulation apply automatically on the extra cost of the construction, the qualification of the labor, the choice of the insulating materials, and the non disposition of a strategic plan and adequate communication tools to mobilize and sensitize stakeholders, including governments, businesses, professionals and the general public, to energy efficiency measures in buildings. Hence the need to work on these last points, while proposing the optimal insulating materials for this type of construction.

2 Literature Review of RTCM

2.1 Benchmark on the Energy Consumption of the Building Sector

The results of global statistics on energy consumption in 2010 showed that the building sector alone accounts for around 28% of final energy consumption and accounts for around a third of CO_2 emissions [1], as shown in Fig. 1:

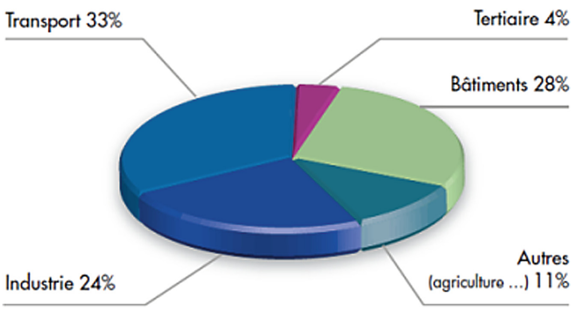


Fig. 1. World building sector final energy consumption in 2010 [1]

The southern Mediterranean region is no exception to this observation since, on average, the building sector accounts for around 38% of the energy consumed (this percentage varies between 27% and 65% depending on the country). Compared to other sectors of activity, it represents the largest source of savings and is often around 40% in most countries in the region [1].

In Morocco, the building is the second largest energy consumer after transport with a 25% share of the total energy consumption of the country, of which 18% is reserved for residential and the rest for the tertiary sector as shown in Fig. 2 energy consumption due to various sources leads to an increase in the release of CO2 gas and subsequently an imbalance of our ecosystem [3].

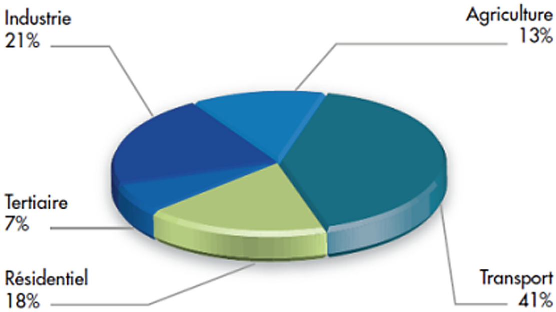


Fig. 2. Structure of consumption by sector [1]

2.2 RTCM Requirements

The RTCM covers the housing sector and the tertiary buildings [1] and applies initially only to new buildings and gives priority to the urban sector since energy consumption in rural areas is generally low, as well, the application of RTCM in these areas is difficult due to the dispersal of habitat and its informal nature.

In the habitat the regulation targets all socio-economic categories of buildings, namely:

- Economic;
- Standing.

For the tertiary sector, four segments are particularly covered:

- The hotels;
- Administrative buildings (offices);
- Buildings of education and higher education;
- Hospitals.

2.3 Moroccan Climate Zoning

The climate zoning works were carried out in close coordination between the National Meteorology Department (DMN) and ADEREE, with the support of international expertise [1].

The Moroccan territory has been subdivided into homogeneous climatic zones based on the analysis of climatic data recorded by 37 weather stations over the period 1999–2008 (10 years). The construction of the zones was done according to the criterion of the number of winter degree days and the number of summer day degrees [1, 4].

Two types of zoning were established by the DMN [1, 4]:

• Zoning based on heating degree days at 18 °C;

• Zoning based on cooling degree days at 21 °C.

The 6 climate zones are listed in Table 1 and the final zonation map includes the six climate zones shown in Fig. 3 [2].

Table 1. Climate zones [2]

Zone 1	Agadir
Zone 2	Tanger
Zone 3	Fès
Zone 4	Ifrane
Zone 5	Marrakech
Zone 6	Errachidia

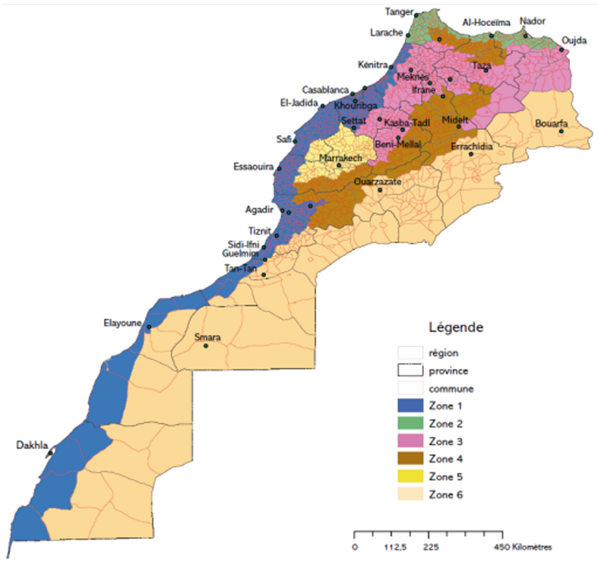


Fig. 3. Morocco's climate zoning adapted to Morocco's Construction Thermal Regulation [2]

Morocco's thermal building regulations target both the residential and tertiary sectors. The requirements of the first sector are the same for the different socio-economic categories of the buildings, they differ only from one climatic zone to another by fixing for each zone the minimum technical specifications, namely the rate of the bay windows, the minimum resistance of the floors on the ground, the solar factor of glazing and the thermal transmission coefficient of exposed roofs, external walls and glazings [1, 2].

On the other hand, the thermal regulation targets specifically in the tertiary sector the four main branches of the tertiary sector, namely:

- Administrative buildings;
- Schools;
- Hospital buildings;
- Hotels [1, 2].

In addition, the technical specifications of the by-law and its impacts are determined for each of the branches and also for each of the zones similar to the residential sector, namely, the rate of the bay windows, the minimum resistance of the floors on the ground, the solar factor of the glazings and the thermal transmittance of exposed roofs, exterior walls and glazing [1, 2].

2.4 Economic Impacts of the RTCM on the Construction of Green Buildings

In order to determine the economic impact of the RTCM on economical construction, a series of thermal simulations were carried out on reference buildings using the TRNSYS software, whose objective is to establish the optimal technical options to significantly improve the thermal performance of the target buildings compared to the current situation, considered as a reference. For this, the choice of reference buildings is as follows:

* For residential buildings:

- An economic group;
- A semi-standing collective;
- An individual villa of economic type [1].

* In the case of tertiary buildings:

- A hotel;
- A hospital;
- A school;
- An administrative building [1].

2.4.1 Impact on Heat Requirements in Heating and Air Conditioning

In the residential sector, the application of the thermal regulation should allow gains of 40% to 65% depending on the zones compared to the reference situation, as shown in Fig. 4 [1].

And in the case of the tertiary sector, the thermal simulations show that the gain in thermal requirements for heating and cooling varies according to the climatic zones compared to the reference situation. Figure 5 shows a gain that varies between 52% to 74% for administrative buildings [1].

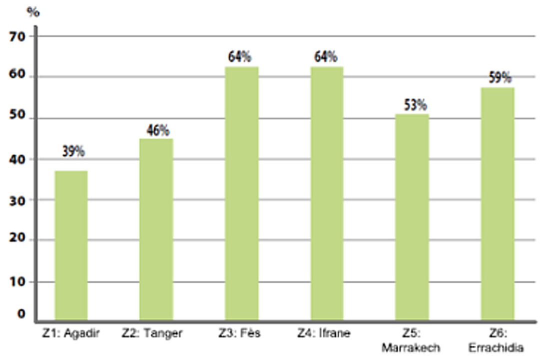


Fig. 4. Impact of thermal regulation on the reduction of heating and cooling needs of residential buildings (Ti = 26 °C in summer) in Morocco (% reduction)

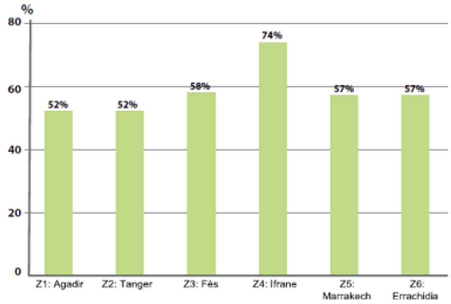


Fig. 5. Impact of thermal regulation on the reduction of the heating and cooling needs of administrative buildings in Morocco (% reduction)

Figure 6 shows a gain that varies between zones between 32% and 70% for schools [1]

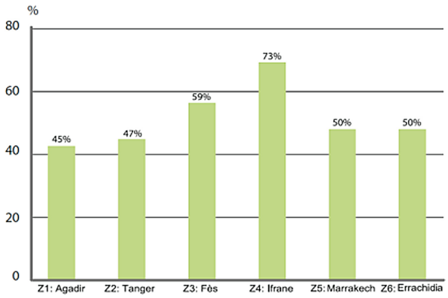


Fig. 6. Impact of thermal regulation on the reduction of heating and cooling needs of school buildings in Morocco (% reduction)

Figure 7 shows a gain that varies between 40% to 73% for hospital buildings

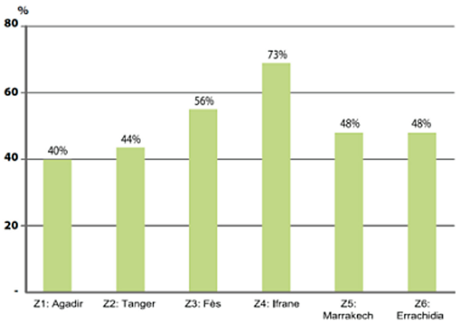


Fig. 7. Impact of thermal regulation on the reduction of heating and cooling requirements of hospital buildings in Morocco (% reduction)

Figure 8 shows a gain that varies between zones between 32% and 70% for hotels [1].

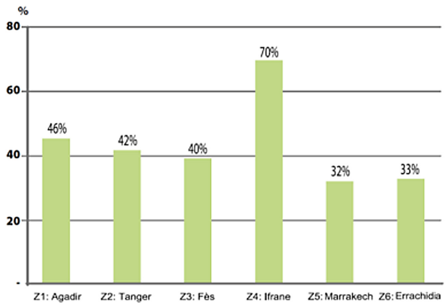


Fig. 8. Impact of thermal regulation on the reduction of heating and cooling requirements of hotel establishments in Morocco (% reduction)

Generally, the largest gains are observed in cold areas like Ifrane and Fez for both sectors.

2.4.2 Impact on Final Energy Consumption

The thermal regulation requirements allow for final energy savings for the consumer of around 22 kWh per year per m^2 of covered building. Figure 9 shows savings for the residential sector ranging from 8 kWh/m^2/year (zone Z1) to 75 kWh/m^2/year (zone Z4) [1].

In the case of the tertiary sector, and taking into account the heating and cooling modes as well as the efficiency of the equipment used, the final energy gain varies according to the sectors and climatic zones.

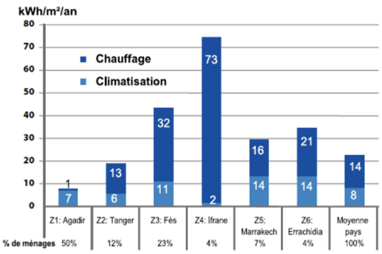


Fig. 9. Final energy saving for heating and cooling according to climate zones: Residential sector

– For administrative buildings, the gain varies from 31 kWh/m^2/year to 52 kWh/m^2/year (Fig. 7) [1];

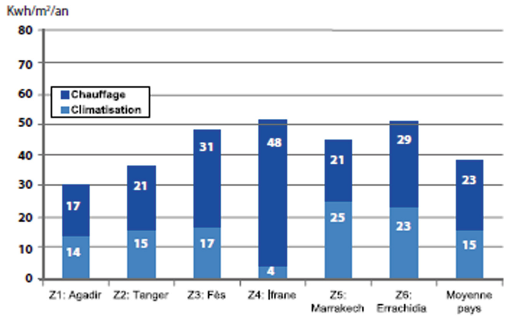


Fig. 10. Final energy saving for heating and cooling according to climatic zones: administrative buildings.

– For school buildings, the gain varies from 23 kWh/m^2/year to 202 kWh/m^2/year and an average of 48 kWh/m^2/year (Fig. 8) [1];

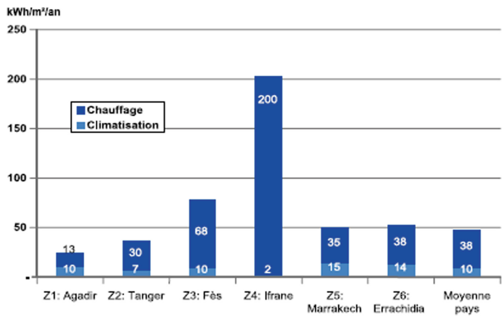


Fig. 11. Final energy saving for heating and cooling according to climatic zones: schools

– For hospital buildings, the gain ranges from 23 kWh/m^2/year to 115 kWh/m^2/year and an average of 39 kWh/m^2/year including 22 kWh for air conditioning (Fig. 9) [1];

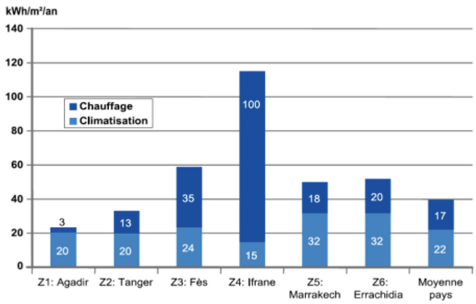


Fig. 12. Final energy saving for heating and cooling according to climatic zones: hospital building

– For hotels, the gain varies from 19 kWh/m^2/year to 80 kWh/m^2/year (Fig. 10) [1].

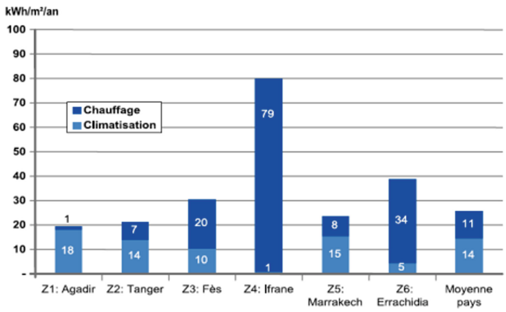


Fig. 13. Final energy saving for heating and cooling according to climate zones: hotel establishment

PS: These savings were evaluated by taking into account the prevailing modes of heating and cooling in the different regions of Morocco and the average efficiency of the equipment used [RTCM].

2.4.3 Impact on the Energy Bill of the Final Consumer

Given the current energy tariffs, these savings imply a gain for the final consumer in the energy bill for heating and cooling.

This gain is estimated at an average of 18 Dh/m^2/year and varies from 11 Dh/m^2/year in zone Z1, which represents more than 50% of dwellings, to 30 Dh/m^2/year in zone Z4 which does not represents only 4%. Figures 11, 12, 13, 14 and 15 show the different gains on energy bills, listed for each zone and sector [1] (Figs. 18 and 19).

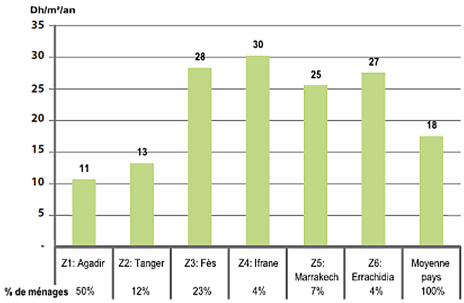


Fig. 14. Gains on the energy bill for the consumer according to the climate zones: Residential sector

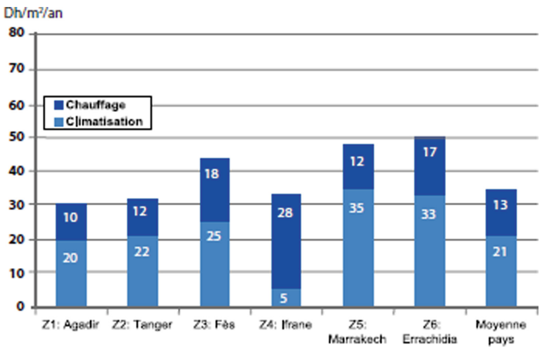


Fig. 15. Gain on the energy bill for the consumer according to the climatic zones: administrative buildings.

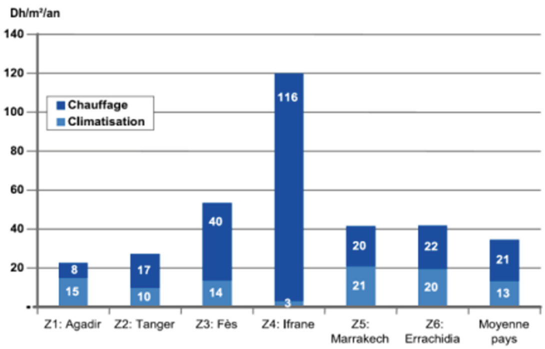


Fig. 16. Gain on the energy bill for the consumer according to the climatic zones: schools

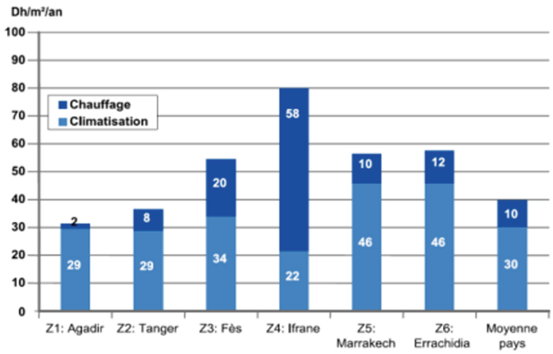


Fig. 17. Gain on the energy bill for the consumer according to the climatic zones: hospital building

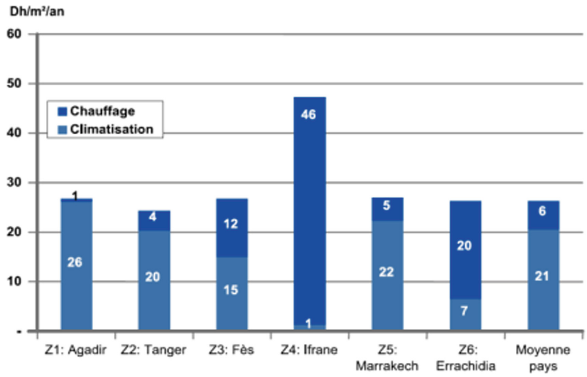


Fig. 18. Savings on the energy bill for the consumer according to the climate zones: hotel establishment

2.4.4 Incremental Cost of Compliance with the Thermal Regulation

Compliance with the technical specifications of the regulation implies an average investment cost increase of approximately 112 Dh/m^2, i.e. an average of 3.2% of the average construction cost.

This additional cost is higher or lower depending on the zone and the category of habitat, given the difference in the measures to be implemented. It thus varies from 43 Dh/m^2 in the Agadir area for luxury apartments to 315 Dh/m^2 for economic villas in the areas of Ifrane and Fez.

In relative terms, this extra cost represents a particularly high percentage of the construction cost for the category of economic housing, especially off-shore (Z1 and Z2).

Figures 16 and 17 show the simulated extra cost for the 3 categories of "Economic apartment, luxury apartment and economic villa" for the 6 climatic zones generated by the application of the RTCM in Dh/m^2 and in % [1, 4].

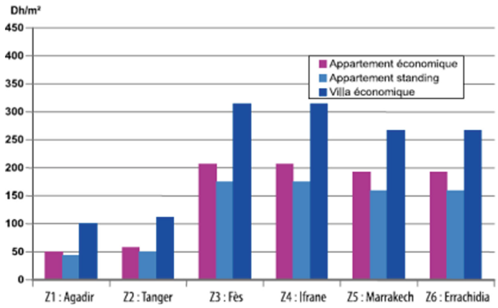


Fig. 19. Investment costs generated by the RTCM according to climate zones

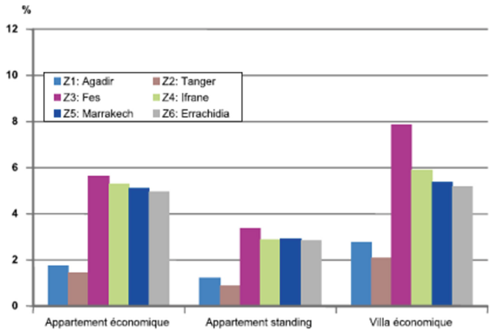


Fig. 20. Percentage of investment incremental due to RTCM by housing category and region

We note that zones 3 and 4 (Fes and Ifrane) generate the highest additional cost in the 3 housing categories [1] (Figs. 20 and 21).

Table 2. Surcharge for administrative buildings in %

Z1	Agadir	0,42
Z2	Tanger	0,46
Z3	Fès	2,72
Z4	Ifrane	2,62
Z5	Marrakech	2,48
Z6	Errachidia	2,48

Similarly for the tertiary sector, the zones Z3 (Fes) and Z4 (Ifrane) in the 4 establishments under study of the tertiary sector generate the highest additional cost by the application of the RTCM as indicated in the Tables 2, 3, 4 and 5 [1].

Table 3. Incremental cost for schools in %

Z1	Agadir	1.93
Z2	Tanger	2.05
Z3	Fès	5.23
Z4	Ifrane	5.23
Z5	Marrakech	4.13
Z6	Errachidia	4.13

Table 4. Surcharge for hospital establishments in %

Z1	Agadir	1.05
Z2	Tanger	1.15
Z3	Fès	2.65
Z4	Ifrane	2.65
Z5	Marrakech	2.05
Z6	Errachidia	2.05

Table 5. Hotel surcharges in %

Z1	Agadir	0.45
Z2	Tanger	0.52
Z3	Fès	1.85
Z4	Ifrane	1.85
Z5	Marrakech	1.65
Z6	Errachidia	1.65

2.5 Avoided Emissions of CO2 by the Application of the RTCM in the Constructions of Tomorrow

Taking into account the emission factors considered in Morocco for fuels and for the electricity grid, the cumulative avoided emissions over the next 20 years would be around 20 MCO2 for the residential sector.

And for the tertiary sector, averages of avoided CO2 emissions are summarized for each sector:

- 16 kgeCO2/m^2/year for administrative buildings;
- 6 kgeCO2/m^2/year for schools;
- 20 kgeCO2/m^2/year for hospital buildings;
- 13 kgeCO2/m^2/year for hotels [1].

3 Insulating Materials Adapted to the RTCM

The Construction Thermal Regulation in Morocco (RTCM) provides a pragmatic solution to the problem of excessive energy consumption in the building sector, be it residential or tertiary, and this mainly at the level of the construction plan using known insulating materials by a low thermal conductivity adapted to each climatic zone.

The integration of these insulating building materials will significantly reduce the need for air conditioning and heating. This reduction alone covers 50% of energy savings. Figure 17 is a study of the southern Mediterranean region over the period 2010–2030 which shows that we can gain 35% in heating and 14% in air conditioning [1] if we apply an effective envelope and a thermal insulation appropriate to using insulating materials guaranteeing low thermal inertia.

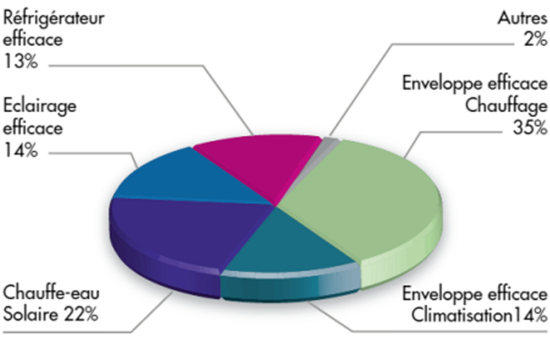
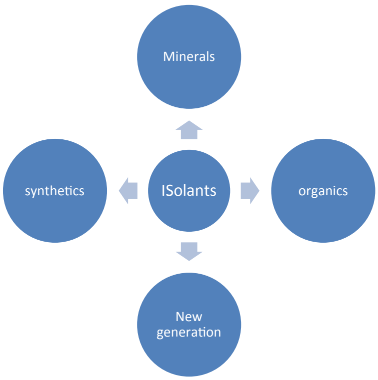


Fig. 21. Structure of energy efficiency potential in the southern Mediterranean region over the period 2010–2030 [1].

Good thermal insulation means a good insulating material introduced to the building envelope. Insulation materials are usually listed in four families. This classification is made according to their natures and origins [2]:



Examples of mineral insulators with their conductivity:

- Glass wool: 0.03 to 0.045
- Rockwool: 0.032 to 0.04
- Cellular glass: 0.035 to 0.048
- Perlite: 0.045 to 0.06
- Vermiculite: 0.045 to 0.08
- Expanded clay: 0.09 to 0.16
- Pozzolan: 0.1 to 0.2

Examples of organic insulators with their conductivity:

- Cork: 0.032 to 0.045
- Wood fiber: 0.037 to 0.049
- Cotton wool: 0.037 to 0.042
- Linen wool: 0.037 to 0.042
- Cellulose wadding: 0.037 to 0.044
- Hemp: 0.04 to 0.046
- The coconut fiber: 0.037 to 0.050
- The chènevotte: 0.048 to 0.06
- Sheep's wool: 0.035 to 0.042
- Duck feather: 0.033 to 0.042

Examples of synthetic insulators with their conductivity:

- Expanded polystyrene: 0.029 to 0.035
- Extruded polystyrene: 0.028 to 0.037
- Polyurethane: 0.022 to 0.030
- Phenolic foam: 0.018 to 0.035

Examples of new generation insulators with their conductivity:

- Airgel foam: 0.011 to 0.013
- Insulating panels under: 0.0042 to 0.0050
- Reflective insulation

Beyond the insulation materials whose main role in a construction is to improve the thermal performance of the walls, it was recently developed materials originally used to ensure the structure of the building, with improved thermal performance. This allows these building materials to also provide an insulation function. For example:

- Hemp brick: 0.048 to 0.06
- Cellular concrete: 0.035
- Monomour brick: 0.12 to 0.18 up to 0.07 if the cells are filled with an insulator;
- Agglo monomur in pumice stone: 0.09 to 0.12
- Foam concrete: 0.07 to 0.20

In connection with this type of materials, several studies have been developed to study the possibility of substitution or incorporation of the results of this research into conventional building materials in order to have ecological and energy-efficient buildings.

In this context, the article by Rahim and all 2017 [5] presented the results of the testing of a new concrete based on hemp and rapeseed, these materials have shown some response to the requirements of the RTCM given their low thermal conductivity of about 0.12 and 0.09 W/mK for hemp and rapeseed respectively.

And in Bourhaneddine Haba's thesis, 2017 [6], the author investigated the effect of adding date palm wood in concrete, the results showed that the dry thermal conductivity of date palm concrete is lower. at 0.3 $Wm^{-1}K^{-1}$. However, despite the fact that this type of concrete has a low thermal conductivity, the hygrometry problem "rapid absorption of water" blocks their expanded use until today, since this phenomenon influences the mechanical strength of the final product.

On the other hand, the article by "Cinzia Buratti, Elisa Moretti, Elisa Belloni, Fabrizio Agosti" [7] studied the use of innovative insulation panels based on natural basalt fibers.

After measuring the thermal conductivity of this type of panels, it is included between 0.030–0.034 W/mK. Compared with other traditional solutions such as rock wool or glass wool, this mineral material will be a good insulation solution that meets both the sanitary and mechanical requirements of the required building products.

As well, the authors "F. Asdrubali, AL Pisello, F. D'Alessandro, F. Bianchi, M. Cornicchia, C. Fabiani" [8] developed in their article tests on the thermal and acoustic performances of the panels of corrugated board commonly used in the packaging industry. The results show that this type of cardboard panels has promising performances in terms of acoustic insulation capacity and thermal insulation performance, slightly lower than the commonly used insulation panels. The results of the tests showed that 50 and 75 mm matching C flute samples had a thermal conductivity of 0.053 ± 0.001 W/mK and concordant E flute samples had slightly different λ values, both within their limits. maximum permissible error, namely 0.058 ± 0.001 and 0.060 ± 0.001 W/mK, respectively for 50 and 75 mm.

4 Conclusion

The simulations applied previously on buildings applying the requirements of the RTMC have shown that this type of construction will allocate an additional cost that will add to the cost of the average investment, this extra cost will mostly be amortized on energy gains related to air conditioning and heating.

And by comparing this extra cost in the 3 housing categories and in the 6 zones, we find that this extra cost is the lowest in the category of standing buildings. From where it leads to a reflection to apply this regulation in a practical way to this category of housing because it will not increase the cost of the construction in a crucial way and what will lead to have by the savings in energy bills and reimbursement of additional expenses. Because if the household heats up and/or air-conditioning these gains will result in a saving on the final energy consumption, and if the household does not heat up or air-conditioning, the application of the thermal regulation will result in an improvement of the comfort thermal.

Through this reflection, we will participate in the construction of sustainable energy-efficient buildings and support the country in the development of the green economy. However, the level of application of this regulation is still poor since the players in the field of construction are not yet trained in the application of the RTCM, as well, the information to its application remains little disseminated to convince its interest to users.

Hence the need for sensible action in this direction will enable the expected energy savings in the building sector to be achieved quickly. Among the proposed actions for an effective implementation of the RTCM:

- Establishment of a strategic plan and adequate communication tools to mobilize and sensitize stakeholders, including governments, businesses, professionals and the general public, to energy efficiency measures in buildings;
- Support and technical assistance to professionals and administrations responsible for monitoring the application of thermal performance requirements, in order to strengthen their capacities in this area;
- Encourage architects, engineers and contractors to use high-performance thermal design principles of the building envelope;
- Make available to project owners, public decision-makers and funders a work tool integrating the requirements of the RTCM to improve their competence and productivity in this area.

The next perspective considered for the advancement of our research is to launch a survey among architects, engineers, real estate developers, design offices, project managers and all those involved in the construction field in order to have their feedback on the technical applicability of the RTCM in the buildings of tomorrow and also to know the causes of the hardness in its application in sustainable building.

References

1. Règlement Thermique de Construction au Maroc- Version simplifié par l'ADEREE
2. CETEMCO-Guide technique AZEL, Décembre 2018
3. Bouroubat, K.: La construction durable: étude juridique comparative/Maroc-France. Université Paris-Saclay, Droit (2016)
4. Allouhi, A., El Fouih, Y., Kousksou, T., Jamil, A., Zeraouli, Y., Mourad, Y.: . Energy consumption and efficiency in buildings: current status and future trends. J. Clean. Prod. **109**, 118–130 (2015)
5. Rahim, M., Douzane, O., Tran Le, A.D., Promis, G., Langlet, T.: Experimental investigation of hygrothermal behavior of two bio-based building envelopes. Energy Builds. **139**, 608–615 (2017)
6. Bourhaneddine,, H.A.B.A.: Etude in-situ des performances énergétiques et mécaniques des matériaux biosourcés et locaux. Université El-Hadj Lakhdar - BATNA 1 (2017)
7. Buratti, C., Moretti, E., Belloni, E., Agosti, F.: Thermal and acoustic performance evaluation of new basalt fiber insulation panels for buildings. Energy Procedia **78**, 303–308 (2015)
8. Asdrubali, F., Pisello, A.L., D'Alessandro, F., Bianchi, F., Cornicchia, M., Fabiani, C.: Innovative cardboard based panels with recycled materials from the packaging industry: thermal and acoustic performance analysis. Energy Procedia **78**, 321–326 (2015)