Thermal and acoustic performance expectations on timber buildings

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Abstract

In recent years, building technologies have been developed in order to improve comfort and energy saving. European institutions and single countries firmly invite individuals to choose high energy-saving strategies in order to decrease carbon emissions and energy consumption. Examples could be found in thermal insulators added to façades and improvement of glazing performance. At present, two technologies are the most used in construction realization: traditional (concrete, masonry or in general heavyweight structure) or wood (timber, crosslam or in general timber lightweight structure). Designers, scientists and builders have their own opinions on these two topics, but good insulation performance are achievable with both of them. Nevertheless, for lay people as well as for designers, wooden structures seem more comfortable, reliable and insulated. Therefore, an international survey was realized in order to investigate what individuals expect from these two different construction technologies in terms of insulation performance. Results indicate that timber buildings stereotypes are confirmed for acoustic and thermal insulation and show how scientific communication may help to deal with new or untraditional constructions.

Keywords

Timber buildings, lightweight structures, subjective evaluation, impact noise, low frequency; airborne noise; survey

Introduction

People always yearn for good indoor comfort inside dwellings. In history, architects, engineers and, in general, designers try to understand how physics phenomena behave in order to improve their constructions.[1] At beginning, buildings were realized using the only available plastic material: wood. Then, in years, the use of stones and then concrete became bigger and slowly lightweight (LW) buildings were forgotten, mainly because of fire resistance issues.

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Nevertheless, recently their construction has begun to quickly rise, induced by Kyoto protocol.[2] The use of renewable raw or recycled materials is firmly encouraged all over the world,[3–8] since they could help CO_2 storage and control, both in new and in renovated constructions.[9–11]

The advantages of using sustainable materials are nowadays well demonstrated by several researches.[12–14] The introduction of energy efficiency and acoustic insulation protocols[15–17] may improve people and designer awareness on indoor comfort and new construction procedures. Technological progresses transformed building from 'construction' to 'production', moving from yard to industry. This paramount transition changes houses from slowly hand-made artefacst to serial industrial precast products. This formed pros and cons.

Secure advantages are higher quality, repeated and repeatable controls during process, possible complex shapes, very few waste production, optimization of transports and high final performance. Disadvantages are correlated to lack of mass and then poor sound insulation, especially at low-frequency range,[18–21] thermal inertia and limits in height or length of the indoor volumes; another difficulty is a non-standardization of the building technologies (crosslam, glulam, timber-concrete, wood-frame open-truss, etc.).[22–23]

Nowadays, LW constructions are sensibly present more in cold northern countries for two reasons:

1. availability of raw material;
2. high thermal insulation performance provided.

Nevertheless, in these regions, traditional buildings are present at the same time and often provide similar properties. People are used to heavyweight (HW) constructions because in recent years (usually after Second World War), new edifices of this typology quickly rose up and are yet used nowadays.

Both construction technologies could use the same insulating layers,[24,26] but achieving different final results.[27–31] For example, for acoustic performance, external sources as well as the presence of different components could influence final outcomes.[32,33]

As a matter of fact, in lay people's mind (non-expert) seem to coexist two different stereotypes:

1. LW buildings are very comfortable, every single parameter or results is good for living and nothing could go wrong.
2. HW buildings indoor environment is related discomfort caused by cold (or) hot sensations (depending on seasons) and often poor sound insulation is provided.

The aim of this work is to investigate the subjective evaluation of lay people (non-expert) using questionnaire describing some features and comparing them to wooden and traditional technologies.

Materials and methods

A web-based questionnaire (Figure 1) was sent to lay people (non-expert) and designers (non-expert) in many countries, such as Italy, Austria, Spain, Slovenia, Belgium, United Kingdom, Japan, Australia and Kenya asking to complete it without thinking that there might be a correct answer, but just marking their own personal opinion on the presented topic.

The survey is described in Figure 1, where the 'timber questions' are reported and compared to 'traditional' ones. Only one answer per question was requested and allowed. More than 400 answers were received. The questions were divided into four different blocks, referring to dedicated topics:

*** 1. Please rate the importance of the following aspects when living in a TIMBER building:**

	very important	important	irrilevant	not so important	not at all important
Acoustic insulation	○	○	○	○	○
Thermal insulation	○	○	○	○	○
Structural stability	○	○	○	○	○
Durability	○	○	○	○	○
Insulation from rain	○	○	○	○	○
Resistance to mold	○	○	○	○	○
Healthy inner environment	○	○	○	○	○
Sustainability	○	○	○	○	○

*** 2. Please rate the importance of the following aspects when living in a TRADITIONAL building (bricks and mortar, concrete, ...)**

	very important	important	irrilevant	not so important	not at all important
Acoustic insulation	○	○	○	○	○
Thermal insulation	○	○	○	○	○
Structural stability	○	○	○	○	○
Durability	○	○	○	○	○
Insulation from rain	○	○	○	○	○
Resistance to mold	○	○	○	○	○
Healthy inner environment	○	○	○	○	○
Sustainability	○	○	○	○	○

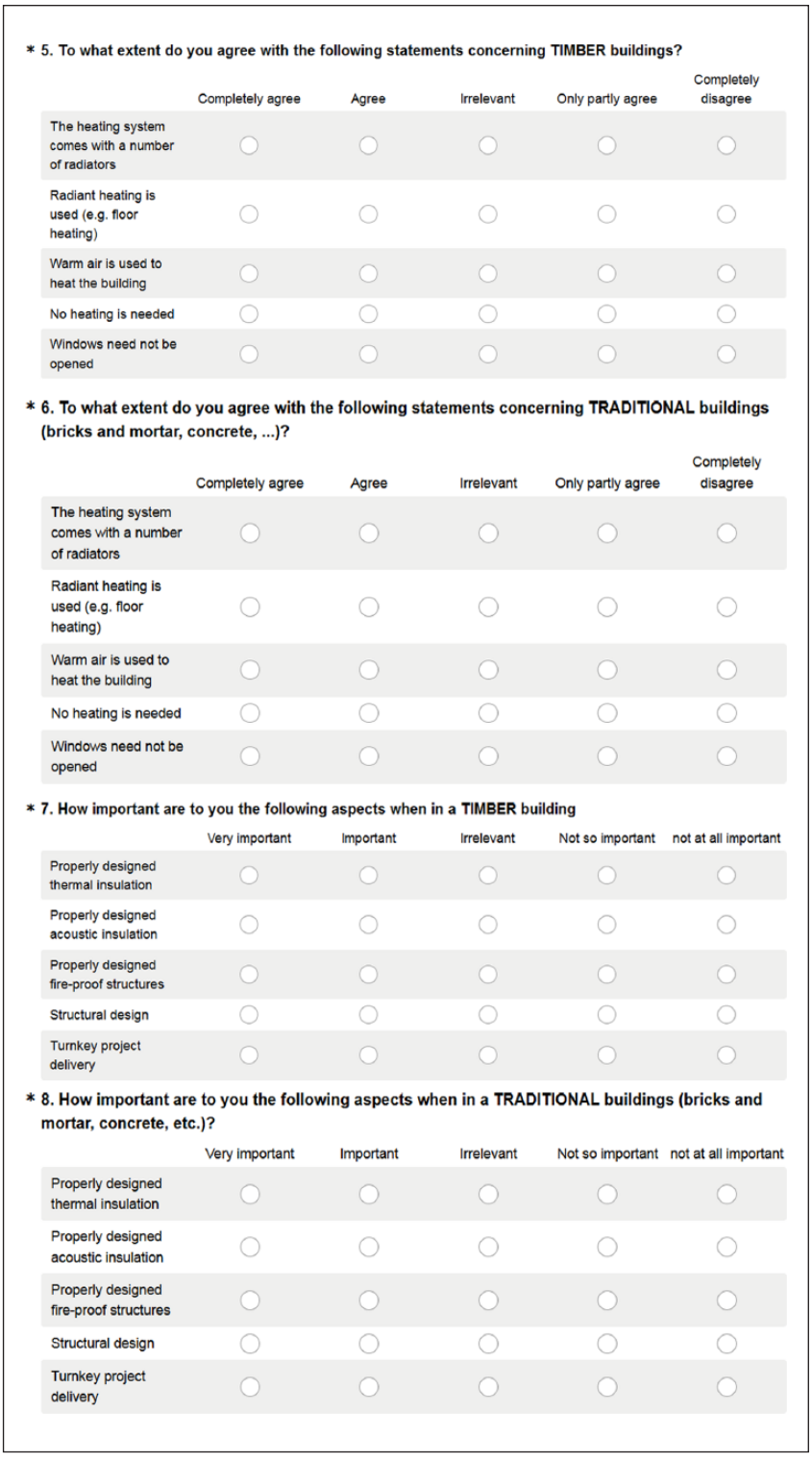
*** 3. To what extent do you agree with the following statements concerning TIMBER buildings?**

	Completely agree	Agree	Irrelevant	Only partly agree	Completely disagree
Wood creates a confortable home environment	○	○	○	○	○
Wood ensures thermal insulation	○	○	○	○	○
Wood ensures acoustic insulation	○	○	○	○	○
Wood ensures structural stability	○	○	○	○	○

*** 4. To what extent do you agree with the following statements concerning TRADITIONAL buildings (bricks and mortar, concrete, ...)?**

	Completely agree	Agree	Irrelevant	Only partly agree	Completely disagree
Bricks, concrete, etc. create a confortable home environment	○	○	○	○	○
Bricks, concrete, etc. ensure thermal insulation	○	○	○	○	○
Bricks, concrete, etc. ensure acoustic insulation	○	○	○	○	○
Bricks, concrete, etc. structural stability	○	○	○	○	○

(Continued)



* 5. To what extent do you agree with the following statements concerning TIMBER buildings?

	Completely agree	Agree	Irrelevant	Only partly agree	Completely disagree
The heating system comes with a number of radiators	○	○	○	○	○
Radiant heating is used (e.g. floor heating)	○	○	○	○	○
Warm air is used to heat the building	○	○	○	○	○
No heating is needed	○	○	○	○	○
Windows need not be opened	○	○	○	○	○

* 6. To what extent do you agree with the following statements concerning TRADITIONAL buildings (bricks and mortar, concrete, ...)?

	Completely agree	Agree	Irrelevant	Only partly agree	Completely disagree
The heating system comes with a number of radiators	○	○	○	○	○
Radiant heating is used (e.g. floor heating)	○	○	○	○	○
Warm air is used to heat the building	○	○	○	○	○
No heating is needed	○	○	○	○	○
Windows need not be opened	○	○	○	○	○

* 7. How important are to you the following aspects when in a TIMBER building

	Very important	Important	Irrelevant	Not so important	not at all important
Properly designed thermal insulation	○	○	○	○	○
Properly designed acoustic insulation	○	○	○	○	○
Properly designed fire-proof structures	○	○	○	○	○
Structural design	○	○	○	○	○
Turnkey project delivery	○	○	○	○	○

* 8. How important are to you the following aspects when in a TRADITIONAL buildings (bricks and mortar, concrete, etc.)?

	Very important	Important	Irrelevant	Not so important	not at all important
Properly designed thermal insulation	○	○	○	○	○
Properly designed acoustic insulation	○	○	○	○	○
Properly designed fire-proof structures	○	○	○	○	○
Structural design	○	○	○	○	○
Turnkey project delivery	○	○	○	○	○

Figure 1. Web-based questionnaire.

Figure 2. Group 2: survey compiling.

1. General issues.
2. Influence of the structural material.
3. Influence of the conditioning systems.
4. Influence of design.

The principal aim was to analyse what people think about every single aspect. The comparison with traditional construction is aimed at relating HW and LW lay people feelings. In fact, wooden structures are perceived like new, robust and eco-friendly houses, whether traditional are evaluated as old fashioned and pollutant.

Another aim of the comparison is to avoid focusing people's attention on just LW houses. For this reason, some questions (insulation from rain, healthy indoor environment and fire resistance) were inserted only with the aim to divert people's concentration on the main investigation (thermal and acoustic insulation) and to obtain non-affected answers.

It was chosen to include no more than 10 questions (8 focused on topics and 2 related to age, sex and education), since people's attention to surveys is very reduced and though it was avoided to receive uncompleted investigations.

During the preparation of the tests, subjective evaluations related to acoustic[26,27] and thermal issues[28,29] were deepened and dedicated questions (acoustic, energy saving and comfort), as well as general issue (fire resistance and structural stability) were included. In this article, only answers related to the aim of the research were reported.

The responses were collected both from on line results (Italian and international) and from hand-compiled procedure (open days) in anonymous form.

The same survey was given to people attending a LW wooden building open day. They were divided in several groups and many guided tour through the building under construction were organized.

Here, participants were asked to complete the same questionnaire before and after the visit (Figure 2); participants were divided into a group of 3–4 people; one group per time was introduced in the construction with an accompanying guide explaining every single aspect related to

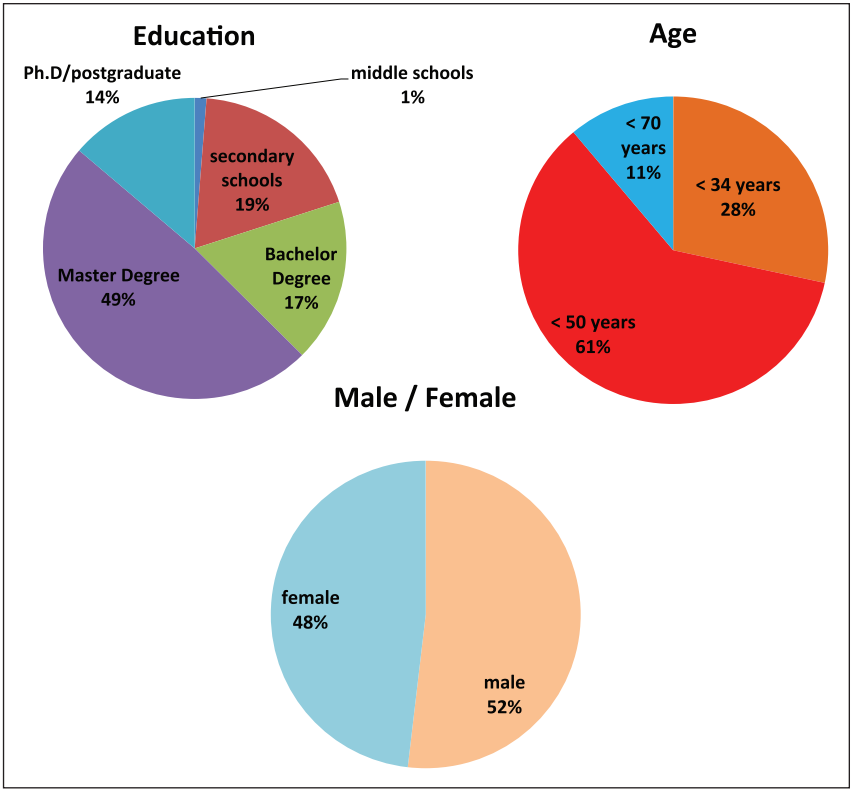


Figure 3. General participant data – Italian results.

energy saving, thermal, air, fire and acoustic insulation, eco-compatibility, structural stability and durability.

Results

For every answer, a percentage comparison is reported. In order to compare differences from Italian answers to international ones, first section is dedicated to the former whether another to the latter ones. For brevity, only some results are shown.

Italian results

The Italian answers to the survey are reported below. General data related to participant are reported in Figure 3.

Starting from Figure 4, general requirements are described. For thermal and acoustic insulation, it is evident how people presents two different approaches. For the first one, almost everyone thinks that it is a very important feature both for LW and for HW buildings, whether for acoustic insulation, only half of the participants believe that this is real important property. However, in both cases, the comparison gives nearly the same percentage results.

Figure 5 describes the opinions on the influence of the materials constituting the structures. Here, it is evident how there is no common trend at all. The wood is believed to provide some kind

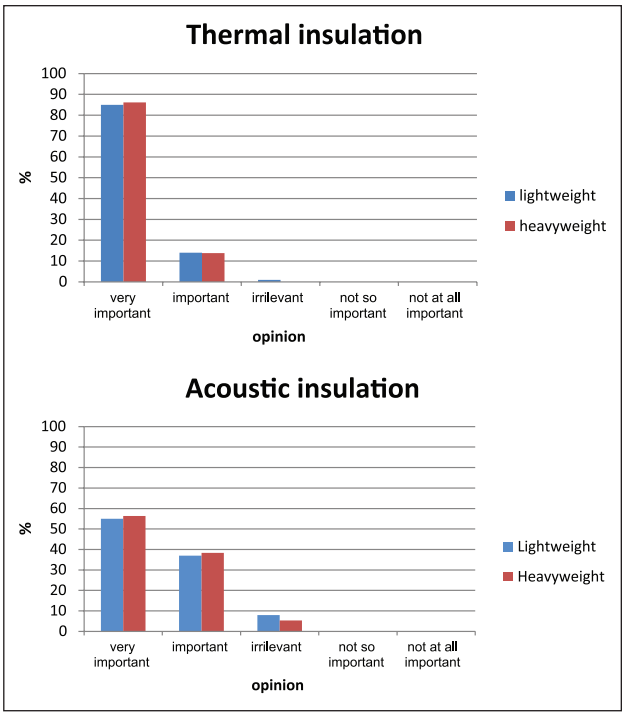


Figure 4. Thermal and acoustic insulation opinion – Italian results.

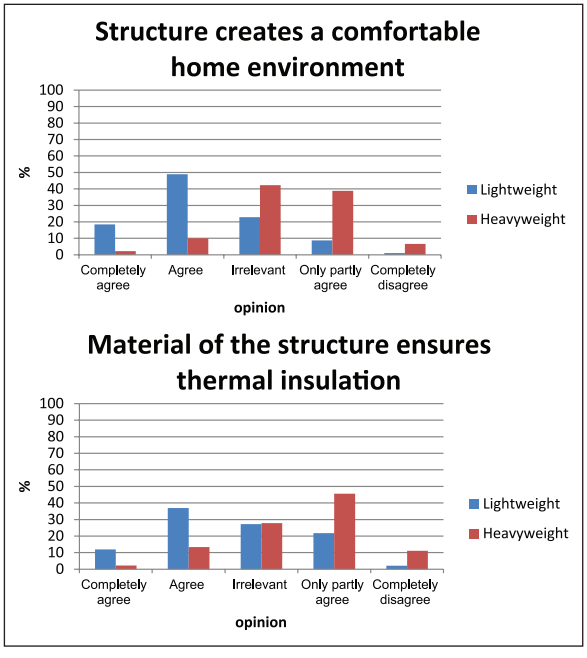


Figure 5. Influence of the materials – Italian results.

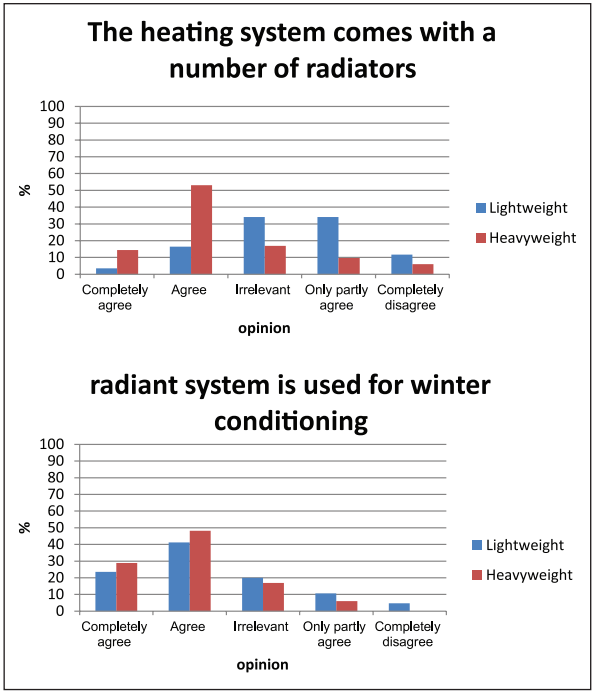


Figure 6. Influence of the conditioning technologies – Italian results.

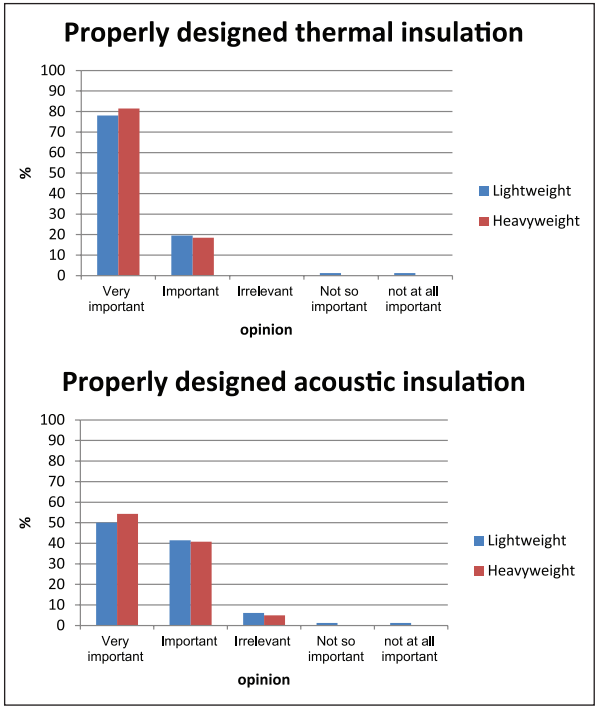


Figure 7. Opinion on design importance – Italian results.

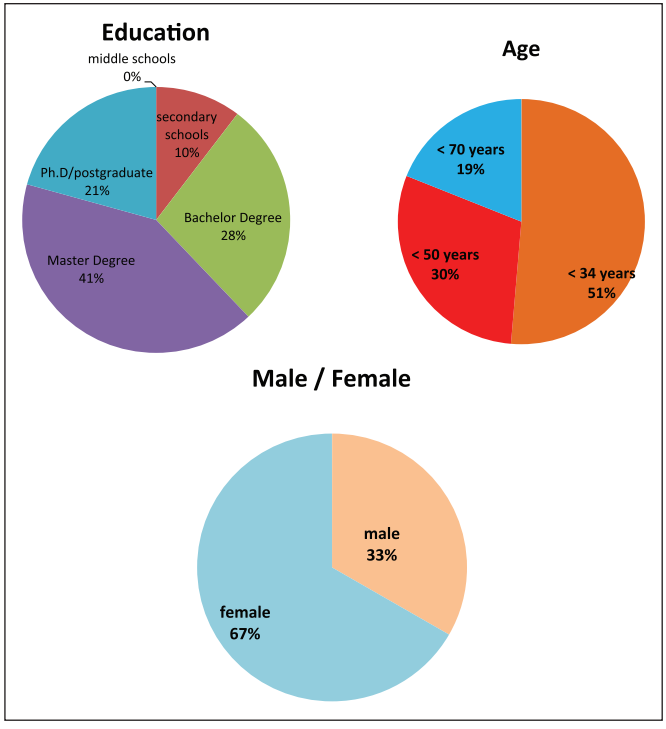


Figure 8. General participant data – International results.

of comfortable influence to indoor environment and the wooden structure is quite imagined to guarantee thermal insulation.

Figure 6 describes the opinions on the conditioning technologies. Here, it is evident how there is no common trend. Radiators are associated with traditional HW buildings. Nevertheless, when asked on radiant or air system, people connect them to both types of constructions.

In Figure 7, the opinions on the importance of the design steps are reported. Once more, thermal insulation is the most valued parameter in spite of acoustic protection.

International results

The international answers to the survey are reported below. General data related to participant are reported in Figure 8.

Starting from Figure 9, the general requirements are described. For thermal and acoustic insulation, it is evident how people presents two different approaches: For the first one, almost everyone thinks that it is a very important feature both for LW and for HW buildings, whether, for acoustic insulation, only half of the partecipants believe that this is a real important property. However, in both cases, the comparison gives nearly the same percentage results.

Similar trends and values are found for Italian opinions (see Figure 4). In Figure 10, the opinions on the influence of the materials are reported. Here, there is no similar trend to the Italian ones as the materials of the HW constructions are believed to create comfortable home environment and to influence thermal insulation.

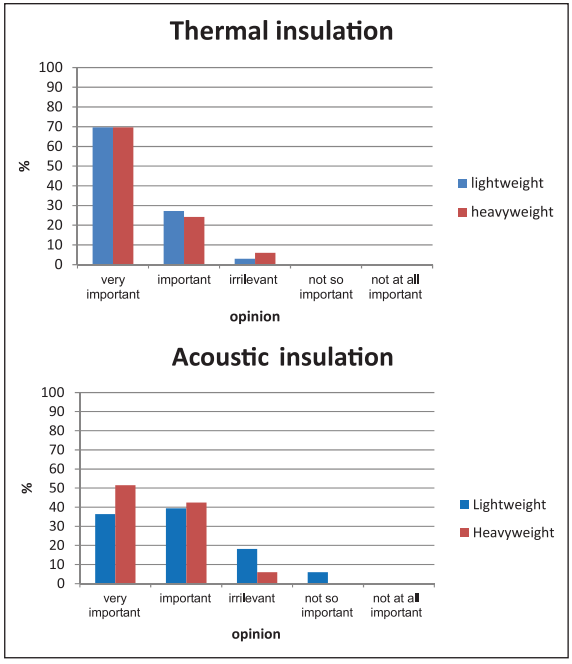


Figure 9. International results: general topic.

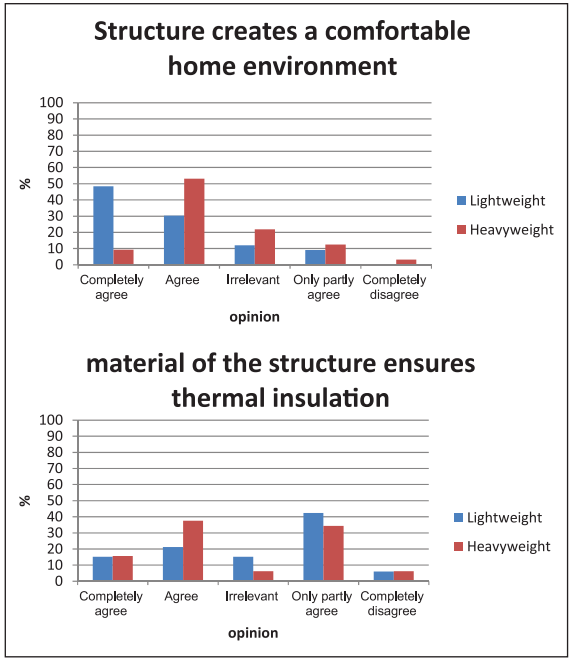


Figure 10. International results: influence of materials.

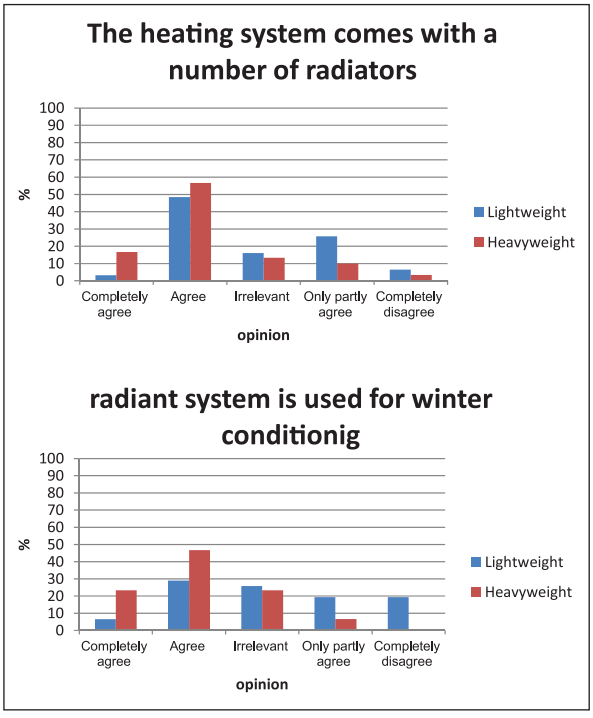


Figure 11. International results: influence of conditioning system.

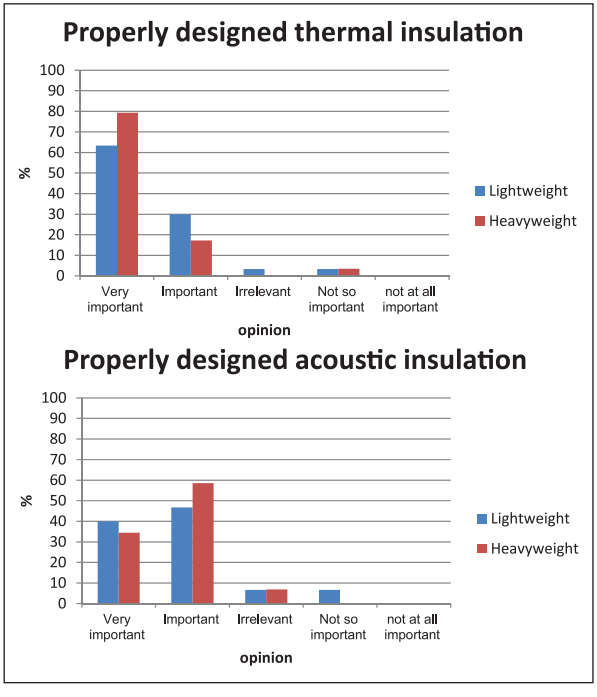


Figure 12. International results: influence of proper design.

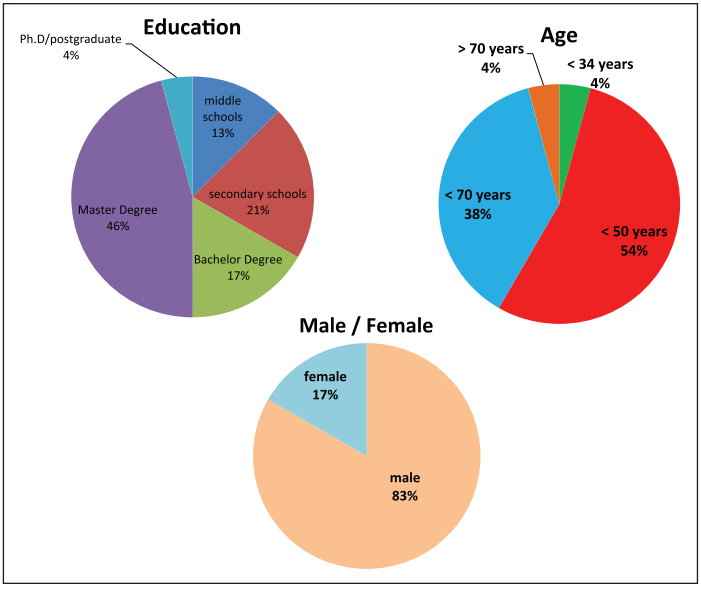


Figure 13. General participant data – open day results.

In Figure 11, results concerning the influence of conditioning systems are reported. Here, similar trends could be found similar to Italian ones, except the radiators one (LW).

In Figure 12, the influence of proper design is reported. As for the Italian opinions, similar trends could be verified. A major importance is related to the thermal and acoustic insulation of HW constructions indicating that for this kind of construction, people do not feel confident on final results whether for LW does.

Open day results

The open day answers to the survey are reported below. General data related to participant are reported in Figure 13.

Starting from Figure 14, the general requirements are described. For thermal and acoustic insulation, it is evident how people presents two different approaches: For the first one, almost everyone thinks that it is a very important feature both for LW and for HW buildings and it slightly improves after the visits, whether, for acoustic insulation, only half of the partecipants believe that this is a real important property for LW constructions. After the open day, the opinion doubles their presence on LW, so, as demonstrated before, education plays a very important role.

In Figure 15, the influence of the open day is highlighted once more. Nevertheless, here communication failed since people understood that the structure ensures the thermal and acoustic insulation as well as the good home environment.

In Figure 16, the influence of the conditioning systems is reported. Here, results clearly evidence how for traditional buildings no variation was recorded while for timber ones, radiant system and radiators would not be chosen as conditioning.

Discussion

An international web-based survey was realized and used to understand what lay people expect from both HW and LW timber buildings. Then, during a timber construction open day, it was asked

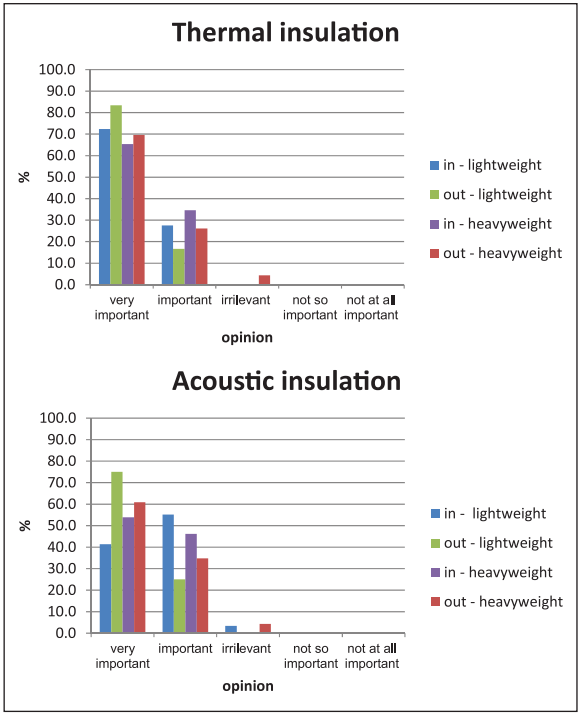


Figure 14. Open day results: general topics.

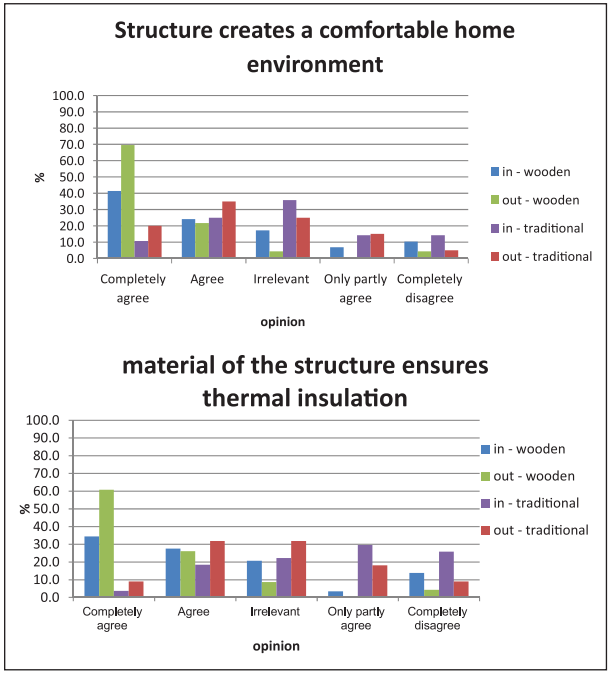


Figure 15. Open day results: influence of materials.

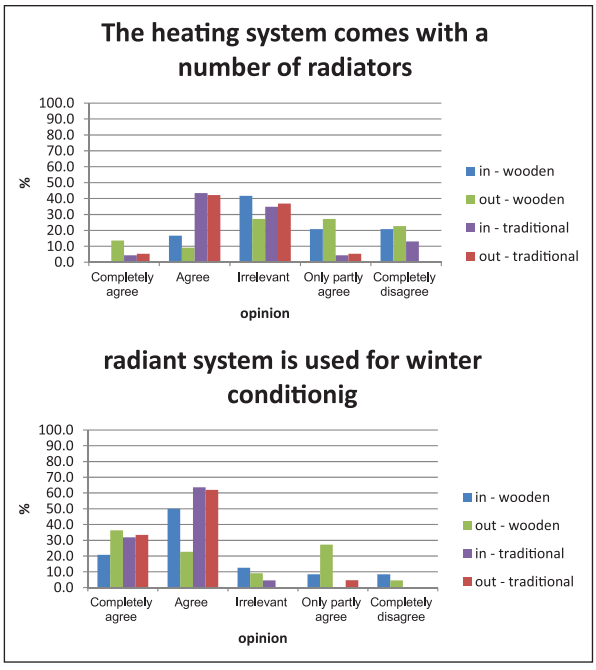


Figure 16. Open day results: influence of conditioning system.

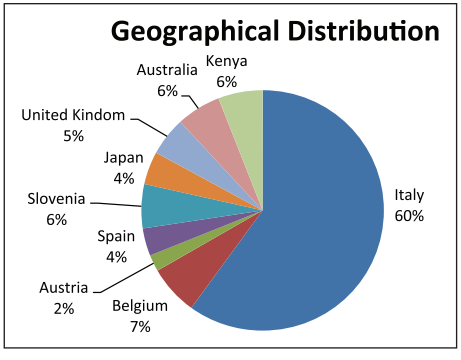


Figure 17. Geographical distribution of the received answers.

to complete the same questionnaire both before and after the visit. In Figure 17, the statistical geographical distribution is reported as a sum of all the received answers.

In Table 1, a summary of the results related to thermal and acoustic insulation issues was reported for international and Italian distribution. The results were divided in LW and HW. Only 'very important' and 'important' outcomes were described, since these answers were the most interesting ones.

It is interesting to notice that both surveys present very similar results and that people care much more about thermal insulation than acoustics. The importance of performances is in line with the need of a proper design. This is demonstrated since the two questions were intentionally positioned

Table 1. Summary of thermal and acoustic related results – international and Italian outcomes.

Description	Very important %	Important %
International results		
Thermal insulation HW	70	24
Properly designed thermal insulation HW	79	17
Thermal insulation LW	70	27
Properly designed thermal insulation LW	63	30
Acoustic insulation HW	52	42
Properly designed acoustic insulation HW	34	59
Acoustic insulation LW	36	39
Properly designed acoustic insulation LW	40	47
Italian results		
Thermal insulation HW	86	14
Properly designed thermal insulation HW	81	19
Thermal insulation LW	85	14
Properly designed thermal insulation LW	78	20
Acoustic insulation HW	56	38
Properly designed acoustic insulation HW	54	40
Acoustic insulation LW	55	37
Properly designed acoustic insulation LW	50	41

HW: heavyweight; LW: lightweight.

far from each other. Nevertheless, they provided almost same results for both LW and HW constructions.

In Table 2, the results of open day survey are presented. It is evident how the technical presentation along the visits positively influenced people's opinions, moving answers from 'important' to 'very important'.

As a general conclusion, it could be understood that people expect very good thermal insulation and indoor comfort performance from LW building and that these aspects are taken for granted. However, very important educational projects have to be carried out since no energy saving results could be achieved if the same people are not aware on how this kind of house has to be used and why and how it provides insulation from cold, hot, rain, wind, etc.

It is almost evident that sound insulation or reduction is less important compared to thermal insulation. This fact is in contrast with literature results since Ljunggren et al.[34,35] using a questionnaire proposed by Simmons and colleagues[36] demonstrated that low-frequency noise is the most annoying issue reported by timber buildings inhabitants, according to the literature results.[37–40]

Furthermore, overall results show how almost everyone meditates the following stereotyped properties related to timber constructions: they presents high energy performances, they suffer of fire hazard and they represent sustainable buildings. On the other hand for HW constructions no particular stereotype was found.

Lay people trust timber building because they are felt like 'perfect house' to live in and where every traditional issue is solved. However, there is no deep distrust in traditional constructions, even if their rates are poorer and the attention on the design steps is higher.

Real thermal insulation and proper design are the most rated parameters, whether acoustic issues are very far from being a principal interest. This fact is in contrast with real timber

Table 2. Summary of thermal and acoustic related results – open day outcomes.

Description	Very important %	Important %
Open day results – IN		
Thermal insulation HW	65	35
Properly designed thermal insulation HW	68	27
Thermal insulation LW	72	28
Properly designed thermal insulation LW	67	29
Acoustic insulation HW	54	46
Properly designed acoustic insulation HW	48	43
Acoustic insulation LW	44	55
Properly designed acoustic insulation LW	55	43
Open day results – OUT		
Thermal insulation HW	70	26
Properly designed thermal insulation HW	79	16
Thermal insulation LW	83	16
Properly designed thermal insulation LW	86	9
Acoustic insulation HW	61	35
Properly designed acoustic insulation HW	72	28
Acoustic insulation LW	75	25
Properly designed acoustic insulation LW	82	14
Open day results – VARIATION		
Thermal insulation HW	+5	−9
Properly designed thermal insulation HW	+11	−11
Thermal insulation LW	+11	−12
Properly designed thermal insulation LW	+19	−20
Acoustic insulation HW	+7	−11
Properly designed acoustic insulation HW	+24	−15
Acoustic insulation LW	+31	−30
Properly designed acoustic insulation LW	+27	−29

HW: heavyweight; LW: lightweight.

constructions performance, since nowadays, thermal insulation reached its maximum values,[41–43] but acoustic insulation is one of the most complained issues.[35,36]

At the same time, structural wood is believed to perform almost every issue from good indoor comfort to thermal or sound insulation, as well as physical stability and durability. This belongs to the stereotype that 'timber provides warm environment and good feelings'. Physics demonstrates that these parameters depend from case to case and from single components.[44–46] As an example, thermal insulation depends on external protection layer[47] which could be (and is often) realized using mineral wool and polystyrene.[48]

From the acoustic point of view, wood is not a good sound insulator since its poor mass and its periodicity of beam installation provides a reduced comfort at low-frequency ranges.[49–52] Furthermore, the impact noise is very difficult to reduce because of the typical timber structure's configurations.[53–56]

The received differences related to answers are because, probably, most of the interviewed people live, or lived, in a HW building; thus they know their shortcomings, but they do not have any experience with timber buildings; as a consequence they do not have knowledge of the 'problems' that LW buildings might present. The idea of non-expert people of LW buildings coincides to the stereotype of 'perfect house'.

Conclusion

An international web-based survey was realized and used to understand what lay people expect from both HW and LW timber buildings. The results showed how almost everyone believes in the timber building stereotypes:

- high acoustic insulation and comfort;
- high energy performance;
- fire hazard;
- great sustainability.

However, for HW constructions, no particular stereotype was found. It could then be concluded that for popular opinion, timber buildings are better than traditional ones, also from acoustic point of view. Furthermore, the use of an open day guided tour permitted to provide results before and after the visit. Results clearly show how the influence of the education changes people's mind in almost all questionnaire fields. In particular, the opinion on acoustic insulation designing requirement change from 40% (before the visit) to 75% (after the visit) confirming the paramount role of education.

Acknowledgements

Marco Canaito and Federica Bettarello collected elaborated and described all the survey data. Patrizio Fausti overviewed the whole research. Lucia Marsich, Alessio Ferluga and Chiara Schmid contributed with materials and collection of data. Marco Caniato wrote the paper.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

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