Design of a small scale wood house to study thermal and energetic performances of modern timber-frame construction

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Abstract: The presented work is a part of a more global study who aims to introduce sustainable development in an engineering school. A full academic year was required to complete this realistic small scale “timber-frame construction” design. Young pupils from 12 to 14 years old, their school professors and researchers from ENSEIRB-MATMECA engineering school were involved in this study. According to the recent French “very high energetic performance building standard”, the small scale house (1/10 scale) was realised using the real building techniques and real wood materials. This first paper focuses on the building of the modelling. Insulation performances and thermal behaviour will be tested in a near future and results published later. A comparison to our first house modelling built in auto aerated concrete AAC will be also performed. Then, this small scale house will be converted in a didactical and practical tool for supporting electronic projects at ENSEIRB-MATMECA.

Key words: Sustainable Development, Didactical wood house model making,

1. Introduction

1.1 ENSEIRB MATMECA engineering school short overview
This study was initialized at ENSEIRB-MATMECA school: The “Ecole Nationale Supérieure d’Electronique, Informatique et Radiocommunications de Bordeaux” is one of the oldest French graduate engineering schools, in France. ENSEIRB-MATMECA is now member of IPB (institute polytechnique de Bordeaux) strongly linked to the Bordeaux 1, Science and Technology University.

2. Project situation

2.1 Collaboration
This project was carried out thanks to collaboration with LTP Saint NICOLAS, 92 rue de Vaugirard 75006 Paris, for the realization of the small scale house itself and college Chambery 33400 Villenave d’Ornon.

2.2 Sustainable Development context
Since Rio de Janeiro conference (1992), Kyoto protocol and agenda 21 definitions [2], the necessity of a harmonious development is now admitted by a majority of scientific and political personalities. Even if sustainable development is a complex concept, which concerns a wide range of social, scientific, economical and environmental issues, each of us is able to do something for humanity evolution [3]. The good debate is not to know if “sustainable development is gadget or a necessity”. In fact, a soft but radical cultural change is needed in Engineering Education to embrace broad skills, environmentally aware attitudes, knowledge and fundamental values, human behaviour, as well as a sense of ethical responsibility.

Among education goals, energy saving and green gasses reduction are major thematic. They should be included in the scientific engineering school program whatever the main field of study since they are located at the intersection of electronic, chemistry, physics, thermal, mechanics.

Two recent opinion polls in 2010 and 2011 among ENSEIRB-MATMECA students showed that around 40% are not aware or not really involved in sustainable development. More than 60% do not know job opportunity in sustainable development field.

Lastly, only 49% of the students would like to see included a specific sustainable development teaching in our engineering school.
Whereas the national statistic and predictions studies for the next ten years announce a potential creation of 100,000 jobs in sustainable development field, job opportunities in green business seems to be still fuzzy in student’s mind. Thus, this student’s feedback confirms that a big work of awareness and education is required in our electronic engineering school.

2.3 French issue of construction field
In France, the construction industry accounts for 40% of consumed total final energy and 25% of national CO2 emissions [4], [5]. Debates of “Grenelle of l’Environment” led to the adoption of the law “Grenelle 1” in February 2009. This new law stipulates that all new buildings being the subject of one ask for licence of build, deposited before the end 2012, will have to present a consumption of primary energy lower than 50 kWh/m²/year on average. This same law is applied as of 2010 for the public buildings and tertiary sectors. After 2020, new buildings will have to become positive energy buildings, that is, they will produce more energy in situ than they will consume. Lastly, for the existing park, consumption primary energy will have to be reduced by 38% from here to 2020 with the objective to renovate 400,000 residences each year as from 2013. The challenge is enormous and requires from political and technical actors an integrated and global approach.

New buildings French RT2005 Thermal standard [6] has to be applied to the residential and tertiary new buildings since September 1, 2006. This standard is focused on energy saving and the comfort during summer. For the existing old buildings, a standard has also to be applied when renovation work is undertaken. And application of the last and stricter buildings RT2012 French standard will progressively replace RT2005.

3. Aims of the present study

3.1 General aim
This study aims to introduce sustainable development teaching in an electronic engineering school while respecting the main thematic and scientific fields of study. A first house modelling [1] was already designed two years ago. The positive results obtained and the high number of student’s projects generated by this first experience encourages us to go on in that way.

Thus, this second small scale green house project was born.

3.2 Social aims
One of the aims was to build connexion and links between different motivated people working in sustainable development field. Moreover, working on this kind of study requires various competencies and knowledge, as indicated in §2.2.1. These human resources are rarely found and available in a single department. Thus, this project is an opportunity to federate several competencies for a common and unique goal.

3.3 Technical aims
Building a small scale “timber-frame” house with real raw materials has many goals:
- training for secondary school students in handmade work
- training to wood house building techniques,
- study of raw materials properties

More over, once finished, the model will be used as:
- demonstrator (exhibition in town halls or sustainable development events)
- pedagogical support for practical lessons [7] and electronic projects, for sensitizing engineering students in first and 2nd year study. In particular, it will allow the design of electronic devices such as electric heating with its temperature control system. Thermal measurements using infra-red camera and other temperature sensors will be performed during practical lessons. Comparison of insulation efficiency between different kinds of house construction. In addition with scientific aspects, life cycle analysis, global energy and carbon assessment can be introduced.

3.4 General Interest
Small scale model cartoon houses exist in private architect offices and in the national agency ADEME [8]. They explain new available green technologies for individual and collective buildings just for general public sensitizing but they are not functional and enough fine to make possible real measurements and experiments. There exist also « timber frame green houses » full scale (1:1) demonstrator “Napevomo” and “Sumbiosi” [9] created respectively in 2009 and 2012 by Nobatek company and the Bordeaux ENSAM engineering
school for solar decathlon challenge [10]. However, these high technology houses are obviously not easily transportable, and their designs required heavy financial and technical means.

Thus, our small scale house will be an original educational tool built in genuine materials and fully functional, for easy and cheap in-door experiment. The chosen scale (1/10) makes the model big enough for ergonomic uses and small enough to be carried or moved easily. And it will give place to many multi thematic projects fully compatible with the ENSEIRB-MATMECA main goals.

4. Small scale modelling specifications

4.1 Generalities
The miniature house must be manufactured according to the true technical rules of the architect, building trade, carpenter, plumber, painter, roofer, and so on. The choices of raw materials and manufacturing are done according to RT2012 standard and give priority to passive insulation. In order to reduce the heat losses by the walls, it is obvious that it is necessary to reduce surfaces in contact with outside; for a given volume, the compactness is thus very important.

4.2 Small scale house technical specifications
All house ground plan for mechanical and architectural definition have been made with solid works software (student licence).

The small scale house is directly inspired by “Napevomo” house ENSAM/Nobatek house [9] designed for the 2009 solar decathlon challenge. This is a one floor 25m², flat roof, square shape compact small house (cf. Figure 1).

At 1/10 scale, the overall dimensions are 50 cm x 50 cm. The modelling will be located on 20cm high piles to allow an easy access under the house where some electronic devices and accessories will be installed.
Ceiling and flat roof:

- Optional green roof
- Edge or acroterium,
- Balk (wood beams)
- A micro porous watertight thin film located on the external side of the structure,
- A thermal insulator layer,
- A vapour barrier thin film
- Sheetrock (Plaster)

Windows

The 4 windows are single, double or optional triple glazed windows assembled as indicated in figure 5 within a wood frame.

Main door

It is micro machined in a PVC block.

5. Project progress

The project has been scheduled over a full university year as indicated in the next paragraph.

- Project definition, architectural drawings and detailed quotation, (One month)
- Basic raw material needs evaluation and purchase (2 weeks)
- Student’s group constitution, Tasks repartition, and scheduling (one week)
- Checking and training with the required tools (saw, drilling machines, solid works software …)
- Manufacturing: At rate of one weekly sessions of 4h, group of 7 pupils supervised by 2 teachers; Wall erection, windows milling and micro machining, insulator assembly, roof wood frame, rendering, coating (8 months).

6. Concrete realisation

Figures 6 to 11 show the mains steps of the house’s building.
7. Project assessment
After the building of the small scale house, the first part of this sustainable development didactical project is now ended.
The realization of the small scale timber frame house model required approximately 1500 cumulated hours at LTP workshop. Around 500 parts have been designed, cut, machined, and manually assembled. The finishing and surroundings realisation represented around 300h at ENSEIRB-MATMECA.
As we must show as well as possible, an ethical behaviour and respect ourselves the sustainable development concept, the project was completed with a minimum budget (labour costs excluded). Raw materials and various basic devices represented a few ten Euros as indicated in table 1. Some of insulators and wood pieces were salvaged materials.

<table>
<thead>
<tr>
<th>Material and devices</th>
<th>Price (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building materials</td>
<td>450</td>
</tr>
<tr>
<td>Sundries (paper, glue…)</td>
<td>60</td>
</tr>
<tr>
<td>Total</td>
<td>510</td>
</tr>
</tbody>
</table>

Table 1: Project cost

This team project was an excellent individual and collective human experience for all the participants, especially for the teenagers (future joinery) who worked a lot, to complete the project “on” time.
This second collaboration between secondary school and university is globally positive. The small scale house will be shared between LTP and ENSEIRB MATMECA for possible improvements.

8. Project continuation
The next steps of the project are going to be done in the near future and will be published later:
1° Thermal modelling of the small scale timber frame house:
An equivalent thermal modelling will be created to investigate the power heating consumption and insulation efficiency, like for a real house [11]. This modelling will be fitted thanks to experimental measurements and characterisations. Tests will be performed to validate the modelling and also to measure heat losses in different configuration, using among other tools, infra-red thermography. Results should be published in the near future.

2° In the same way of minding, an other timber frame house modelling (traditional Romanian house) should be designed in Craiova University very soon. After validation tests, comparative studies between the presented modern wood house and the traditional house model will be performed. Collected data will be used within the framework of a collaborative work between ENSEIRB-MATMECA and Faculty of Electrical Engineering, University of Craiova.

3° Electronic equipment:
Several students’ project will work to design electronic circuits (temperature sensors+ µController+ halogen heater) for indoor temperature regulation, control and measurement, data storage and lightening management.

4° Holistic approach:
A house can be seen as a “simple scientific object”, but it can be also seen as a global system, (architectural, technical, economical, and ecological). Thus, life cycle, global energy performance along the house life, carbon assessment will be investigated for each model.

9. Conclusion
The small scale house design was completed successfully thanks to the motivation and the implication of all. Major interests for all participants were the multi thematic, and cross disciplinary aspects. Thus, it was an opportunity for each partner to share their respective knowledge.

With the first design [1] and this second one’s, we have now two educational tools which can be included in a more global and ambitious action who aims to introduce sustainable development in our engineering school. We hope that these actions will impact -with humility- the style of Education for the future generation [12].

Acknowledgment
Special thanks to all the pupils who worked hard to create this small scale house modelling in LTP Saint NICOLAS, 92 rue de Vaugirard 75006 Paris.

References:
[9] C. Gracz « Choix et implantation de systèmes de pilotage d’un habitat à énergie positive SUMBIOSI » internal training report Nobatek, Bordeaux Sept 2011