# ON THE PERFORMANCE OF MASSIVE AND WOODFRAME PASSIVEHOUSES IN BELGIUM: A FIELD STUDY

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ABSTRACT

*In this paper we present the results of a field study in which the indoor climate and the energy use for space heating in 6 passive houses in Belgium were monitored. The test group consisted of 4 houses with a massive shell construction and 2 timber frame houses. 2 houses were inhabited and 4 were used for promotional activities by the builders. The results are compared to the performance predicted by the PHPP method. We can conclude that the results are in good agreement with the predictions and that no significant difference in performance is found between the massive and timber frame constructions.*

## 1. INTRODUCTION

In Belgium, the passive house concept is slowly finding its way to the mainstream housing market. Local Flemish large housing contractors traditionally prefer massive shell construction over timber frame shells because of the historic availability of brick production in the region and limited local wood production. Therefore, they recently proposed the ‘massive passive’ house as an alternative construction method for passive houses, based on traditional building techniques.

Although this type of construction has been used in passive house construction before, eg in Germany [1], no information is available on the performance of this construction type. Additionally, there is a general lack of available data on the in situ performance of passive houses in Belgium. Therefore, 6 recently completed single family passive houses were selected and monitored during a 4 month field study, in which indoor climate, in situ performance of the HVAC installation and energy use for space heating were measured. This paper presents the results from that field study. For comparison, the measured energy use for space heating of the selected houses is compared to that predicted by the monthly mean quasi steady state calculation method PHPP[2].

## 2. FIELD STUDY

### Cases

The first 4 passive houses with a massive shell that were completed were selected for the field study. The test group was completed with 2 timber frame houses (see Table I.). During the test period, only 1 of the massive houses and 1 of the timber frame houses were occupied, while the other 4 were used as demonstration projects for promotional purposes by the builders.

In the uninhabited houses, the HVAC system was operated at a constant setpoint, while in the occupied dwellings, the control of the system was left to the occupants. The 4 demonstration projects were equipped with electric convectors for space heating, while the 2 occupied houses were principally heated by a heating coil in the air handling unit (AHU), supplemented with a heater (case 6) or a woodstove (case 4).

| | Constr. | Occ. | Installation |
|---|---|---|---|
| 1 | Massive | U | convectors |
| 2 | Massive | U | convectors |
| 3 | Massive | U | convectors |
| 4 | Massive | O | AHU + stove |
| 5 | Timber | U | convectors |
| 6 | Timber | O | AHU + heater |

**TABLE I: OVERVIEW OF THE CONSTRUCTION TYPE, OCCUPANCY (OCCUPIED (O) / UNOCCUPIED (U)) AND HVAC TYPE OF ALL THE CASES IN THE FIELD STUDY**

### Measurements

The measurement campaign was executed during the winter of 2010 (see Table II.). In each of the monitored cases, the indoor climate parameters (T and RH) were measured and logged in all rooms using ONSET loggers [3]. In the houses where electric convectors are used for space heating, the associated energy use were monitored with VOLTCRAFT AC power loggers [4]. In the dwellings that use a heating coil in the AHU for space heating, the associated energy use was calculated from the measured air flow rate and temperatures before and after the heating coil. Both of these houses have additional heating with a woodstove and an electric heater respectively. The latter was monitored with an integrated power consumption meter and the first by calculating the sheath losses in accordance with lab measurements on the stove. This was done by bookkeeping the amount of fuel burned. In all dwellings, the efficacy of the heat recovery unit is calculated from the air temperatures measured in front and after the unit. In case 5, the incident solar radiation was also measured in cooperation with Stroomop bvba. An overview of the installed measuring equipment in the different cases is given in Figure 1. and Table II. The measurement error was 1°C on the temperature loggers, 10% on the airflow box and 1% on the power loggers.

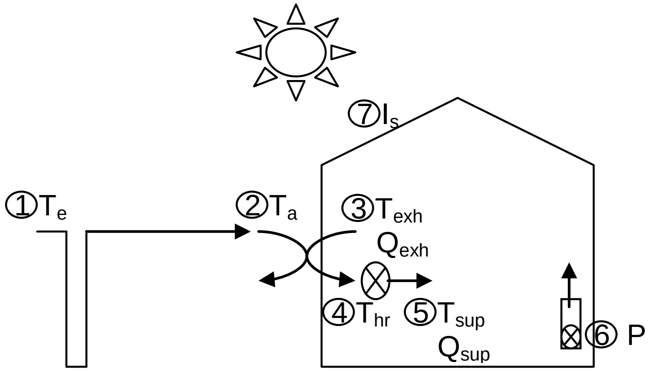


FIGURE 1: INSTALLATION SCHEME OF THE CASES WITH INDICATIONS OF THE MEASURING EQUIPMENT. OUTDOOR TEMPERATURE ($T_E$), AIR TEMPERATURE AFTER EWHX ($T_A$), EXHAUST AIR TEMPERATURE ($T_{EXH}$), TEMPERATURE AFTER HRU ($T_{HR}$), SUPPLY AIR TEMPERATURE ($T_{SUP}$), SUPPLY AIR FLOW RATE ($Q_{SUP}$), EXHAUST FLOW RATE ($Q_{EXH}$), HEATER POWER (P) AND SOLAR IRRADIATION ($I_S$)

| | Period | Logger location |
|---|---|---|
| 1 | 06 jan - 31 jan | 1,2,3,5,6 |
| 2 | 14 jan - 01 mar | 1,3,5,6 |
| 3 | 02 feb - 31 mar | 1,2,3,5,6 |
| 4 | 14 feb - 02 apr | 1,2,3,4,5,6 |
| 5 | 01 dec - 07 jan | 1,2,3,4,5,7 |
| 6 | 07 dec - 08 feb | 1,2,3,4,5,6 |

TABLE II: OVERVIEW OF MONITORED PERIOD AND LOGGER POSITIONS OF ALL THE CASES

## Results

The measurements results demonstrate that in all 6 cases, the indoor temperature is very constant. In 4 cases, the bedrooms were not heated.

Nevertheless, the bedroom temperature remained much closer to the living room temperature than in conventional dwellings [5] (see Figure 2.)

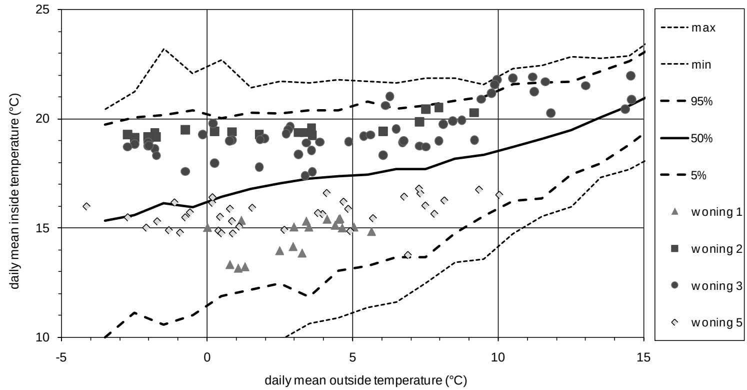


**FIGURE 2: OUTDOOR TEMPERATURE DEPENDANCE OF INDOOR TEMPERATURE IN 4 PASSIVE CASES (DOTS) AND CONVENTIONAL DWELLINGS (LINES).**

As was mentioned before, the setup of the measurements allowed for in situ assessment of the efficacy of the heat recovery units (HRU). Cases 1 to 3 were equipped with the same unit with a theoretical efficacy of 0.88. The measured efficacy in both cases 1 and 2 was 0.88 ± 0.1. The unit in case 3 was measured over 2 periods of about 1 month, in which average efficacies of 0.74 and 0.69 ± 0.1 respectively were found. The mean outdoor temperature for the measured periods were 0.5, 1.9, 2.6 and 8 ± 1 °C for case 1, case 2, case 3a and b respectively. The air flow rate in case 3 is about 10% smaller compared to cases 1 and 2. Although the efficacy of the earth/water heat exchangers could not be calculated due to a lack of measurement results for the soil temperature, the particular use of a earth/water heat exchanger as frost protection for the heat recovery unit is clearly demonstrated in Figure 3, where the minimal air temperature measured after the EWHX is 6.6 °C with an outdoor temperature of -5°C on December 26th. By comparing the results to those in Figure 4, however, it is also shown that the gain in supply air temperature due to this measure is rather small. The total efficacy of the EWHX and the HRU is 0.94, while that of the HRU alone is 0.88. The pressure drop over the EWHX was not measured, nor was the pump energy for the water circuit in the EWHX.

The ventilation flow rates in each of the 6 cases were below those required by the Belgian ventilation standard NBN D 50 001 [6], which is part of the Flemish building code (see Figure 5). All flow rates were measured at the maximum operation speed of the AHU.

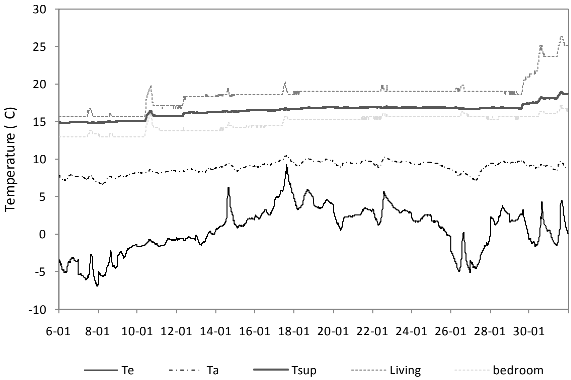


**FIGURE 3: EARTH/WATER HEAT EXCHANGER AS AN EFFECTIVE FROST PROTECTION FOR THE HRU.**

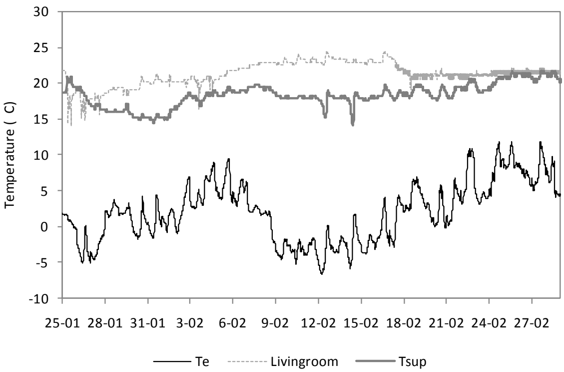


**FIGURE 4: OUTDOOR AND SUPPLY AIR TEMPERATURE IN CASE 2 (NO EARTH/WATER HEAT EXCHANGER)**

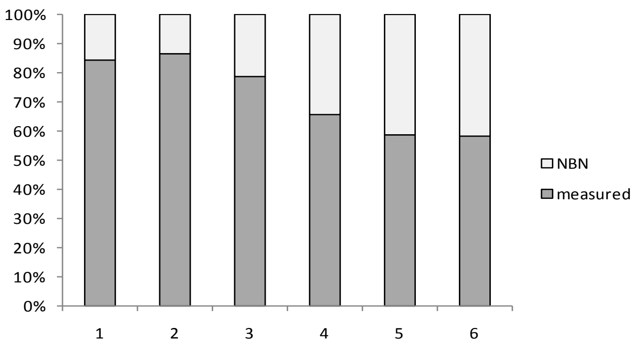


**FIGURE 5: MEASURED VENTILATION FLOW RATES AS A FRACTION OF FLOW RATES REQUIRED BY THE BUILDING CODE**

## 3. PHPP

For each of the 6 cases, the results from the measurement campaign were used to recalculate the boundary conditions that were used in the PHPP software.
Only for case 5, specific solar radiation data was available. For the other cases, solar gains were estimated. The radiation measurements from case 5 and those from the UGent weather station were used to determine a realistic uncertainty interval for the mean solar irradiation used in PHPP. Internal gains were calculated using the PHPP sheet for each of the cases in accordance with in situ observations. An overview of the uncertainty intervals that were assumed for case 3 is given in Table III.

| | Q (M³/H) | $\eta_{HRU}$ (-) | $I_g$ (W/M²) | $I_s$ (W/M²) | g (-) |
|---|---|---|---|---|---|
| min. | 59 | 0.59 | 0.48 | 26.8 | 0.3 |
| mean | 65 | 0.69 | 0.82 | - | - |
| max. | 72 | 0.80 | 1.16 | 42.2 | 0.5 |

**TABLE III: OVERVIEW OF UNCERTAINTY INTERVALS ON DERIVED VARIABLES AND PARAMETERS FOR PHPP FOR CASE 3. VENTILATION AIRFLOQ RATE (Q), HRU EFFICACY ($\eta_{HRU}$), INTERNAL HEAT GAINS ($I_G$), SOLAR GAINS ($I_S$) AND SOLAR ADMITTANCE VALUE FOR THE GLAZING (G)**

The measured energy use was in good agreement with the predicted energy use for space heating for each of the cases. Case 5 was the only case where the predicted energy use was higher than measured. For case 2 and case 6 the measured energy use was higher than the predicted (see Figure 6.)

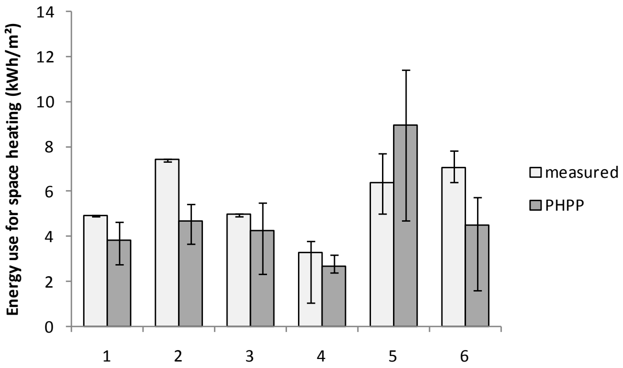


**FIGURE 6: DIFFERENCE BETWEEN PREDICTED AND MEASURED ENERGY USE FOR SPACE HEATING. ONLY IN CASES 2 AND 6 SIGNIFICANT DIFFERENCES WERE FOUND. VALUES SHOWN ARE IN KWH/M³ FOR THE MEASURED PERIOD ONLY.**

## 4. CONCLUSIONS

The energy use for space heating and the indoor temperatures of 6 Belgian passive houses were monitored in the winter of 2010. The test group consisted of 4 passive houses with a massive shell construction and 2 timber frame houses. The results were compared to the energy use for space heating predicted with PHPP. The observed energy use was in good agreement with the prediction for all 6 cases, nevertheless, in 2 of the 6 cases, the measured energy use was higher than predicted. Although, for 3 of the massive shell cases, the measurements followed shortly after completion, no significant differences with the performance of the other cases could be observed.

## EXAMPLE REFERENCES


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2. PHP vzw and PHI Darmstadt, 2007, Passive House Planning Package. Monthly mean quasi steady state planning tool.
3. ONSET HOBO H08-032-03 and H08-003-02 relative humidity / temperature logger
4. VOLTCRAFT Energy Logger 4000 electric power logger
6. Janssens, A. and Vandepitte, A. 2006 , Analysis of indoor climate measurements in recently built Belgian dwellings, IEA Annex 41 work meeting.
5. BIN ,1991, Ventilatievoorzieningen in woongebouwen, NBN D 50 001, Brussels (in dutch)