COMPUTATIONAL STUDY ON ENERGY SAVING STRATEGIES FOR THE 'SOLAR GARDEN HOUSE'

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ABSTRACT The 'Solar Garden House' is an example of a recently developed concept for energy conscious building design. One of the striking features of the Solar Garden House, designed by architect Jon Kristinsson, is a huge sun space connecting two small housing blocks. The sun space is meant as an air collector from which heated air can be conducted through a cavity wall in each of the mentioned housing blocks.

A preliminary computational study, carried out at Delft University of Technology, indicated that the contribution of the cavity wall was negligible. This paper reports on a study dealing with the alternative use of the sun space as a device for pre-heating air for ventilation purposes. Also the impact of local building legislation (concerning ventilation in buildings) on energy savings has been examined.

Figure 1 shows an image of the Solar Garden House as built in the Netherlands.

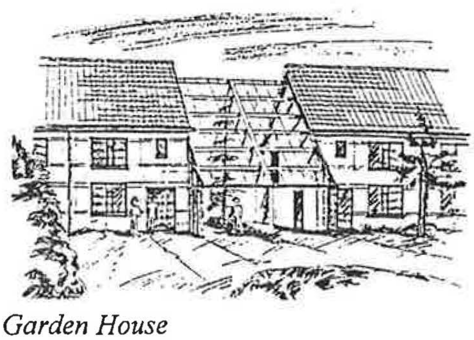

Figure 1: the Solar Garden House

1. INTRODUCTION

In the Netherlands recently a number of Solar Garden Houses have been built. However without preceding computational study. To obtain a reliable estimate of the energy performance of the system a computational study has been carried out at Delft University of Technology. Main conclusion of this study was that the contribution of the cavity wall, meant as an energy-saving building component, was negligible [1].

The here discussed study deals with the alternative use of the sun space as a device for pre-heating air for ventilation purposes. Main goal is to compute and compare energy demands for the following design options for use of pre-heated air:

a. the original 'Solar Cavity Wall' concept.
b. alternative ventilation strategies.
c. combination of a and b.

2. VENTILATION STRATEGIES

Three different ventilation strategies have been considered:

a. No air exchange between sun space and house. Both sun space and house are ventilated with fresh air. See figure 2a.
b. Air exchange between sun space and house. The amount of air moving from the sun space to the house equals the amount of air moving in the opposite direction. Sun space and house are also ventilated with fresh air. See figure 2b.
c. One-way ventilation from sun space to house. In this case pre-heated air from the sun space is transferred to the house. See figure 2c.

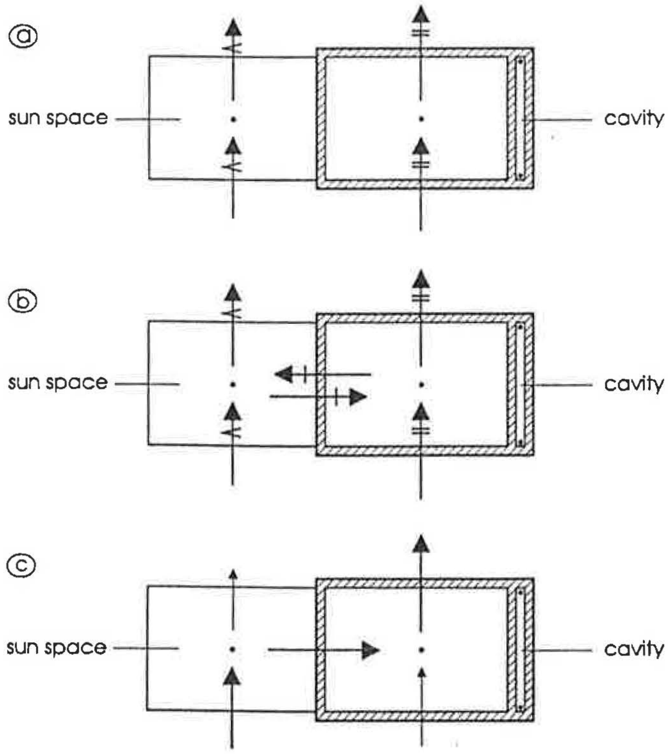

Figure 2: ventilation strategies.

3. ASSUMPTIONS

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3. ASSUMPTIONS

A physical model of the Solar Garden House has been made in which the different ventilation strategies are included. Energy demands for the different design options have been computed using the finite element based computer program BFEP [2].

In computing the energy use for heating purposes an auxiliary heating efficacy of 90 percent has been assumed. All computations are based on actual U-values and other relevant constants of all parts of the building envelop. (The Solar Garden House is very well insulated; it has an insulation package of 0.13 m and triple glazing.)

For all variants complete mixing of all incoming air is assumed in the sun space as well as the house.

The outer climate - air temperatures and solar irradiation - is simulated by means of the reference year for the Netherlands.

Within the house three different temperature zones are distinguished. For each temperature zone ventilation fold and thermostat settings can be set separately.

In all calculations concerning alternative ventilation strategies the ventilation of the cavity wall is turned off.

4. APPROACH

The energy savings of all considered variants will be related to the energy consumption of a reference house. Reference house and Solar Garden House are identical, except for the following aspects:

a. insulation package of 50 mm.
b. standard double glazing.
c. no flow of pre-heated air through the cavity wall.

Energy savings S are calculated using the following formula:

$$S = \frac{E_{ref.house} - E_{variant}}{E_{ref.house}} * 100\%$$

with: $E_{ref.house}$ = energy consumption of the reference house per year [GJ]
$E_{variant}$ = energy consumption of the considered variant per year [GJ].

Dutch legislation on ventilation is divided in two parts: legislation concerning the amount of incoming fresh air in a room and legislation concerning the origin and the destination of the air. The last mentioned part prescribes for specific rooms that the ventilation air must be outside air. It is clear that this legislation imposes restraints on using the sun space as a pre-heating device, as the air in the sun space is not outside air. Therefore energy savings will be considered for two situations:

a. All legislation concerning ventilation is applied. Further consideration results in 16% via the sun space for air exchange between sun space and house and 58% via the sun space for one-way ventilation from sun space to house (see table 2).
b. The legislation concerning origin and destination of air is neglected.

For a fair comparison of the different variants the ventilation fold of the house (n_{house}) is kept constant at 0,9 h^{-1}. This value is the lowest ventilation fold allowed for the house itself. The ventilation fold of the sun space ($n_{sun\ space}$) varies depending on ventilation strategy and applied or neglected legislation. For all variants the contribution from pre-heated air from the sun space to the ventilation of the house is indicated in percents of the total amount of air needed for ventilation of the house.

5. RESULTS

For the reference house and the operational Solar Garden House the following results are obtained:

variant:	remarks:	ventilation folds:	energy consumption per year:	savings:
reference house	'normal' insulation; cavity wall is not operational	$n_{sun\ space}$ = 0,5 h^{-1} n_{house} = 0,9 h^{-1}	30,16 GJ	-
Solar Garden House	air flow rate in cavity wall: 303 m^3/h	$n_{sun\ space}$ = 0,5 h^{-1} n_{house} = 0,9 h^{-1}	20,94 GJ	31 %

Table 1: computational results for the reference house and the operational Solar Garden House.

Computations in accordance with all local legislation produce the following results for the different ventilation strategies:

ventilation strategy:	remarks:	ventilation folds:	energy consumption per year:	savin gs:
no air exchange between sun space and house	cavity wall not operational	$n_{sun\ space}$ = 0,5 h^{-1} n_{house} = 0,9 h^{-1} (0 % via sun space)	20,76 GJ	31 %
air exchange between sun space and house	cavity wall not operational	$n_{sun\ space}$ = 0,5 h^{-1} n_{house} = 0,9 h^{-1} (16 % via sun space)	19,70 GJ	35 %
one-way ventilation from sun space to house	cavity wall not operational	$n_{sun\ space}$ = 0,7 h^{-1} n_{house} = 0,9 h^{-1} (58 % via sun space)	17,24 GJ	43 %

Table 2: computational results for the alternative ventilation strategies in accordance to all legislation.

For all variants this is the lowest energy consumption attainable according to current Dutch legislation. Results are shown graphically in figure 3.
Neglecting the legislation on origin and destination of the air the results change to the following:

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one-way ventilation from sun space to house	cav ope

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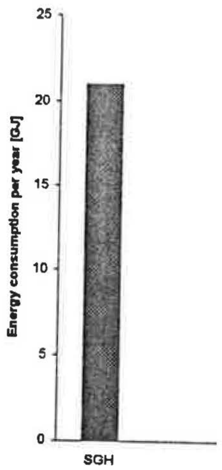

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76 GJ	31 %
70 GJ	35 %
24 GJ	43 %

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ventilation strategy:	remarks:	ventilation folds:	energy consumption per year:	savings:
no air exchange between sun space and house	cavity wall not operational	$n_{sun\ space} = 0{,}5\ h^{-1}$ $n_{house} = 0{,}9\ h^{-1}$ (0 % via sun space)	20,76 GJ	31 %
air exchange between sun space and house	cavity wall not operational	$n_{sun\ space} = 1{,}2\ h^{-1}$ $n_{house} = 0{,}9\ h^{-1}$ (100 % via sun space)	13,96 GJ	54 %
one-way ventilation from sun space to house	cavity wall not operational	$n_{sun\ space} = 1{,}2\ h^{-1}$ $n_{house} = 0{,}9\ h^{-1}$ (100 % via sun space)	16,10 GJ	47 %

Table 3: computational results for the alternative ventilation strategies neglecting legislation on origin and destination of the air.

To demonstrate the limitations caused by Dutch legislation on ventilation these results are also shown graphically in figure 3.

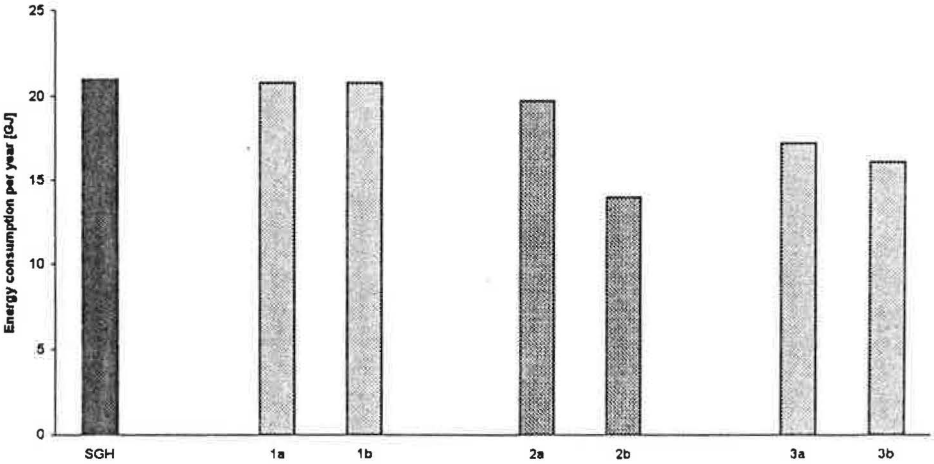

Figure 3: comparison of different ventilation strategies: the Solar Garden House (SGH), no air exchange between sun space and house (1), air exchange between sun space and house (2) and one-way ventilation (3) according to all legislation (a) and neglecting the legislation on origin and destination (b).

6. CONCLUSIONS AND REMARKS

1. All here discussed alternative ventilation strategies have a lower (or nearly equal) energy demand in comparison with the operational Solar Garden House. As 'no air exchange between sun space and house' practically equals the energy demand of the operational Solar Garden House the contribution of the Solar Cavity Wall is shown to be nil.
2. Comparing the three alternative ventilation strategies in accordance to all legislation 'one-way ventilation' gives the lowest energy consumption.
3. Neglecting the part of the legislation that prescribes origin and destination of the ventilation air, 'air exchange between sun space and house' is the best option. However, this option does not guarantee a sufficient amount of fresh air in the domestic building, as part of the ventilation will be with recirculated old air. Therefore this option is theoretical only.
4. The performance of the house applying 'one-way ventilation' could be improved by more flexible interpretation of the legislation: considering the air in the sun space as outside air. The only condition is that the quality of the air in the sun space (being a kind of outdoor space) should be guaranteed.

REFERENCES:

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2. Augenbroe, G.L.M. (1986) Research oriented tools for temperature calculations in buildings. Proceedings of the International Conference on System Simulation in Buildings, Liege.

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1. INTRODUCTION

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