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The PLEIADE Dwelling: an IEA Task XIII Low Energy Dwelling with Emphasis on IAQ and Thermal Comfort

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Synopsis

The major objective of the IEA task XIII project is to design and construct low energy dwellings which should be technically and economically realistic in the period 2000-2010.

The design criteria for the Belgian dwelling are the following:
- *low energy demand for heating purposes;*
- *good thermal comfort conditions, as well in winter as in summer with attention to the problem of overheating;*
- *very good airtightness ($n_{50} \leq 1\ h^{-1}$);*
- *good indoor air quality conditions;*
- *attractive design for majority of potential clients;*
- *only use of realistic technical solutions.*

This paper includes a description of the overall design of this rowhouse, special attention being given to the conception of the envelope wit respect to the airtightness.

A detailed description of the philosophy of the balanced ventilation system with heat recovery and of the air heating system is given.

Results about the seasonal heating demand with special attention for the heating demand related to the ventilation are included. Also an estimation of the air change rates during periods of night ventilation is given (simulations with VENCON) and the impact of night ventilation on the thermal comfort conditions (simulations with MBDS).

Finally, an indication of the monitoring plans is given.

1. Introduction

The major objective of IEA Task XIII 'Advanced Low Energy Dwellings' of the Solar Heating and Cooling programme is to think about the concept of low energy dwellings to be built in the period 2000-2010.
This Advanced Low Energy Dwelling should not only be a 'high tech' product but also be conform with national standards and local requirements. Also the concept of the dwelling should be attractive for future builders.
Therefore, the construction of such an Advanced Low Energy Dwelling is a challenge for the involved teams with respect to the severe objectives and requirements.

2. The objectives of the IEA Task XIII project

IEA Task XIII started in 1990. In total, some 14 countries participate in the project : Austria, Belgium, Canada, Denmark, Finland, Germany, Italy, Japan, the Netherlands, Norway, Sweden, Switzerland, United Kingdom and United States. Operating Agent is Prof. A.G. Hestness from the University of Trondheim (Norway).
The aim is to built in all participating countries a dwelling which should be for the period 2000-2010 a realistic low energy solar dwelling. An important boundary condition is that the techniques to be used should be cost effective within 10...15 years. It is clear that such criteria cannot be evaluated in absolute terms in 1993 but one should at least try to exclude as much as possible techniques which don't give any reasonable perspective for a costeffective application.

At present, the construction in several countries is already finished or under way: Belgium, Canada, Germany, Netherlands, Norway.

The project at IEA level is assumed to finish in 1995. The results should include also information regarding the monitoring activities in these dwellings.

3. The Belgian context for the IEA participation

For Belgium, the Belgian Building Research Institute together with Architecture et Climat of the University of Louvain-La-Neuve take part in IEA Task XIII. The Belgian participation is financed by the Walloon Region.

Besides these 2 teams, a large number of other organizations are involved in the project :

- Electrabel :
  It is the Belgian electricity and gas company. Electrabel acts as owner of the dwelling. Moreover, its 2 laboratories, Laborelec (for all electrical applications) and A.R.G.B. (for all gas applications) are fully involved in the project and are responsible for the heating systems to be used in the dwelling. A gas system as well as an electrical heating system will be installed in order to allow a comparison between different systems;
- Laborelec : see above;
- A.R.G.B. : see above;
- a professional architectural office, leaded by Ph. Jaspard;
- COMITA : COMITA is the association of all Belgian thermal insulation associations. The major role of COMITA is related to the choice and installation related aspects of the thermal insulation and glazing systems;
- Belgian Centre for Domotics (B.C.D.), which is the Belgian association of organizations involved in domotics;
- a whole range of sponsors.

Given the facts that :

- the last low energy demonstration dwelling was constructed in Belgium some 10 years ago;
- many demonstration dwellings often suffer from problems as overheating, durability problems, and are therefore not really a propaganda for building low energy dwellings;

it was a clear objective from the beginning of the project to construct a dwelling which by most of the potential builders will be appreciated.

In practice the following list of requirements was set up :

- a very good thermal insulation level (there are requirements regarding the insulation level in the Flemish and Walloon Regions);
- good thermal comfort conditions, as well in winter time as in summer time but with a particular interest for avoiding overheating problems in summer;
- a potential for good indoor air quality conditions, by means of combining a good building airtightness with a well designed balanced ventilation system;
- good daylighting conditions;
- nice architecture;
- attention for durability aspects;
- use of domotics for optimization of thermal comfort, energy use, general comfort and security.

The PLEIADE (Passive and Low Energy Innovative Architecture DEsign) dwelling should fulfil all these requirements.

4. The PLEIADE dwelling

The dwelling, of which the construction started in May 1993, is situated in Louvain-La-Neuve, some 30 kms South-East of Brussels in a new housing estate.

4.1. Groundplan

The PLEIADE dwelling is a 2-storey rowhouse, with a width of 9 meters and a depth of 10 meters. There is some additional space in the attic and there is also a basement. The rear facade of the dwelling is orientated South-West. The ground plans as well as the front and rear facade are presented in figure 1 to 4.

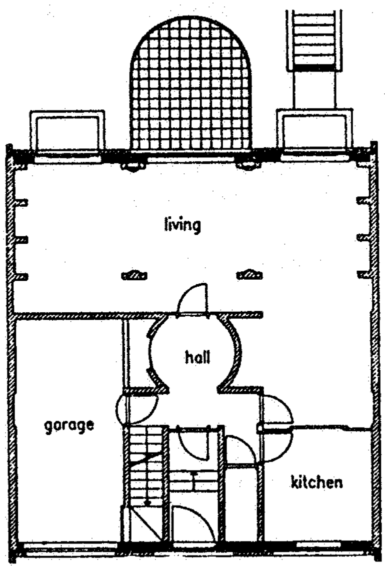

***Figure 1:* Groundfloor of the PLEIADE dwelling**

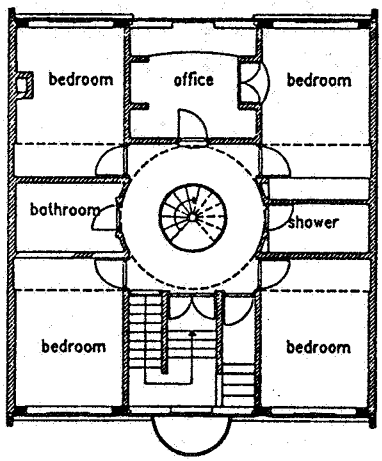

***Figure 2:* First floor of the PLEIADE dwelling**

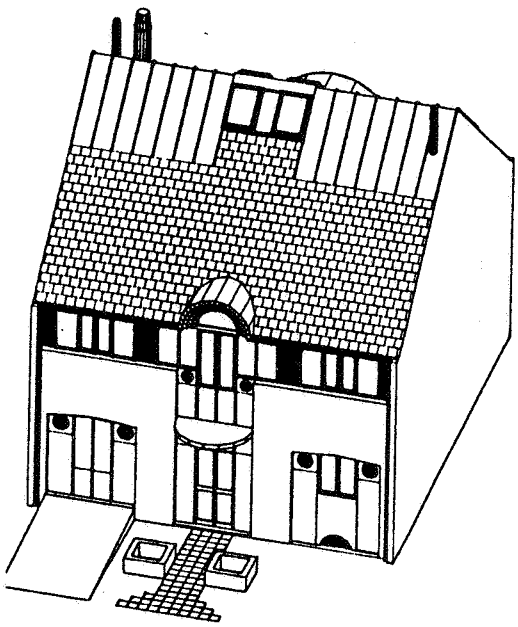

***Figure 3:* Front facade of the PLEIADE dwelling**

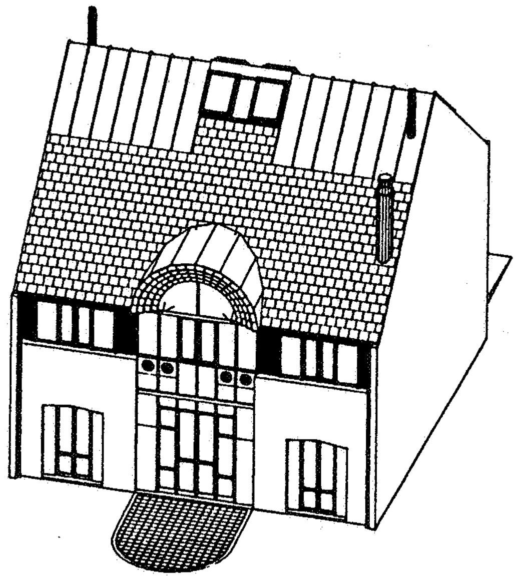

***Figure 4:* Rear facade of the PLEIADE dwelling**

4.2. Some important features

Walls, roofs and floors are, according to Belgian standards, extremely well insulated. The U-values are given in table 1.

Component	U-value (W/m²K)
Walls	0.14...0.20
Inclined Roof	0.12
Windows	1.14...1.32
Floor above basement	0.19

Table 1: U-values of different building components

The U-value of the walls of 0.14 ... 0.20 W/m²K corresponds with about 250 mm of thermal insulation. In Belgium, cavity walls consisting of an inner and outer leave in brickwork are normally used with some 40...80 mm insulation in the cavity. Such technology cannot be used for a very large insulation thickness. Outside insulation could be an alternative. However, the urbanistic requirements in Louvain-La-Neuve are very severe and require brickwork. In order to obtain a very good U-value, the facade walls have no mechanical function and are not supporting the floor. This allows to have a cross section as shown in figure 5. This concept has also some advantages with respect to the airtightness as is described in §5.
Another important feature concerns the various systems for providing the energy to the building. Briefly summarized, they are the following :

- an air heating system selected by A.R.G.B., with a gas heated boiler. A 4 zone control system is foreseen allowing different heating regimes for the different zones;
- in parallel with the air heating system on gas, there are also electrical radiators (direct or with accumulation) selected by Laborelec;
- for the production of the domestic hot water, solar water collectors are planned in combination with a gas boiler (no accumulation)
- an advanced domotics system able to control the heating and ventilation system, lighting and security aspects. B.C.D. is in charge of the choice and installation of the system.

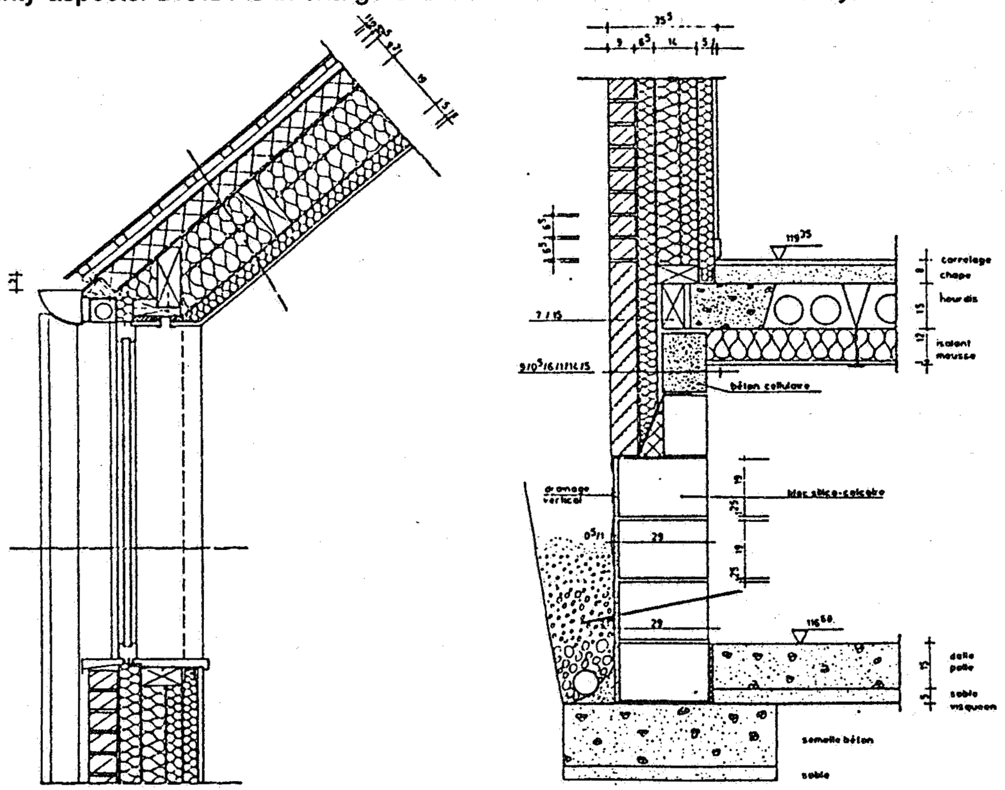

Figure 5: Some cross sections of the facade walls of the PLEIADE dwelling

5. Aspects regarding building airtightness, ventilation and indoor air quality

From the beginning of the project, the achievement of good indoor air quality conditions is a top priority. However, the need to have a low energy consumption requires specific attention to the building airtightness and the efficiency of the ventilation system.

5.1. Building airtightness

The objective is to achieve an overall airtightness of $n_{50} \leq 1\ h^{-1}$. This is for the Belgian situation a very severe requirement. In principle, the airtightness of the facade walls can be very good since a continuous vapour barrier consisting of a PE-foil is foreseen (see figure 5) and should be continuous over the whole facade surface. The PE-foil shall be fixed on the window frames. Given the fact that no previous experience exists in Belgium, the installation of the PE-foil will require specific attention.
The measurement of the airtightness is planned and, if necessary, improvements will be made. BBRI disposes of a large experience in airtightness testing.

5.2. The ventilation system

5.2.1. Basic ventilation

The first requirement of the ventilation system is that it should comply with the requirements of the Belgian standard NBN D50-001 [1]. Table 2 gives the nominal air flow rates for the various rooms as specified in NBN D50-001. The system consists of mechanical supply and mechanical extraction with a static heat recovery system. According to the standard, fresh air supply is required in the bedrooms whereas recirculation air is allowed for the living room. Transfer openings are foreseen in the inner doors corresponding with an air flow rate of 25 m³/h for a pressure difference of 2 Pa.

Room	Air flow rate (m³/h)	Remarks
Bedrooms (3.6 m³/h,m²)		
Bedroom 1	34	Outside air
Bedroom 2	33	Outside air
Bedroom 3	33	Outside air
Bedroom 4	33	Outside air
Office	22	Outside air
Living room	134	Recirculated air
Kitchen	50	Air extraction
Bathrooms (2)	50	Air extraction
Toilet(2)	50	Air extraction

***Table 2:* The nominal air flow rates for the various rooms as given in NBN D50-001**

Some specific features of the system :
- given the fact there is also an air heating system, an integration of the 2 systems is required. However, the achievement of good thermal comfort and good indoor air quality conditions are given the same importance. Therefore, separate fresh air ducts and preheated air ducts are foreseen for the bedrooms and office. This clearly complicates the system but it was considered as a must in a low energy building with good IAQ conditions;
- there is a static heat exchanger with an efficiency of some 60...65 %. Nevertheless, it is expected to have within 10 years better heat exchangers giving efficiencies in the order of 65...75 % at competitive costs;
- there is a by-pass over the heat exchanger avoiding pre-heating in summertime mode.

5.2.2. Intensive ventilation

The Belgian standard requires also provisions allowing intensive ventilation during certain periods. These openings should correspond with 3.2 ... 6.4 % of the floor area. To achieve this, openable windows or doors are required. In the PLEIADE dwelling, specific attention is given to this kind of intensive ventilation, especially for allowing night time ventilation during hot periods.

6. Simulation results regarding ventilation aspects

6.1. Ventilation and CO_2-concentrations in winter time

The total air change rate as well as the CO_2-concentration in the living room were simulated by using VENCON, developed by TNO-BOUW and used at B.B.R.I. since 1988. The building was modelled as consisting of 17 zones. For an internal temperature of 20 °C and wind pressure coefficients corresponding with a building surrounded by obstructions equal to the height of the building, the total air change rate is given in table 3.

	0 m/s	4 m/s		10 m/s	
	0°	0°	180°	0°	180°
15 °C	0.52 h^{-1}	0.52 h^{-1}	0.51 h^{-1}	0.57 h^{-1}	0.54 h^{-1}
0 °C	0.51 h^{-1}	0.52 h^{-1}	0.51 h^{-1}	0.57 h^{-1}	0.54 h^{-1}
-10 °C	0.51 h^{-1}	0.51 h^{-1}	0.50 h^{-1}	0.57 h^{-1}	0.54 h^{-1}

Table 3: ***Total air change rate for mechanical air flow rates and transfer openings dimensioned according to NBN D50-001***

The results show that the total air change rate is rather stable and varies little as a function of the climatological conditions. It means that the airtightness is sufficient.

In Belgium, kitchen hoods are commonly used [3]. In case a cooker hood with a nominal air flow rate of 300 m³/h is used (which is not at all exceptional), there is an unbalance in the total air flow rate of more than 300 m³/h. This leads to large pressure differences across the building envelope. For the kitchen, a pressure difference of about 50 Pa is found. Probably a cooker hood with a built-in heat exchanger and direct supply air will be used.

6.2. Air flow simulations in summer time [3]

In order to obtain acceptable thermal conditions in summer time, a combination of appropriate shading provisions in combination with night time ventilation is required.

Several simulations regarding the air change rates during nighttime were done by using the following assumptions :

- living : 3 openable windows, each 0.25 m²;
- bedrooms : openable window, 0.25 m²;
- attic space : 2 * 1 m² openable window

The results for the total air change rate and for the lowest air change rate in one of the bedrooms are given in tables 4 (bedroom doors closed) and 5 (bedroom doors open).

		Ti = 20 °C		Ti = 15 °C	
		n_{tot} (h^{-1})	n_{min} (h^{-1})	n_{tot} (h^{-1})	n_{min} (h^{-1})
v = 1 m/s	0 °	5.9	2.8	8.2	3.7
	180 °	6.1	2.8	8.3	3.6
v = 4 m/s	0 °	13.1	3.1	14.1	3.8
	180 °	13.1	3.0	13.6	3.8

Table 4: ***Total air change rate for the whole dwelling and lowest ventilation rate in one of the bedrooms, Ti = 25 °C, bedroom doors closed***

		Ti = 20 °C		Ti = 15 °C	
		n_{tot} (h^{-1})	n_{min} (h^{-1})	n_{tot} (h^{-1})	n_{min} (h^{-1})
v = 1 m/s	0 °	6.5	5.4	8.6	3.2
	180 °	.6.7	9.1	8.8	8.9
v = 4 m/s	0 °	17.6	32	18.5	33
	180 °	17.5	34	17.6	35

Table 5: ***Total air change rate for the whole dwelling and lowest ventilation rate in one of the bedrooms, Ti = 25 °C, bedroom doors open***

Interpretation :

Bedroom doors closed :

The average air change rate for the whole dwelling is for wind speeds of at least 1 m/s of the order of 6...8 h^{-1}.

Bedroom doors open :

No significant increase in total air change rate for the whole dwelling is found. for v= 1m/s;
For v= 4 m/s, which is rather abnormal during very hot periods, the increase in total air change rate is more significant. Moreover, the increase in the minimum air change rate in the bedrooms is enormous. This is due to the fact of having cross ventilation.

6.3. Thermal modelling for summer conditions

The multizone dynamical programme MBDS was used for predicting the temperature fluctuations in the different rooms of the PLEIADE dwelling [4]. The simulations were done for very high outdoor temperatures ranging between 15 °C (night) and 32 °C. Several strategies were regarded. Table 6 briefly describes the strategies as well as the observed extremes in room temperature. Figure 6 shows the simulated temperature for strategy 2.

Nr.	Description	Maximum (°C)		Minimum (°C)	
		Living	Bedroom South	Living	Bedroom South
1	No solar protection fixed air change rate n= 0.05 h^{-1}	41	45	38	40
2	Same as 1. but 19.00-7.00 : 960 m³/h entering in living and distributed over other rooms	28	30	22	27
3	Same as 2. but total air flow rate 1210 m³/h distributed over all rooms	29	29	24	25
4	Same as 3. but solar protection with shading coefficient of 0.2 when incident solar radiation greater than 150 W/m²	25	25	22	23

Table 6: ***Minimum and maximum temperatures for various strategies during a hot period***

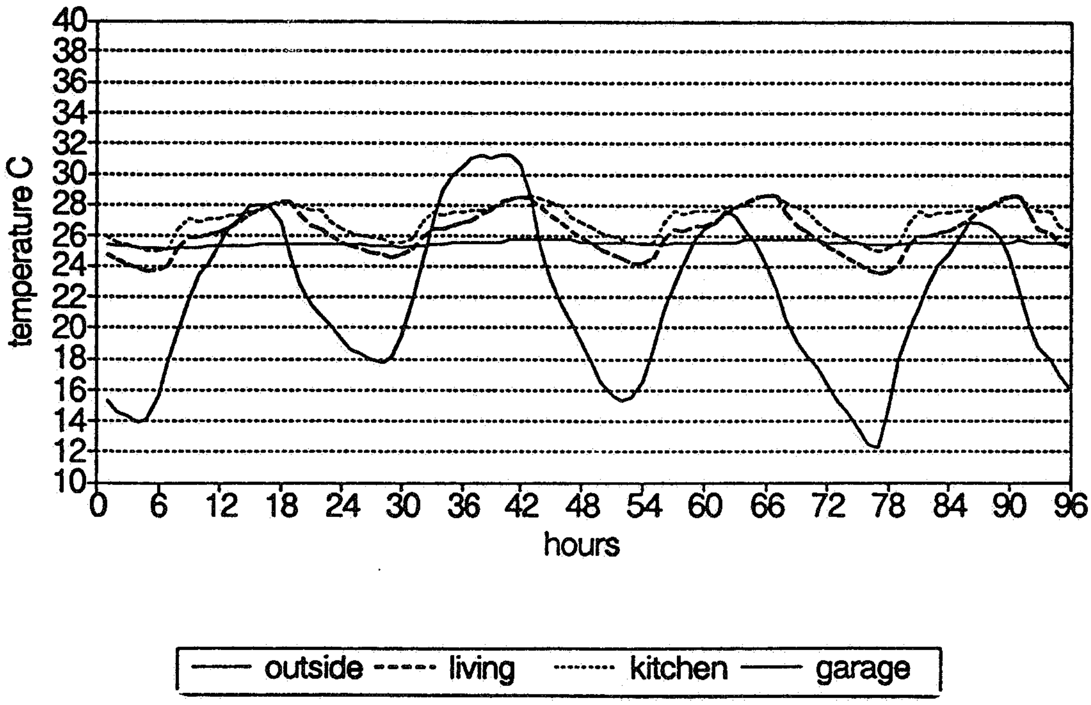

Figure 6: ***Simulation of night ventilation performances applied in the PLEIADE dwelling***

7. Future actions

The first stone of the PLEIADE dwelling was installed on June 25, 1993. The inauguration of the building is planned for the spring of 1994. During the construction, instrumentation allowing monitoring will be installed. Monitoring campaigns are planned in summertime and wintertime. They will be mainly done by B.B.R.I. with additional measurements by Laborelec and A.R.G.B. regarding the energy consumption. Analysis of the measurements and comparison with simulated results is planned and will be done by all partners of the project.
Till the end of 1994, the building will be unoccupied. In 1995, measurements including the effect of occupancy are planned.

8. Conclusions

With the design and the construction of the PLEIADE dwelling, the partners of the project aim to achieve a dwelling which is not only very attractive from the energy point of view but which also is very attractive from an architectural point of view and which has excellent qualities regarding thermal comfort and indoor air quality. All these features should be realised within realistic and modest budgetary limitations.

First practical results are expected in the summer of 1994 and will be probably reported at the 1994 A.I.V.C. conference.

9. Acknowledgments

The authors wishes first of all to thank the Walloon Region for the financial and moral support which is given to the project. Moreover, they like to thank Electrabel and its laboratories Laborelec and A.R.G.B., COMITA, B.C.D. as well as all the sponsors to the project.

10. References

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