ACTIVE HOUSE CONCEPT VERSUS PASSIVE HOUSE

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Abstract

The passive house concept is the present trend in energy efficient sustainable dwellings. Within the passive house concept every effort is made to minimize the energy use. Substantial savings can be achieved by passive energy systems, especially natural ventilation, summer shading and winter solar heat gain. The development of sustainable buildings is driven by the need to preserve the balance of nature. The ventilation capacity of many of these passive houses is critical. During a three week period different measurements in three of the first passive houses projects in Netherlands were undertaken to define indoor air quality and thermal comfort. Results showed that in some cases ventilation was completely insufficient. Energy saving and sustainability is very important but not at the risk of endangering health of the occupants. This was the starting point for a new approach, which led to an alternative concept: the active house concept. By using ground air collectors, labyrinth foundation, muro-causter and hypo-causter, the whole building envelope and construction is thermally activated by natural pre-cooled air in the summer and natural pre-heated air in winter. A first design is presented to illustrate the concept.

1. Introduction

The built environment uses around 40% of our total energy demands. This results in environmental problems and exhaustion of fossil fuels. This has to change and new approaches have to be developed. One such approach is the latest trend on low energy housing: the Passive House. In Germany and Austria more than 5.000 Passive houses have been built and a lot experience was gained. Also in other European countries the passive house concept is promoted, still only a few houses in the other countries have been built. Designing and building of passive houses in a country is not a matter of straight forward following the experience of the already built examples from Germany or Austria. Each country has its own building tradition, architecture, building technologies, climate and culture (Kaan en de Boer 2005). In Germany, the Passiv Haus Institut took the traditional concept of passive solar building as a starting point and developed concepts for very low energy buildings by combining the principles with a very well insulated and air tight building envelope (Kaan & de Boer 2005).In France as an example only a few passive houses have been built (Thiers and Peuportier 2008), mainly for experimental purposes and the first attempt to reach the Passive House standard in France has failed (CEPHEUS project in Rennes (Feist et al., 2005)).

The general definition of a Passive House is that the energy consumption is limited to around maximum 15 kWh/m² for space heating and around maximum total of 120 kWh primary energy/m² for heating, domestic hot water and electrical consumption by electrical equipment and lighting. To meet these criteria, the Passive House concept focuses first and foremost on reducing the energy demand of the building. Analysis of Passive House solutions shows high priority with regard to the performance of the thermal envelope: high insulation of walls, roofs, floors and windows/doors, thermal bridge-free construction and air tightness (Storm et.al 2006). For good insulated low energy houses the needed heating energy for the ventilation air is around 50 to 65% of the total heat demand (Pottler et.al. 1999). This is the reason that often the ventilation are strongly reduced, some mention values as low as a ventilation rate of 0,4 (de Boer et.al 2005). There is a competition between energy saving on the one hand and a good indoor air quality on the other hand. Storm

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et.al (2006) state; “However, since Passive Houses have air tightness, sufficient ventilation must be paid to the actual realization in practice of the required ventilation rate.”

In the Netherlands architect Erik Franke has built the first Passive Houses in the Netherlands according to the ‘Passivhaus Projectierungs Paket’(PhPP) (Franke 2005). The PhPP is a package of tools for architects to help them with the design of passive houses and was developed by the German ‘Passivehaus Instituut’ in Darmstad. Though in the Netherlands a number of houses have been built according to PhPP, the actual performance of these houses was not yet thoroughly investigated. The aim of a study at the Technische Universiteit Eindhoven was to investigate if the ventilation levels reached by the installed mechanical ventilation systems in these Dutch passiv houses are sufficient (Balvers et.al. 2008). The use and application of mechanical ventilation systems in such low-energy house is the critical aspect for creating an acceptable level of IAQ. As the present passive house concept has some critical aspect related to adequate ventilation, we started to look at other ways for building to utilize the available on-site energy resources in a way that minimizes the need for purchased energy and still maintaining a satisfactory indoor environment.

2. Methodology: Active versus passive

There are many possibilities for direct inter-action between the building fabric and the environment in order to reduce the need for additional energy for conditioning to achieve the desired comfort and cover the residual demand. It is difficult to categorize the various passive systems because they often combine strategies for power generation, passive cooling, passive heating as well as heat storage, heat recovery or avoidance of the various external and internal heat gains.

Besides passive solutions, there are also active systems designed to utilize the environment to either produce power, or to operate in conjunction with some mechanical devices to utilize renewable energy to provide heating and cooling (Wachenfeldt and Bell 2003).

Sometimes it is good to go back all the way to the beginning, the basis. The basis of conditioning buildings are from the Greek and Romans. The Greek historian Xenophon mentioned the teaching of the Greek philosopher Socrates (470-399 BC) about the correct orientation of dwellings to have them cool in summer and warm in winter. The Romans pioneered with heating using double hollow floors through whose core the hot fumes of a fire were passed (Florides et al. 2002). They used with their ‘hypocaust’ and ‘murocaust’ the materials of the build construction to condition the building with hot air, see figure 1.

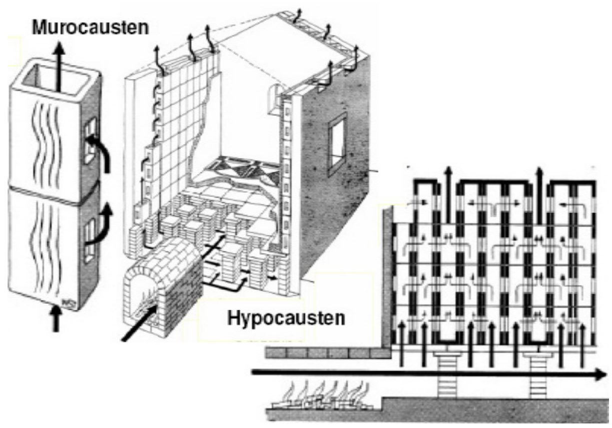

Figure 1. The Roman thermo- and muro-causten system (Florides et al. 2002)

People ruled by Romans assimilated their building techniques and technologies that became one thing with the local ones (Sansone 1999). This was not the only Roman/ Italian influence: Kenda (2006) focused on the beneficial integration of architecture and medicine in Renaissance Italy: Sixteenth century pneumatic architecture, especially the examples of hygienico-pneumatic villas. The villas are connected underground by labyrinth caves and wind channels to provide a unique natural ventilation system (Kenda 2006). These principles became part of the Italian building culture and 19 the century example can be found in Milan, the famous shopping passage Galeria Vettorio Emmannuelle, see figure 2. Here the fundament of the building take over the function of the natural caves.

Galleria Vettorio Emmanuele – Milaan- 1877 – Giuseppe Mengoni

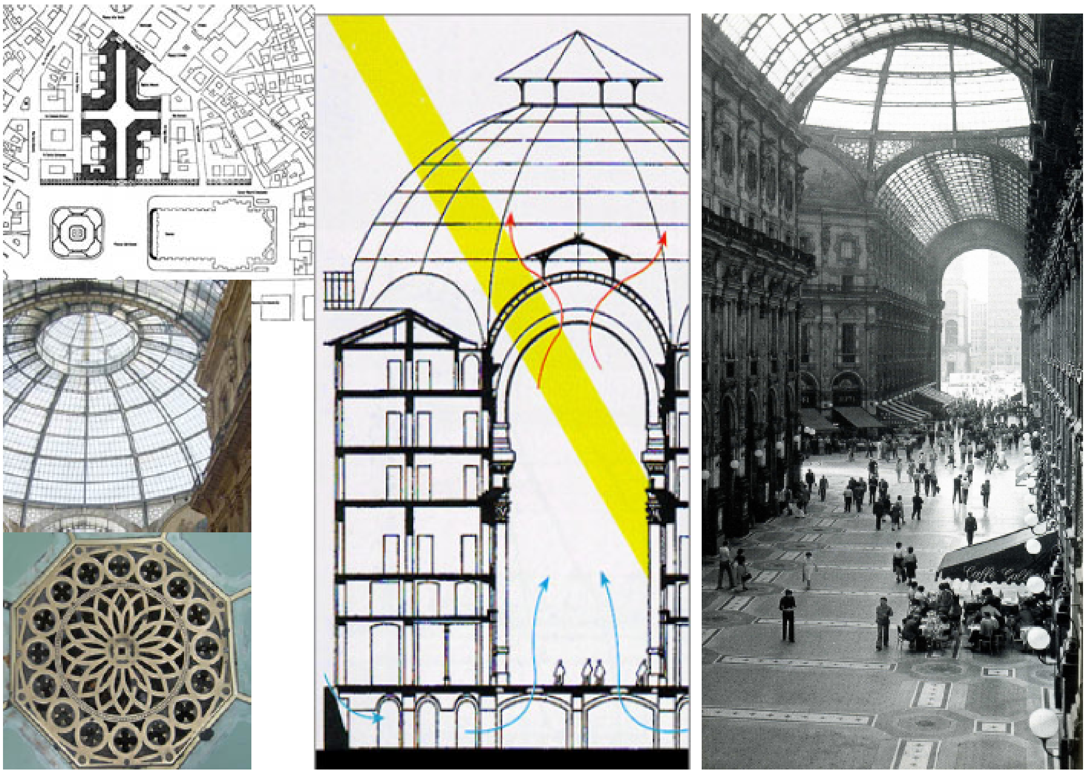

Figure 2 Ventilation through the cellar of the building and floor grilles

2. Methodology; The use of accumulative capacity to save energy

2.1 Active versus passive

As the present passive house concept has some critical aspect related to adequate ventilation, we started to look at other ways for building to utilize the available on-site energy resources in a way that minimizes the need for purchased energy and still maintaining a satisfactory indoor environment.
Besides passive systems with their direct interaction between the building fabric and the environment, which do not produce power and do not need any mechanical devices or significant mechanical energy in order to operate, there are also active systems.
Active systems are designed to utilize the environment to either produce power, or to operate in conjunction with some mechanical devices to utilize renewable energy to provide heating and cooling (Wachenfeldt and Bell 2003). The direct inter-action between the building fabric and the environment in offers many possibilities to reduce the need for additional energy for conditioning in order to achieve the desired comfort and cover the residual demand. It is difficult to categorize the various active systems from true passive systems because they often combine strategies for power generation, passive cooling, passive heating as well as heat storage, heat recovery or avoidance of the various external and internal heat gains (Wachenfeldt and Bell 2003).
A modern variant is the use of the accumulative capacity of concrete constructions to flatten and damp the effect of fast changing outdoor temperatures. One of the first applications of a 'thermolabyrinth' was the 1977 Royal Academy of Music complex in London existing of theatres and music studios by Bill Holdsworth (Holdsworth 2005). Also in Germany there are several project with so called 'Thermo labyrinth' systems built, par example Stadttheater Heilbron, see figure 3 and Terminal 1 Hamburg Airport. Recently in Australia there is built Federation Square in Melborne where the outside air is led in a labyrinth under the square and blown into the atrium of the main building (Bellew 2004, AIRAH 2003). By doing this a significant cooling effect is being realized. Patrick Bellow principal of Atelier Ten has long believe in thermal labyrinhs (Bunn 2004).Other projects a business school designed by Cesar Pelli Architects for the University of Illinois, the Grand Rapids Art Museum in Michigan and the Earth Centre in Doncaster by FeildenClegg Bradley Architects. The Davis Alpine House at Kew Gardens is the most recent evolution of the idea. Wilkinson Eye Architects designed the building in collaboration with Atelier Ten. Bellow gives an extended description of the system and its working (Bellow 2006), see figure 4.

Thermal labyrinth in new municipal theatre in Heilbronn, construction (with sketched-in air flow) 1982

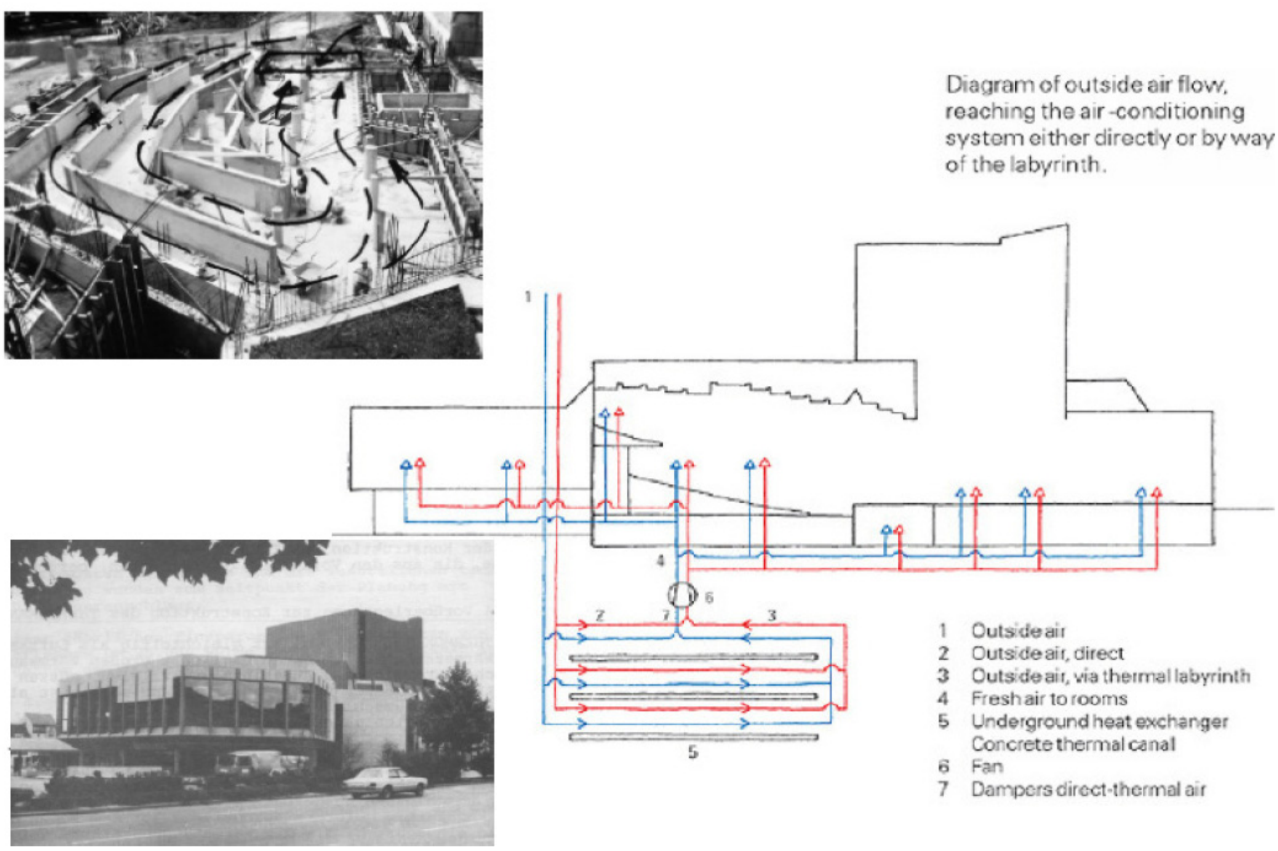

Figure 3 ‘Thermo labyrinth’ systems built, Stadttheater Heilbron

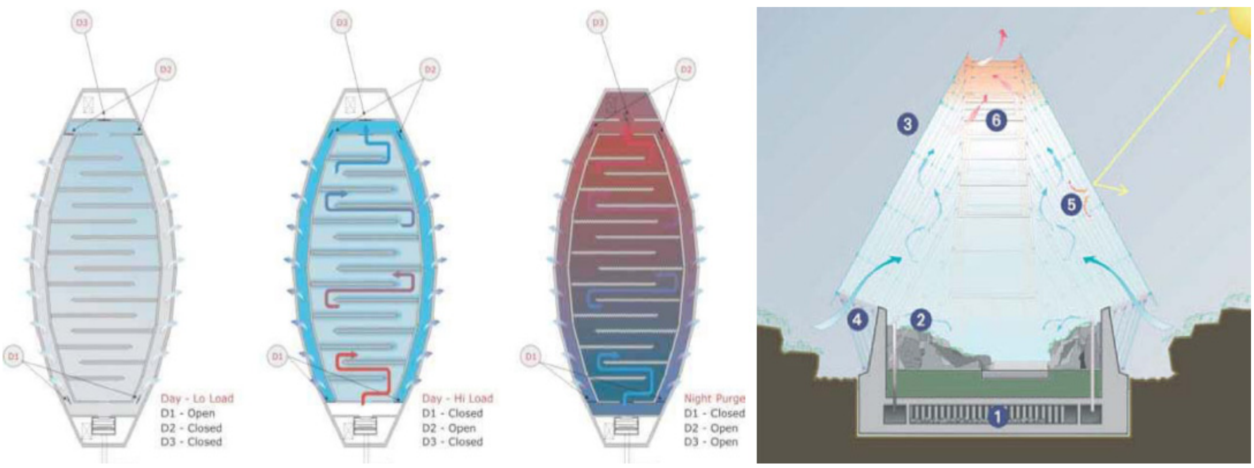

Figure 4 Working Labyrinth cooling ventilation system of the Davies Alpine house (Bellow 2006)

The above left image represents the labyrinth's summer operating mode when hot air is drawn into the structure using mechanical fans. With the control of dampers the air is channeled through a route where it first cools and later is guided into the glass house Ideal living conditions for alpine plants are created by passive environmental controls, see figure 4 right part;

1 An underground concrete labyrinth cools air in summer
2 Cool air from labyrinth passes over plants and replaces rising warm air
3 Clear, low-iron single-glazed skin admits maximum daylight
4 Permanent perimeter fresh-air vents draw in fresh air
5 Automatic internal blind shades sunlight during day and blocks radiated heat loss at night
6 Automated roof vents release heated air

Alpine plants like a cool breeze and cool roots to maintain compact foliage. The glass sides of the building over sail the concrete base and allow air to enter at the base of the glass wall. To induce cool breezes to pass over the plants, vents at the top of the 10 m high internal void open to create a natural stack effect - air rising as it warms up, escaping through the vents, and drawing in cool air at the base to replace it (Bellow 2006).In cooler weather the top vents are closed and the updraft is stopped to retain heat gain within the building. The labyrinth of dense concrete block walls within the structural floor is similar to previous constructions, like the Federation Squire and the Earth Centre in Doncaster.
The undercroft adds to the process, as its concrete labyrinth cools the air that passes through an 80-metre tunnel where it circulates with a simple interweaving latticework of standard precast blockwork (British precast 2007). The thermal mass of the concrete cools the air, and it is then supplied through the alpine house above via a series of displacement tubes nestled among the plants. Drawing fresh air all the way through the labyrinth was a task too strenuous for the natural stack effect; so it had to be pumped up into the glasshouse by mechanical fans. By these fans the air drives through the labyrinth tunnels and is expelled outside at night, so to cool the structure for the morning (Spring 2006). As the building starts to heat up the outdoor air is directed straight into the glasshouse, via vertical pipes that terminate with directional outlets within the plant beds. As the outdoor temperature continues to rise above 18ºC the air is diverted through the labyrinth where it is cooled before passing through the same pipes to cool the plants (Bellew 2006). The result is a remarkable cooling effect, see figure 5.

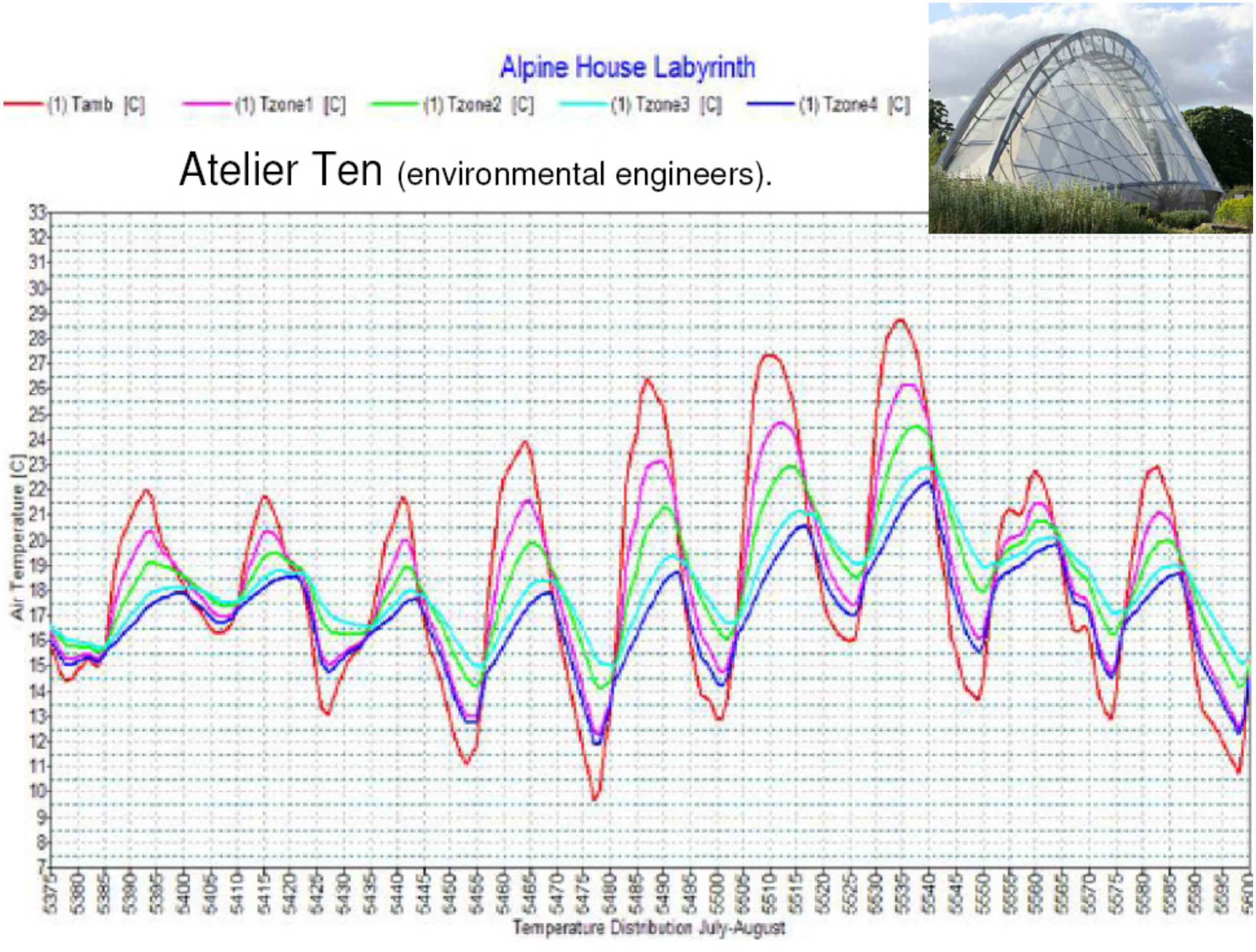

Figure 5 Labyrinth ventilation effect on reducing the temperature of the ventilation air (Bellew 2004)

An interesting modern technology related to the principles of 'thermo labyrinth'systems are earth-air heat exchangers, or ground tubes, or ground-coupled air heat exchangers (De Paepe and Janssens 2003). In the Netherlands only a few of these systems were applied, e.g. the firebrigade stations of Deventer and Soest by the architect Jòn Kristinsson (Kristinsson 2002). In Germany this principle is far more popular and applied in many buildings and passive houses (Pfafferot 1998), mostly with concrete or HDPE tubes as ground collectors.
A concept to use the accumulation capacity of a building in combination with its envelope is the Lega beam Building System (Toft 1993). Hereby between the outer and inner building walls a concrete core is placed, see figure 6. In the space between the walls and the concrete core air flows which can also be cooled of heated with a ground-air collector. In the early nineties the Fraunhofer Institute für Bauphysik studied a similar concept for a hybrid hollow-corefloor-slab-wall-air-collector system with passive discharge to the rooms above and below the slab (Becker 1995, Becker 1997). The system includes a horizontal hollow-core

slab and vertical collectors. The basic repetitious module has a width of twice the core distance. The warmed air enters the slab from the collector through the southern end of one core, is pulled in and pushed through by means of a ventilator, and after discharging heat into the slab's concrete mass it returns to the collector through the southern end of the other core, with a lower temperature than at the collector's outlet (Becker 1995).

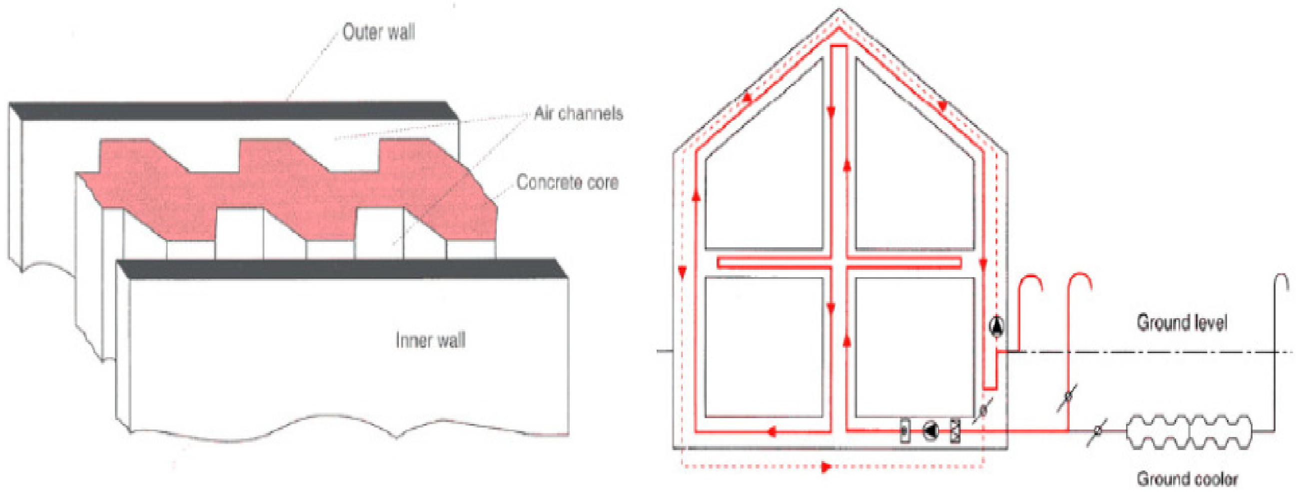

Figure 6. Legabeam Building Systeem (Toft 1993)

Simular solutions are mentioned in the final report of IEA task group 19 (Hastings 1998). The goal of Task 19 was to facilitate the use of solar air systems for residential, institutional and industrial buildings. In 1988 they published a manuscript for an engineering handbook to provide the planner with detailed how-to information six different system types, depending on the needs of the building, climate and budget. One example system types they mentioned was the solar air system with sun collector connected to murocaust and hypocaust (Hastings 1998).
In the air ducts in the ground of the ground-air collectors and also in the labyrinth foundation by cooling of supply air, high relative humidity can occur. Often because of this effect air out these air-ground collectors is some what steel and not that suited to supply directly to the rooms. Especially at humid days there is condensation (Koene & Lightart 2001) When there is a long period of high relative humidity of condensation there is no way to avoid bacteria growth.

By these systems there is contact between the fresh outside air and the concrete, something which we think is not optimal, as dust and participles from the concrete can easily absorbed by the air. A system which does not have that drawback is the ConcreteCool system: concrete core cooling with supply air utilizes the high storage capacity of the concrete ceiling with aluminum ducts within the concrete. The supply air flows through the cooling tubes consisting of aluminum with high thermal conductivity. To improve the heat transfer from the tube to the air, the inner surface was tripled. This system is already used in several German projects (Schröder 2002, Kiefer 2003).These systems, in which only air is used to condition the rooms, are based on ideas which can be traced to the Romans.

BINE Informationsdienst, a service of the Fachinformationszentrum (FIZ) Karlsruhe GmbH and subsidized by the Bundesministerium für Wirtschaft und Technologie (BINE 2006) gives a overview of a few modern principles, of which some already have been applied in projects: Lutzstrassen Apartments in Berlin (Hastings and Mørk 1999) and Gardstens Bostäder aparmentscomplex in Gothenburg (SHINE 2006). These are systems which supply the heat of a thermal suncollector to the floors or walls. Heat from air collectors can be transferred to mass using the room air, or, as in the Lutzstrassed Apartments in Berlin, warmed air can be blown, using fans, through hollow cores in a massive floor, called a *hypocaust* (Hastings, 1999, pp. 92-95), see figure 7. Architects from the Institute for Building, Environment, and Solar Research designed the building with a closed loop from collectors in the south facade through tubes embedded in the concrete floor, and back to the collector. Discharge is by radiant transfer through the slab. This has the advantage of keeping the indoor air temperature from rising rapidly when the collector is heated by the sun.In the apartment Block in Gothenburg, Sweden, by Christer Nordstrom ((Hastings and Mørk 1999)) air warmed from rooftop collectors is ducted by mechanical ventilation to a *murocaust* cavity in the external walls, formed by adding an insulated layer outside the existing not insulated masonry wall, see figure 7 B and C

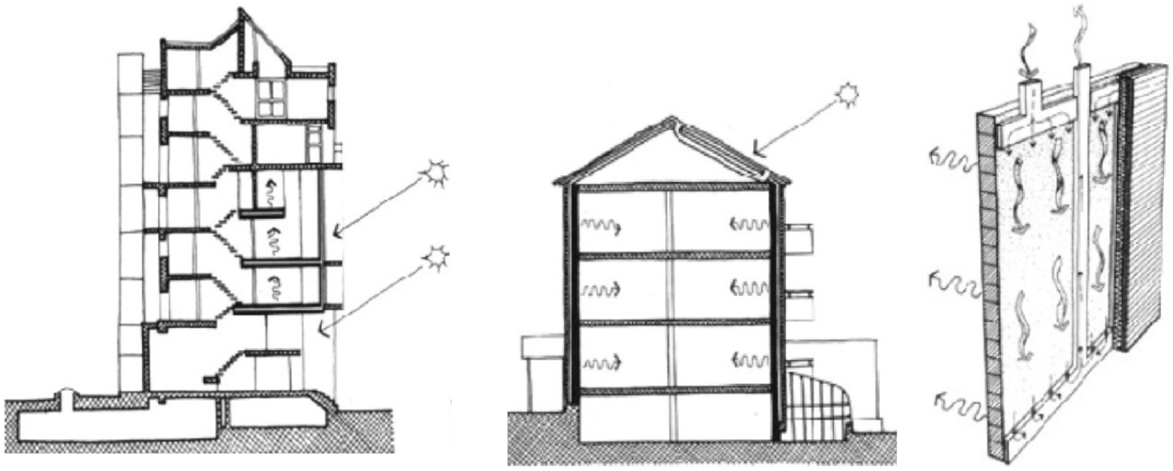

Figure 7 A Hypocaust in the Lutzstrassed Berlin: 7 B and 7 C Murocaust apartment Block in Gothenburg (Hastings and Mørk 1999)

3. Proposed active envelope solution; Active House

To avoid possible negative effects of bacteria growth in the concrete hollow cores the choice is been made for a separate system with strict moisture barriers by aluminum ducts in the buildings constructions, which carries the air through floors and walls (Schröder 2002, Kiefer 2003). With a heat exchanger energy is exchanged between supply air and exhaust air, so there is no direct contact between the air directly blown into the rooms and air which went through the air-ground collector and the labyrint foundation. In our proposed system the outside air is let through a ground-air collector and through a labyrinth foundation into the building. There is a separation of the air into one straim used for ventilation and one stream for conditioning. The air for ventilation is supplied into the rooms through a separate floorcooling system. The air for the conditioning is used to cool or heat the total building envelope. The ground with its nearly constant temperature is used as source for cooling or heating for the floors, walls and ceilings. Activating of the buildings'enveloppe by air supplied concrete core can be done with the aluminium ductssystems (Kiefer 2003) in combination of hypocausten and murocausten concrete core cooling, see the schematic in figure 8.

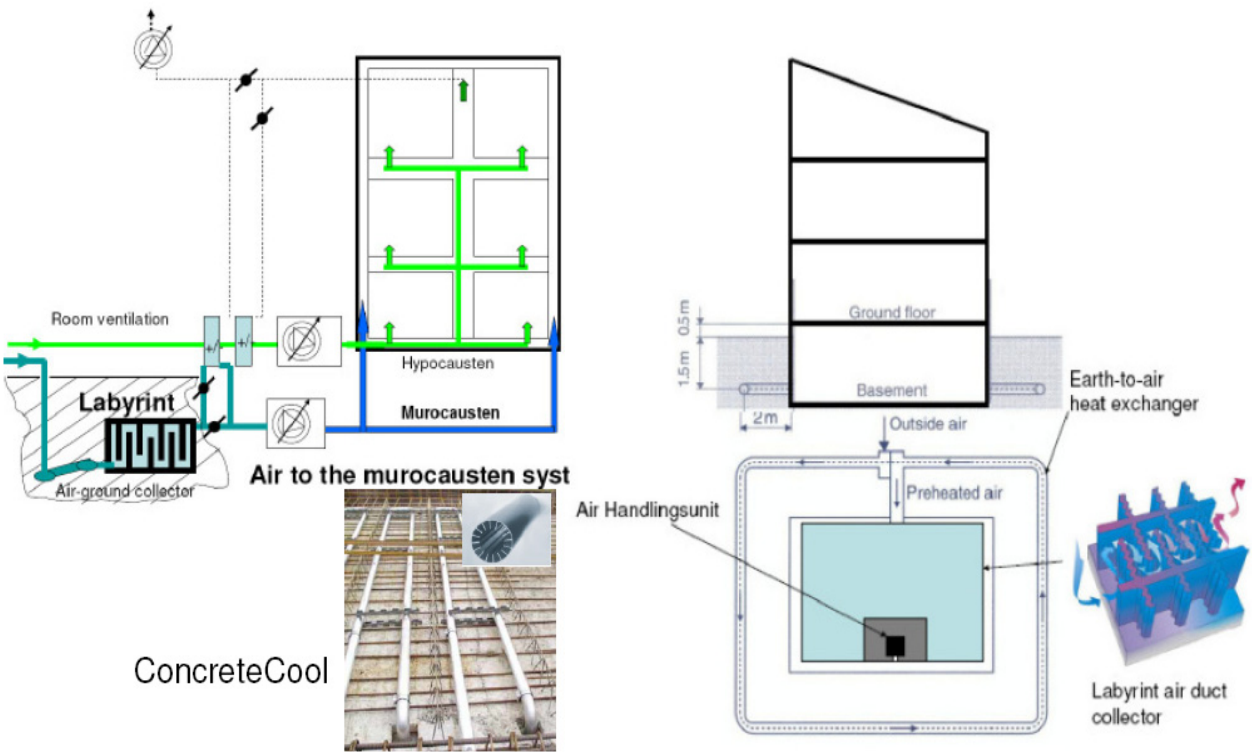

Figure 8. The concrete core activating system ConcreteCool and Principe schematic of the hypocausten /murocausten system in combination with air-ground collector and labyrinth foundation collector.

4. Conclusion

Passive houses are a real hype. Energy saving and sustainability is very important but not at the risk of endangering health of the occupants, which was the cause of some Passive Houses in the Netherlands. This was the starting point for a new approach, which led to an active house concept. By using ground air collectors, labyrinth foundation, muro-causter and hypo-causter, the whole building envelope and construction is thermally activated by natural pre-cooled air in the summer and natural pre-heated air in winter. This principle could play a significant role as alternative for the passive building concepts.

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