State-of-the-art Review : Vol. 2B. Integrated Building Concepts

NNEX 44 : Integrating Environmentally Responsive Elements in Buildings

Andresen, Inger; Kleiven, Tommy; Knudstrup, Mary-Ann; Heiselberg, Per; van der Aa, Ad; Andresen, Inger; Asada, Hideo; Bluemel, Ernst; Marques da Silva, Fernando; Haase, Matthias; Hansen, Hanne Tine Ring; Hayashi, Tatsuya; Heiselberg, Per; Hori, Yuji; Kato, Shinsuke; Knudstrup, Mary-Ann; Kolarik, Jakub; Kolokotroni, Maria; Miura, Mitsuki; Nishizawa, Shigeki; Satake, Akira; Sawachi, Takao; Tochigi, Manabu; Yanai, Takashi; Yoshie, Ryuichiro; Wahlström, Åsa; Warwick, David

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ANNEX 44

INTEGRATING ENVIRONMENTALLY RESPONSIVE ELEMENTS IN BUILDINGS

State-of-the-art Review
Vol. 2B. Integrated Building Concepts

Inger Andresen, Tommy Kleiven, Mary-Ann Knudstrup, Per Heiselberg (editors)

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Acknowledgements

The following experts contributed to this report:

Ad van der Aa
Cauberg-Huygen Consulting Engineers
PO Box 9222
3007 AE Rotterdam
The Netherlands
Phone: + 31 10 4257444; Fax: + 31 10 4254443; E-mail: a.vanderaa@chri.nl

Inger Andresen
SINTEF Building Research
Architecture and Building Technology
Alfred Getz Vei 3
7033 Trondheim
Norway
Phone: + 47 92207049; Fax: + 47 73 598285; E-mail: Inger.andresen@sintef.no

Hideo Asada
UKAJI Building Energy and Environment Research Institute
Japan
E-mail: h_asada@ukj.co.jp

Ernst Bluemel
AEE INTEC
Feldgasse 19
8200 Gleisdorf
Austria
Phone: + 43 3112 5886 25; Fax: + 43 3112 5886 18; E-mail: e.bluemel@aee.at

Fernando Marques da Silva
LNEC, National Laboratory for Civil Engineering
Av. do. Brasil, 101
1700-066 Lisboa
Portugal
Phone: + 351 218 443 862; Fax: + 351 218 443 025; E-mail: fms@lnec.pt

Matthias Haase
Hong Kong University
Pokfulam Road
SAR Hong Kong
China
Phone: + 852 2241 5839; Fax: + 852 2559 6484; E-mail: mathaase@hkusua.hku.hk

Hanne Tine Ring Hansen
Architecture and Design
Aalborg University
Østeraagade 6
9000 Aalborg
Denmark
Phone: + 45 9635 7179; Fax: -; E-mail: htrh@aod.aau.dk

Tatsuya Hayashi
NIKKEN SEKKEI LTD
2-18-3 Iidabashi,
Chiyoda-ku, Tokyo 102-8117
Japan
Phone: + 81 (3) 52263030; Fax: + 81 (3) 52263039; E-mail: hayashit@nikken.co.jp

Per Heiselberg
Indoor Environmental Engineering
Aalborg University
Sohngaardsholmsvej 57
9000 Aalborg
Denmark
Phone: + 45 9635 8541; Fax: + 45 9814 8243; E-mail: ph@bt.aau.dk

Yuji Hori
Building Research Institute
Department of Environmental Engineering
Tachihara 1 Tsukuba, Ibaraki, 305-0802
Japan
Phone:+81-29-879-0609; Fax:+81-29-864-6775; E-mail: hori@kenken.go.jp

Shinsuke Kato
Institute of Industrial Science, University of Tokyo
4-6-1 Komaba Meguro-ku Tokyo,
JAPAN
Phone: + 81 (0) 3-5452-6431; Fax + 81 (0) 3-5452-6432; E-mail: kato@iis.u-tokyo.ac.jp

Mary-Ann Knudstrup
Architecture & Design
Aalborg University
Gl. Torv 6
9000 Aalborg
Denmark
Phone: + 45 9635 9910; Fax: + 45 9813 6705; E-mail: Knudstrup@aod.aau.dk

Jakub Kolarik
Int. Centre of Indoor Environment and Energy
DTU
Nils Koppels Allé, Building 402
2800 Kgs. Lyngby
Denmark
Phone: +44 2882 9959; Fax: +45 4545932166; E-mail: jak@mek.dtu.dk

Maria Kolokotroni
Brunel University
Mechanical Engineering
Uxbridge Campus
Uxbridge,, UB8 3PH
United Kingdom
Phone: +44 1895 266688; Fax: +44 2895 256392; E-mail: Maria.Kolokotroni@brunel.ac.uk

Mitsuki Miura
The Kansai Electric Power Co.,Inc.
Building Energy Group
Civil and Architecture Department
6-16, Nakanoshima, 3-chome
Kita-ku, Osaka, 530-8270
Japan
Phone:+81-6-6441-8821;Fax:+81-6-6446-6464; E-mail: miura.mitsuki@c5.kepco.co.jp

Shigeki Nishizawa
Building Research Institute
Department of Environmental Engineering
Tachihara 1 Tsukuba, Ibaraki, 305-0802
Japan
Phone:+81-29-864-6683; Fax:+81-29-864-6775; E-mail: nisizawa@kenken.go.jp

Akira Satake
Technical Institute of Maeda Corporation
1-39-16 Asahi-cho Nerima-ku, Tokyo 179-8914
Japan
Phone: + 81 (0) 3-3977-2245, Fax: + 81 (0) 3-3977-2251; E-mail: satake.a@jcity.maeda.co.jp

Takao Sawachi
National Institute for Land and Infrastucture Management
1 Tatehara
Tsukuba 305-0802
Japan
Phone: + 81 298 64 4356; Fax: + 81 298 64 6774; E-mail: sawachi-t92ta@nilim.go.jp

Manabu Tochigi
NIHON SEKKI, INC.
Environment & MEP Engineering Dept
29th FL.,Shinjuku I-LAND Tower,6-5-1,Nishi-shinjuku,Shinjuku,Tokyo 163-1329
Japan
Phone: + 81 (0) 3-5325-8403, Fax: + 81 (0) 3-5325-8457;
E-mail: tochigi-m@nihonsekkei.co.jp

Takashi Yanai
NIHON SEKKI, INC.
Environment & MEP Engineering Dept
29th FL.,Shinjuku I-LAND Tower,6-5-1,Nishi-shinjuku,Shinjuku,Tokyo 163-1329
Japan
Phone: + 81 (0) 3-5325-8388, Fax: + 81 (0) 3-5325-8457; E-mail: yanai-t@nihonsekkei.co.jp

Ryuichiro Yoshie
Tokyo Polytechnic University
Department of Architecture
1583 Iiyama, Atsugi, Kanagawa
Atsugi/Kanagawa 243-0297
Japan
Phone: + 81 (0) 46-242-9556; Fax: + 81 (0) 46-242-9556; E-mail: yoshie@arch.t-kougei.ac.jp

Åsa Wahlström
SP Swedish National Testing and Research Institute
PO Box 857
501 15 Boraas
Sweden
Phone: + 46 33 16 55 89; Fax: + 46 33 13 19 79; E-mail: asa.wahlstrom@sp.se

David Warwick
Buro Happold
2 Brewery Place, Brewery Wharf
Leeds, LS10 1NE
United Kingdom
Phone: + 44 113 204 2200; Fax: -; E-mail: David.warwick@burohappold.com

Contents

Definitions

Reactive Building Elements

Building construction elements that assist to maintain an appropriate balance between optimum interior conditions and environmental performance by reacting in a dynamic and integrated manner to changes in external or internal conditions or to occupant intervention, and by dynamically communicating with technical systems. Examples include:

- Facades systems (Double skin facades, adaptable facades, windows, shutters, shading devices, ventilation openings, green facades)
- Roof systems (Green roof systems)
- Foundations (Earth coupling systems)
- Storages (Phase change materials, active use of thermal mass materials (concrete, massive wood), core activation (cooling and heating))
- Whole room concepts

Whole Building Concepts

Integrated design solutions where reactive building elements together with service functions are integrated into one system to reach an optimal environmental and cost performance (see illustration on next page).

Environmental Performance

Environmental performance comprises energy performance with its related resource consumption, ecological loadings and indoor environmental quality (IEQ).

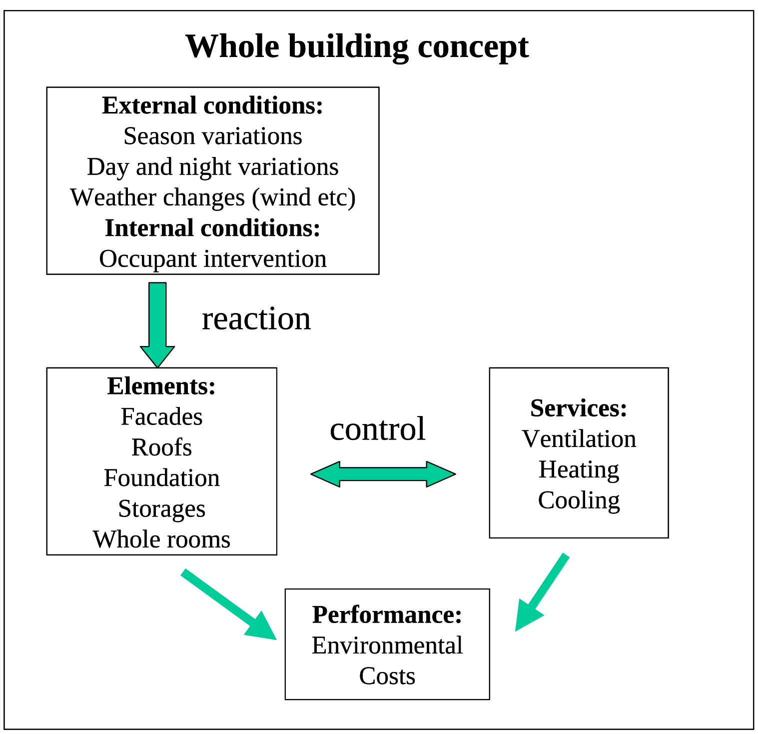


Illustration of the integration between building elements, indoor and outdoor conditions, controls, and performance (Illustration: Åsa Wahlström).

Introduction

The purpose of this report is to give examples of integrated building concepts and related available performance data and information. The report does not aspire to give a complete overview of all possible integrated building concepts and processes. The buildings included in the report have been selected according to the knowledge of the participants in the project, as characteristic examples of the concepts and the challenges they represent. The report will be a common basis for the research and development work that is going to be carried out within the IEA Annex 44 project.

The report contains an overview of 23 case study buildings from 9 countries with integrated building concepts. The overview provides descriptions of the buildings and their contexts, a description of the integrated energy systems, and the overall performance of the building with respect to energy, indoor environment and costs, where available. Also, barriers towards implementation and lessons learnt from the projects are summarized.

The last section gives a summary of barriers and opportunities for wide scale realization of integrated building concepts that can be deducted from the examples given in the review.

Overview of Reference Buildings

The table below shows an overview of the case study buildings included in this report, with an indication of which of the 5 main types of responsive buildings elements they employ. It may be noted that many of the buildings include a range of integrated building elements that are not indicated in the table.

Name of building, country	**Type of use**	**Climate**	**Responsive building elements**				
			AIF	TMA	EC	PCM	DIS
BedZED, UK	Residential + office	Temperate		x			
Commerzbank, Germany		Temperate	x				
Gleisdorf City Hall, Austria	City Hall	Temperate		x	x		
Itoman City Hall, Japan	City hall	Subtropical	x			x	
Kansai Electric Power, Japan	Office	Temperate/hot	x	x		x	
Kvadraturen School, Norway	School	Temperate/cold		x	x		
Kvernhuset School, Norway	School	Temperate/cold		x	x		
Longley Park, UK	Office	Temperate		x			
The Lowry, UK	Theatre	Temperate		x	x		
Mabuchi Motor, Japan	Office	Moist and mild	x	x		x	
Marzahn, Germany	Residential	Temperate		x			
Menara Mesiniaga, Malaysia	Office	Hot and humid		x			
MIVA, Austria	Office	Temperate		x	x		
M+W Zander, Germany	Office	Temperate		x			
Nikken Sekkei, Japan	Office	Mild					
Passive Hauptschule Klaus-Weiler-Fraxern, Austria	School	Temperate		x	x		
Photo-Catalytic Material Building, Japan	Experimental	Mild and humid					
Pourous building, Vietnam	Residential	Hot and humid		x			
RWS Terneuzen, The Netherlands	Office	Temperate		x			
Sakai Gas Building, Japan	Office	Mild		(x)			
Solar XII Building, Portugal	Office + lab	Hot and dry	x	x	x		
W.E.I.Z, Austria	Office	Temperate		x	x		
ZUB, Kassel, Germany	Office	Temperate		x	x		

AIF: Active Integrated Facades, TMA: Thermal Mass Activation, EC: Earth Coupling, PCM: Phase Change Materials, DIS: Dynamic Insulation Systems

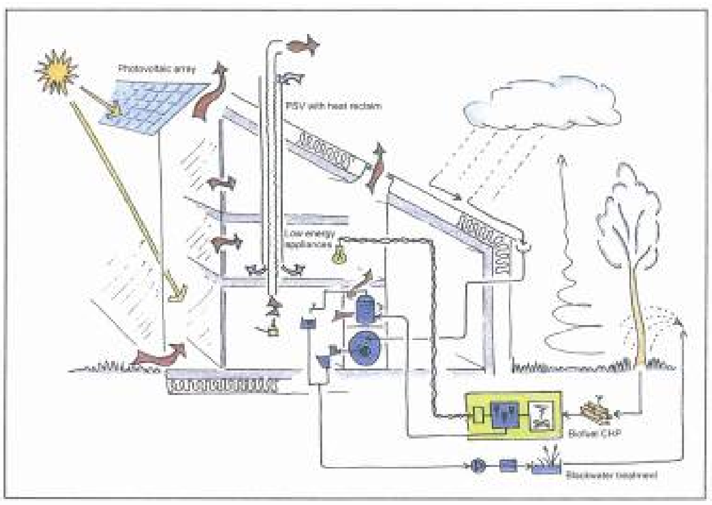
BedZed

Name of building: BedZED (Beddington Zero Energy Development)
Type of building: Residential / commercial
Location: Hackbridge, Sutton, U.K.
Owner: the Peabody Trust and the Bioregional Development Group
Start of operation: June 2001
Architect: Bill Dunster Architects
Engineering: Ove Arup and Partners
Net conditioned area: 83 dwellings and 3000 m^2 for offices and services
Total energy use: 80% less than standard practice
Cost: £ 15.7 mill

Climate, site and context

The climate is mild and temperate, typical for the London area. The building complex is built on a brown field in a London suburban area, which means that the degree of exposure to wind and sun is quite high. The quality of the local environment is very good, as the complex is situated in a suburban area on a brown field with an ecological park as the adjacent site.

Description of integrated building concept



Need permission

Heating system
The heating system is designed with 19^{o}C as a minimum target temperature and the system relies on the following sources of energy:

- "Passive solar heating
- Heat from occupants
- Heat from lighting and appliances

- Heat from cooking and domestic hot water
- Super-insulation
- Very high air-tightness
- Heat-exchange in the ventilation
- High thermal inertia
- Bio-fuelled combined heat and power unit (CHP)”

Cooling system
There is no cooling system per say, however, the complex uses thermal mass as well as the heat-exchange system in the wind cowls to keep the temperature steady during hot summer and cool winter periods.

Ventilation system
The ventilation principle is a natural system with a passive heat- exchange system (wind cowls). The effective opening area equals at least 5 percent of the floor area in the habitable rooms and they are designed for night time cooling by using secure locking [2]. The inlets are placed in the low polluting rooms, such as the living room and bedrooms, and the outlets are placed in the kitchen, the bathroom.

Electric systems
The complex is designed to use natural daylight instead of electric lighting, in order to save energy for electricity and reduce the cooling load in summer. The daylight in the offices has been of the highest priority, as these primarily are used during the day. This, and the internal heat gain in the offices, has affected the orientation of the offices in the complex, which means that these have been placed with a north orientation in order to ensure diffuse daylight levels and a minimum degree of solar heat gain.

The complex also relies on PV-cells which are used for reloading the electric cars which are used for car pooling.

Energy meters are placed in a way, which increases the user’s awareness of the energy consumption and all appliances are low-energy appliances.

Control system
The ventilation is controlled by the users supported by the wind cowls which secure a minimum level of ventilation in the units. The heating system is designed to maintain a background temperature in the dwellings during longer periods of un-occupancy. This is achieved by using a thermostatically controlled vent from the domestic hot water cylinder cupboard.

Architectural issues
The architectural expression and the terrace-houses were inspired by the architectural expression of traditional British housing and the project has a very holistic approach to sustainability, as it considers both urban design and architectural design elements in the solution. The architectural expression has also been under great influence of the technical solutions, e.g. in case of the wind cowls, the double high rooms, the green terraced roofs, the choice of material and the orientation of the different units etc.

The project considers technical, functional and ecological principles, and these principles are integrated and expressed through the architectural expression of the building complex, while keeping the price of the units down.

The project seems to contain a great deal of identity due to the urban design and the variety of the service functions placed on the site. The identity is very communal and it is based on ecological principles as well as new trends, such as the network community, where people work from their homes.

The aesthetic expression of the technical solutions, such as the wind cowls and the PV-panels, helps underline the identity of the complex. The shape of the building as well as the different expressions of the facades provide an architectural quality, as it provides different types of spaces depending on which side of the building is experienced and at which level.

Performance

The first period of monitoring has already shown that compared with current UK benchmarks:

- Hot water heating is about 45% less.
- Electricity for lighting, cooking, and all appliances is 55% less.
- Water consumption is about 60% less.

Summary of barriers

Extra costs related to innovations, design research and quality control, and implementation of new working methods.

Open questions and needs for future research

The effect of the wind cowls and potential for further development aesthetically and technically.

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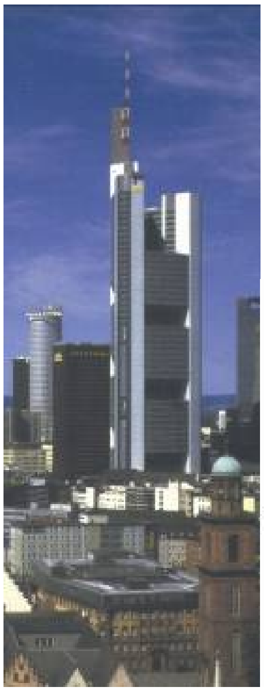
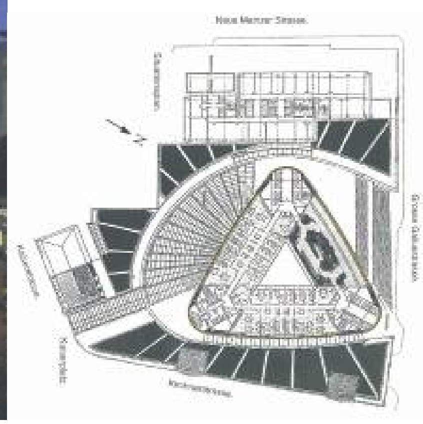
Commerzbank Headquarters





Name of building: Commmerzbank
Type of building: Office
Location: Frankfurt am Main, Germany.
Owner: Commerzbank
Start of operation: Summer 1997
Architect: Foster and Partners
Engineering: Ove Arup and Partners
Net conditioned area: 100 000m^2, 53 stories
Total energy use: Naturally ventilated 70% of the year (monitored)
Cost:

Need permission

Climate, site and context

The climate in Frankfurt am Main is temperate. See average temperatures, precipitation, sunshine hours etc. in the illustration below. The area around the skyscraper is pretty open, possibly because of its height. It is, however, situated in the inner city area of Frankfurt am Main in a high density urban area with high levels of noise and air pollution from traffic.

Hannover, Germany

Latitude: 52.28N **Longitude:** 009.41E **Altitude:** 59m

Temperature (°C)

	J	F	M	A	M	J	J	A	S	O	N	D
Maximum	3	4	8	13	18	21	22	22	19	14	8	4
Minimum	-1	-1	0	3	7	10	12	12	9	6	2	0
Mean	1	1	4	8	13	16	17	17	14	10	5	2

Precipitation

	J	F	M	A	M	J	J	A	S	O	N	D
Total (mm)	52	37	48	50	62	73	62	64	53	42	52	60

Other Weather Information

	J	F	M	A	M	J	J	A	S	O	N	D
Sunshine (h)	46	75	105	160	226	209	217	217	138	102	58	34

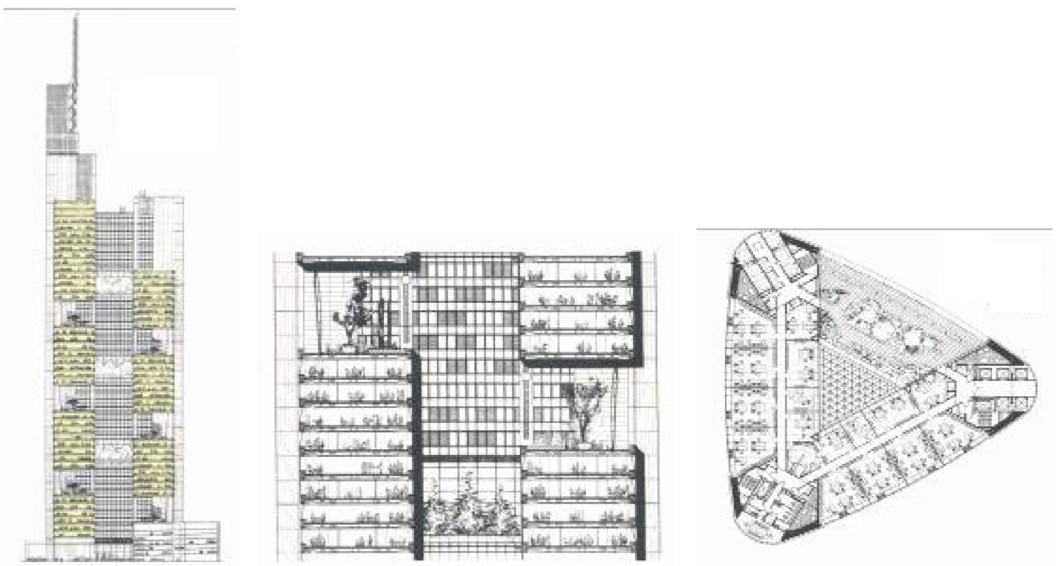
Number of Days Where

	J	F	M	A	M	J	J	A	S	O	N	D
Precip.>=1 mm	11	9	10	10	10	11	10	10	9	9	11	12

The weather statistics displayed here represent the mean value of each meteorological parameter for each month of the year. he sampling period for this data covers 30 years from 1961 to 1990.

[http://www.theweathernetwork.com/weather/stats/pages/C00010.htm date: October 27th 2005]

Description of the building and the integrated building concept



The illustration shows a typical office floor, a vertical section of the building and a segment of the vertical section. This gives an idea of how the atrium and the winter-gardens are placed in the building. The atrium is placed as a vertical core in the centre of the building, connecting the four storey winter-gardens and ensuring ventilation. Need permission

"At fifty-three storeys, the Commerzbank is the world's first ecological office tower and the tallest building in Europe. The outcome of a limited international competition, the project explores the nature of the office environment, developing new ideas for its ecology and working patterns. Central to this concept is a reliance on natural systems of lighting and ventilation. Every office in the tower is daylit and has openable windows, allowing occupants to control their own environment, and resulting in energy consumption levels equivalent to half those of conventional office towers.

The plan of the building is triangular, comprising three ‘petals’ - the office floors - and a ‘stem’ formed by a full-height central atrium. Pairs of vertical masts enclose services and circulation cores in the corners of the plan and support eight-storey Vierendeel beams, which in turn support clear-span office floors. Four-storey gardens are set at different levels on each side of the tower, forming a spiral of landscaping around the building, and visually establishing a social focus for village-like offices clusters. These gardens play an ecological role, bringing daylight and fresh air into the central atrium, which acts as a natural ventilation chimney for the inward-facing offices. The gardens are also places to relax during refreshment breaks, bringing richness and humanity to the workplace, and from the outside they give the building a sense of transparency and lightness. Depending on their orientation, planting is from one of three regions: North America, Asia or the Mediterranean.

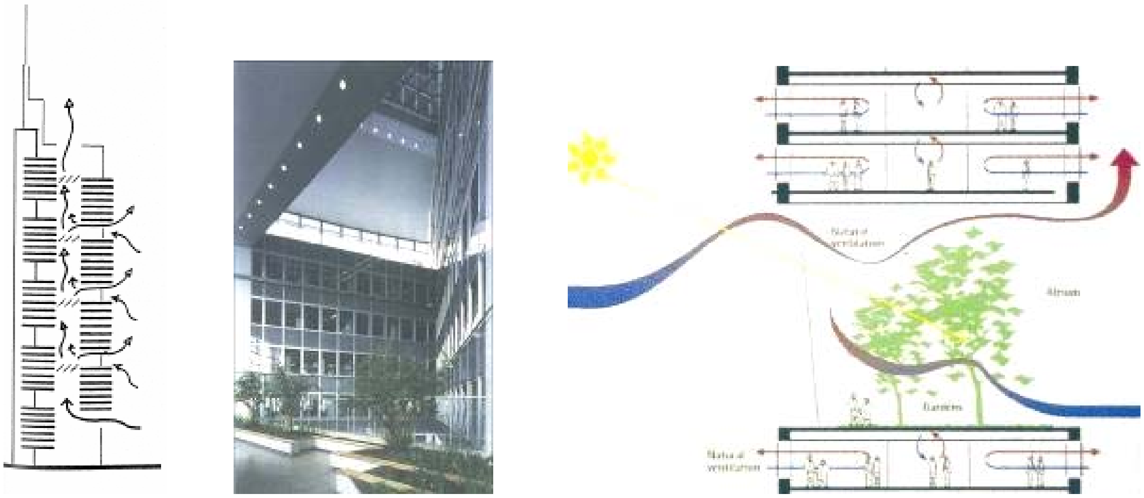
The tower has a distinctive presence on the Frankfurt skyline but is also anchored into the lower-scale city fabric, with restoration and sensitive rebuilding of the perimeter structures reinforcing the original scale of the block. These developments at street level provide shops, car parking, apartments and a banking hall, and forge links between the Commerzbank and the broader community. At the heart of the scheme a public galleria with restaurants, cafés and spaces for social and cultural events forms a popular new route cutting across the site. Interestingly, on the day the Commerzbank opened, the Financial Times adopted it as the symbol of Frankfurt, just as it features Big Ben and the Eiffel Tower as symbols of London and Paris”.

Responsive building elements that have been applied are: Double skin façade, shading, vegetation, atrium, hybrid ventilation, daylight, passive solar heat

Heating system
Ventilation air is preheated in the double skin façade and in the winter gardens. In seasons where the natural ventilation will result in increased energy consumption, the offices are ventilated mechanically with preheated air.

Cooling system
Night cooling and evaporation via the winter gardens help to keep the summer temperatures down. If this is insufficient the building is cooled via mechanical ventilation.

Ventilation system
The interior zones of the building are mechanically ventilated with the minimum air-change rates required for hygiene, while a perimeter heating installation and chilled ceilings regulate the room temperatures. The mechanical ventilation is supported by natural ventilation, and the user of the different offices can regulate the degree of mechanical ventilation by pushing a button or opening a window. Mechanical ventilation is used if it is too windy, too hot or too cold for natural ventilation (it is too cold when temperatures fall below $15^{o}C$). The building is ventilated naturally 70% of the time, while it the last 30% of the time is mechanically ventilated.



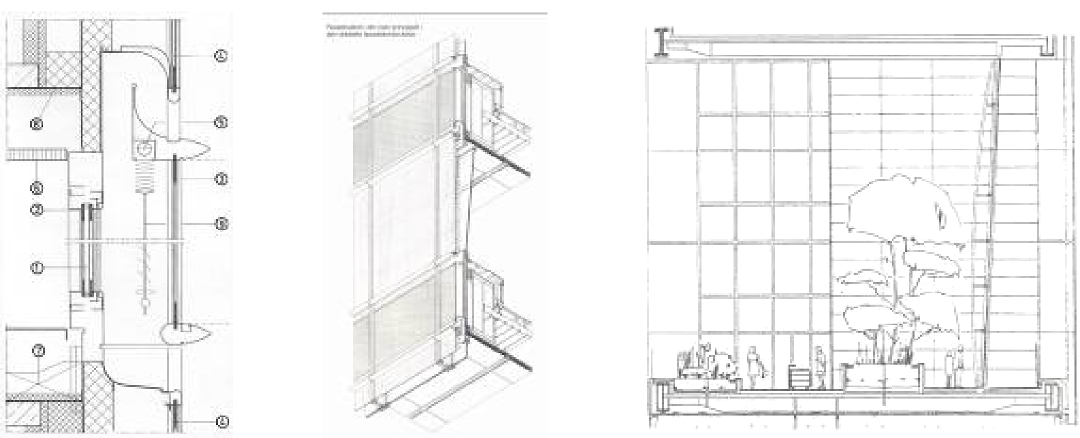
The atrium works as a chimney for the ventilation air. The winter-gardens also work as a thermal buffer during the winter and summer season. In winter it is used to preheat the natural ventilation, while in summer it is used to cool down the external air by 0.5 and 1°C through evaporative cooling. Need permission

Control system

The building is controlled by an intelligent building automation system, where the correlation between heating, ventilation, sanitation, security and communication is controlled.
Lighting, shading, windows and heating and cooling are controlled by sensors, which can be overruled by the user. After a while the system resets itself to a standard setting.

Architectural issues

The shape of the building, winter gardens and atrium provide visual quality in the building for the users, which is usually scarce in high rise buildings. This building has the high-tech feel to it just as most of Foster and Partners projects, thus it still looks like a skyscraper, though the rectangular shape of other high-rise has been replaced by a triangular one.



The Double skin façade enables the ventilation of the offices and at the same time it provides external shading. The system consists of a ventilated cavity between a one layer waterproof glass wall, a climatic buffer and a internal double glass wall which is insulated for thermal bridges. The shading device is placed on the inside of the waterproof glass wall. The Winter garden provides green islands in the high-rise building office landscape. The vegetation is used to produce purer air furthermore it reduces the dust in the in-let air and helps to cool down the building in summertime (ADA 1997). Need permission.

Performance

During the design phase the double skin façade was analyzed and it was concluded that it could provide natural ventilation about 60% of the year. Since the building has been put to use the result has been that the building is naturally ventilated 70% of the time (Daniels 1997).

Open questions and needs for future research

It would be interesting to investigate the users perception of the architectural and climate in the building and the effect of the chimney and winter gardens in the building.

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Gleisdorf Venue Hall

Name of building: Gleisdorf Venue Hall
Type of building: Commercial
Location: Gleisdorf, Austria
Owner: Municipality of Gleisdorf
Start of operation: 2001
Architect:
Engineering: AEE Intec
Net conditioned area: 426 m^2
Total energy use: 50% reduction in peak cooling load. Underground duct reduces supply air temperature by 10°C
Cost: 87000 Euro (investment cost)

Description of the building and the integrated concept

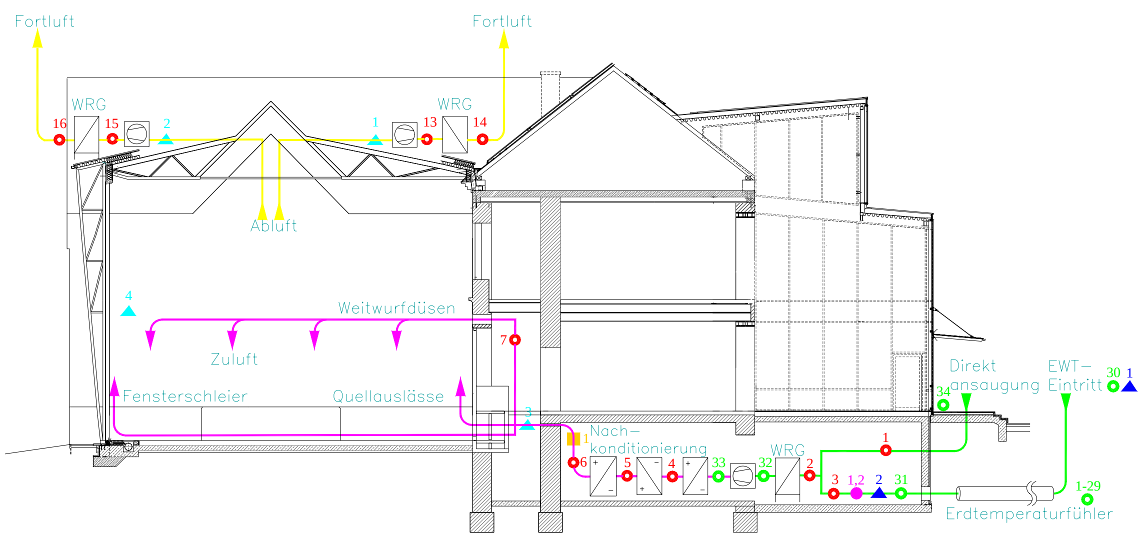
The municipality hall of Gleisdorf is the renovated result of an old convent. The building orientation was already fixed and the old convent yard was built-in and given a glazed area towards south west. The concept of the renovated building was a south west oriented hall with a glazed façade.

The glazed façade of the municipally hall of Gleisdorf, Austria with glazed façade and shading element. This project was one of the first projects in to apply an underground heat exchanger for such large dimensions in general and the project is especially interesting as the this large scale underground heat exchanger application is used in a retrofit project. The application is a good solution for this project as the system applies one room only, which makes it rather simple to manage. There could in general be problems to apply such large earth to ground heat exchanger due to lack of space, but this was in this case no problem.

A high density of occupancy as well as the passive heat gain from the south west façade were taken under consideration for the planning of the fresh incoming air for the heating and cooling supply. It was of high interest not only to assure a comfortable and warm winter operation of the building, but also to secure a comfortable summer indoor climate in the building complex. A sustainable cooling concept was therefore defined, realised and monitored.

The underground heat exchanger was chosen as the base system to provide cooling in the summer and heat for preheating during the heating period. The remaining heating demand is supplied by gas heating, which heat is distributed via a floor heating system. A water to air underground heat exchanger is applied for the distribution of cold/warm air via the ventilation system.

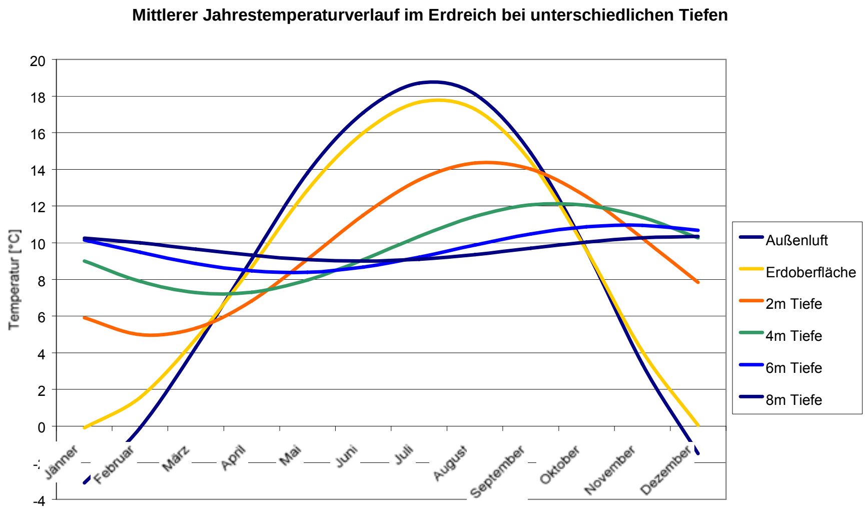
The planning and dimensioning of the underground heat exchanger was carried out with suitable tools. The influencing factors where defined and discussed and the system was integrated in the ventilation and cooling system of the building. The figure below shows a sectional view of the building, showing the heat distribution from the underground heat exchanger with heat recovery and sub-conditioning (gas) with the air flow into the hall, exhaust air flow and the floor heating systems for occasions when this is necessary. The monitoring measure sensors are also shown in the schematic.



Sectional view of the building illustrating the ventilation system and the underground heat exchanger.

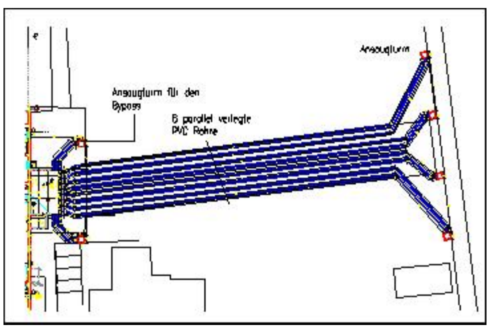
Responsive building elements – underground heat exchanger

The principle, which forms the basis for the use of air circulated earth to air underground heat exchangers is basically very simple. The system uses the seasonal thermal storage ability of the soil, which has a temperature delay compared to the outdoor temperature. This temperature difference between the outdoor temperature and the soil temperature enables a cooling effect of the hot summer air and a heating effect of the cold winter air. The figure below shows that the deeper the heat exchanger is situated, the larger is the active temperature difference, which can be attained between the outside and earth temperature. If hourly mean values are considered (instead of the outside temperatures on a monthly average), much higher temperature differences can be determined in the short-term. This connection shows that the predestined application of air circulated underground heat exchangers is to muffle high outside temperature peaks (and thus performance peaks).



Annual temperature of outdoor air, surface of the earth and earth at different depths for the soil types “pebble stones –dry“, location Graz. The graph is based on the mean monthly values.

A schematic of the installed underground heat exchanger is shown in the figure below, where the four inlet towers on the end of the heat exchanger and the two towers at the building entrance (for bypass operation) are shown.



Schematic of the heat exchanger (left) and front view of the conference facilities flanked by two inlet towers.

The technical data of the underground heat exchanger is listed in the table:

Mass flow rate	Normal operation 20,000 m³/h
Type of construction	Four concrete air inlet towers at the underground heat exchanger inlet. One metal accumulative pipe at the underground heat exchanger outlet, 9 meters
Pipe material	Polyvinyl chloride (PVC)
Total length	8 x 80 meters
Centre distance	1.5 meters
Pipe radius	0.4 meters
Position	1.5 – 2.5 meters under ground level

Performance

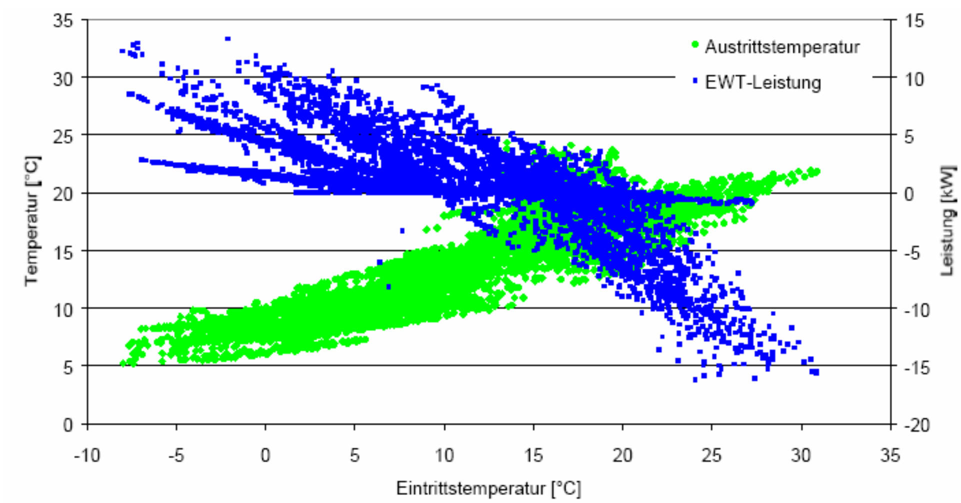
Energy consumption

The underground heat exchanger, serving as base load could reduce the calculated cooling load of the conventional cooling compressor from 100 kW to 50 kW and this is only taken into operation at peak loads. The volume flow through the underground heat exchanger was in the range of 20,000 m³/h during the peak periods.

Generally, it can be said that the underground heat exchanger delivers about 32,500 kWh including heating and cooling during the operation time. It should be noticed, however, that the underground heat exchanger was not operated with its nominal volume flow (20,000 m³/h), but with 9,000 m³/h during the six month period of the monitoring.

The figure below shows the measured outlet temperature from the underground heat exchanger and the simulated outlet temperatures as a function of the inlet temperatures (outdoor temperature). It can be seen that the measures and the simulated values correspond very well. The maximal inlet temperatures of 32°C result in outlet temperatures (both measured and calculated) of 22°C. This corresponds to a volume flow of 9,000 m³/h, a maximal temperature lift of 10 K and a cooling performance of 30 kW.

Although the period of observation took place mainly in the summer of 2001, outdoor temperatures of –8°C were measured, which means heating operation for an underground heat exchanger. Similar temperature-differences were also registered during heating operation (even slightly higher because of the favourable soil temperature). The figure below shows the underground heat exchanger performance and the outlet temperatures as functions of the inlet temperature in year 2000.



The underground heat exchanger performance and the outlet temperatures as a function of the inlet temperature. (*Eintrittstemperatur* = inlet temperature and Leistung = yield of the underground heat exchanger).

Maintenance and operation of the system

The operation of the system is of satisfaction, without problems. The underground heat exchanger and the night ventilation deliver sufficient cold air in the summer to cool the facility and a conventional cooling compressor is not necessary.

Cost

A broad economically and operationally examination showed that energetically as well as economically advantages could be reached through the application of a well planned and operated passive cooling system. Approximate investment costs lie in the region of 87,000 €.

It is not possible to state the value of the running costs, as these are presented as a part of the entire electricity consumption.

Description of the implementation process

AEE INTEC was the initiator of implementing a sustainable energy concept for the refurbishment of the hall. A cooperation with an interested installing company and with the City of Gleisdorf, which has sustainability as is main focus, made this project successful.

Open questions and needs for future research

An application of an underground heat exchanger is in this particular project a very good solution. Problems normally occur for heat exchangers of this size, since there is often a lack of space. Air to water underground heat exchangers are more and more being applied on the market, in comparison to the air to air heat exchanger. The water to air heat exchanger bring less hygienic problematic.

References

Huber, Arthur (2001): „WKM_Version 2.0“ – PC Programm für Luft-Erdregister; Benutzerhandbuch. Huber Energietechnik, Zürich, 2001.

Fink et al. (2003): « Zuluftkonditionierung über einen luftdurchströmten Erdreichwärmetauscher für den Stadtsaal in Gleisdorf“.

Itoman City Hall

Name of building: Itoman City Hall
Type of building: City Hall
Location: Okinawa, Japan
Owner: Itoman City
Start of operation: 2002
Architect:
Engineering:
Net conditioned area: 15434 m^2
Total energy use: 22% reduction in primary energy use
Cost:

Climate, site and context

Itoman city is located on the southernmost tip of Okinawa Hontou (Main Island). Okinawa Hontou is about 600 km southwest of Tokyo. This makes entire Okinawa, a subtropical climate while the rest of Japan mostly classified as temperate climate. The city hall, as shown in the figure below is located in the shore side and is constantly exposed to elements such as intense sunlight, wind from the ocean.

Description of the building and the integrated building concept

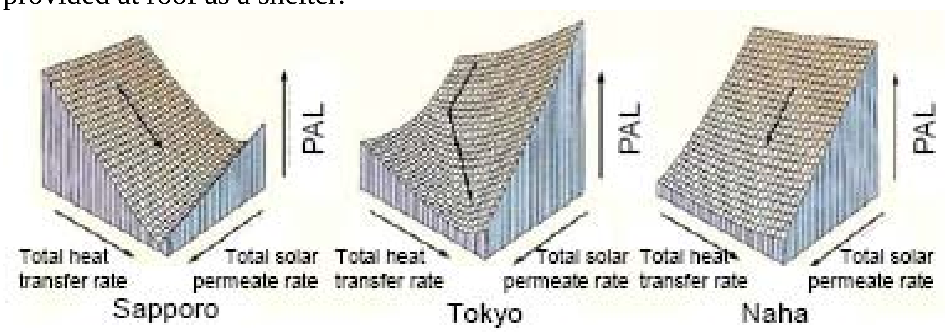
Itoman city hall development project was the first project of the public building zone in Minamihama reclaimed land in Itoman city. Civic Square, Civic Hall and Center for Public Health will be constructed in public building zone in future. These facilities will be form public service network and it will be the new core of Itoman City. Since completion of work in March 2002, the administrative service was provided for the new city hall from May 2002.

Based on the Itoman new energy vision, natural energy utilization / air-conditioning load reduction and infrastructure load reduction were considered as the major theme in this project. In Itoman city hall, solar shading, photovoltaics, natural ventilation, and natural lighting were adopted as technical elements of natural energy utilization and air-conditioning load reduction which suited in sub- tropical climate. In Okinawa, the higher cost is required to maintain the sufficient capacity and reliability of city infrastructure because Okinawa is islands region geographically which is apart form mainland of Japan.

In order to reduce load of the electric power infrastructure, the thermal storage system was provided, also to reduce load of city water infrastructure, the rain water utilization system was installed in Itoman city hall. In addition, valuable chilled water circulation system, air to air heat-exchanger and high frequency fluorescent light devices are adopted in building services to make higher efficiency of energy consumption.

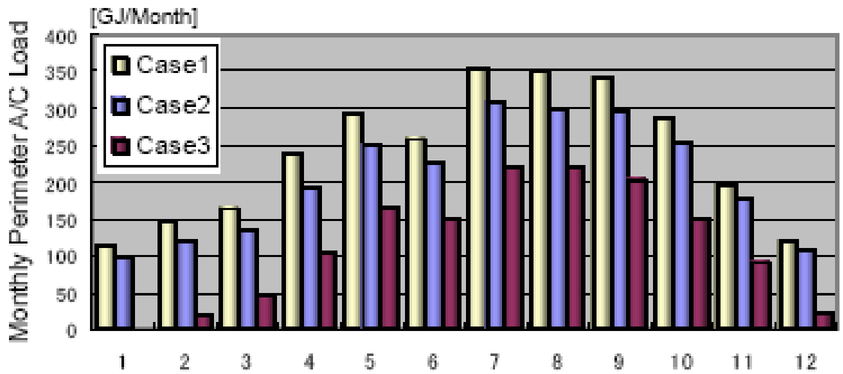
Solar shading

The figure below shows the relationship between the Perimeter zone Annual air conditioning Load (PAL) and total heat transfer rate of the building / total solar permeation rate of the building in Sapporo (cold climate), Tokyo and Naha (subtropical climate). The PAL values at Naha show that reducing total solar permeation rate is more effective to reduce PAL values than reducing total heat transfer rate in subtropical climate. In Itoman city hall, the shapes of external louvers are studied to cut solar radiation efficiently. The horizontal louvers are provided at southern wall of building, pre-cast concrete screens are provided eastern and western wall, the vertical louvers are provided to northern wall and horizontal louvers are provided at roof as a shelter.



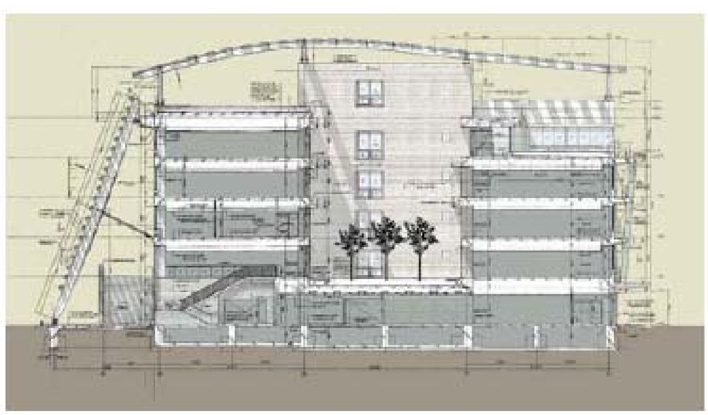
To evaluate PAL reduction effect of the external louvers, three (3) types of buildings are compared, see figure below. In the PAL evaluation, direct solar radiation, sky solar radiation, reflecting solar radiation and heat transfer through the widows and walls in the perimeter area are calculated. The external louvers provided to the Itoman city hall cut the solar radiation effectively especially when the solar altitude becomes low. The evaluated PAL of Itoman city hall is 1,390 [GJ/year]. It is 1,474 [GJ/year] smaller than Case1: No Louvers building, and 1,069 [GJ/year] smaller than Case2: Standard Louvers building.

Case1: No louvers Building	Case2: Standard louvers (balcony) Building	Case3: Itoman city hall

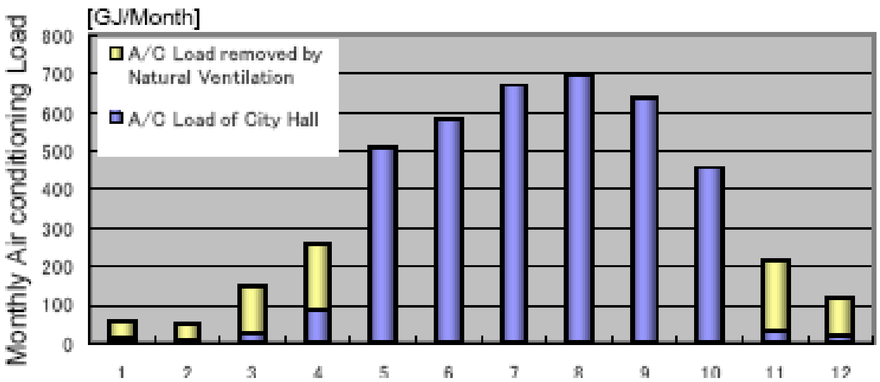


Photovoltaic power generation system
Photovoltaic modules are installed on southern horizontal louvers and horizontal louvers of roof shelter. The total capacity of the photovoltaic modules is 195.6 kW. In order to operate the photovoltaic system at high efficiency, the photovoltaic system was designed as the interactive system with power infrastructure which can reverse the power to Okinawa electric company. In the weekends and holidays, surplus of photovoltaic power over the electrical demand in the building is sold to Okinawa Power Company. As the Itoman city hall is located in the littoral district, consideration on the prevention of the damage caused by briny air had been taken. The solar cells are protected with two sheets of tempered glass provided on both front and back sides to have a self-purification effect by rainwater. In 2003, the annual amount of power generation by photovoltaic system was 213,340 kWh/year. It corresponds to 12% of the total annual power consumption of Itoman city hall.

Ventilation system
In Itoman city hall building, spring, autumn and winter (from November to May next year), the air conditioning system is stopped. The natural ventilation is planned to maintain the indoor thermal environment in acceptable condition during the air condition system are stopped. By the external louvers which cut solar radiation effectively, the large windows could be provided all external walls for the natural ventilation without air-conditioning load increment. The natural ventilation route in Itoman city hall is formed with the sliding windows on the external walls, and sliding doors and extrusion windows facing to two courtyards which are provided in centre of the building.



The ventilation rate by natural ventilation is estimated with ventilation network calculation. When there is 1.0 m/s external wind, the ventilation rate in major rooms in Itoman city hall was presumed to be 12 - 40 times/hour. During the season which air-conditioning system is stopped, indoor thermal environment is moderately maintained acceptably by natural ventilation. The amount of annual air conditioning load removed by natural ventilation is presumed to be 398 GJ/year.



Estimated AC load removed by natural ventilation.

Lighting system

To obtain a skylight with minimum unpleasant glare, the Itoman city hall was designed with a lighting source having external louvers that cut direct solar rays. Two courtyards are provided to introduce natural light into the central part of Itoman city hall. Automatic lighting control with illumation sensors are provided at perimeter area of office spaces in northern wings. The reduced annual total power consumption of lighting by natural lighting is presumed to be 12,944 kWh/year.

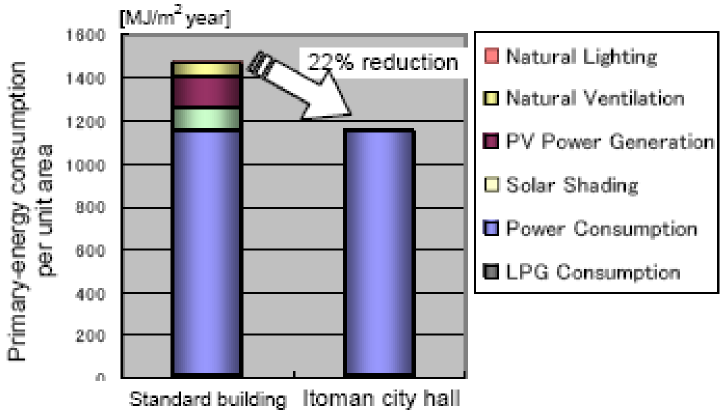
Thermal storage system

Okinawa Electric Power Company is separated from the wide area power supply network which consists of nine (9) electric power companies in mainland Japan. To maintain sufficient capacity and reliability of the power supply, high investment costs are required for electric power supply infrastructure in Okinawa. Shifting the power consumption from daytime to nighttime by a thermal storage system is not only to reduce the operation cost but to help control the increment of the maximum power demand of power infrastructure and effective operation of power infrastructure.

The thermal storage system consists of a stratification type chilled water thermal storage system which has sufficient operation efficiency and the ice-thermal-storage system which has sufficient space efficiency. The chilled water thermal storage system has pre-insulated panel tanks. The thermal storage system is divided into two tanks, and installed in the machine room on the first floor of the water board annex. Two thermal storage tanks are connected with interconnecting pipes, and these tanks are functioning as one stratification type thermal storage tank. The ice-thermal-storage units are installed on the flat roof. The amount of power shifted from daytime to nighttime is 1,576,240 kWh/year. This corresponds to 11.9% of the annual total power consumption in Itoman city hall.

Performance

The reduction rate of annual primary energy consumption by the natural energy utilization and air-conditioning load reduction are evaluated as 22%. The primary-energy consumption per unit area based on the measure value in 2003 is 1,111 MJ/m^2 year.



Since the Itoman city hall opened in May 2002, many visitors, not only Itoman city residents, but also people from other prefectures such as the construction-administrative officers and students on school excursion visit Itoman city hall. These are considered good opportunities to deepen understanding on the global environmental problems and energy problems. It becomes more important to consider the integration of architectural design and building service engineering to fit the building with the local climate at building site in order to get higher basic performance of the building.

References

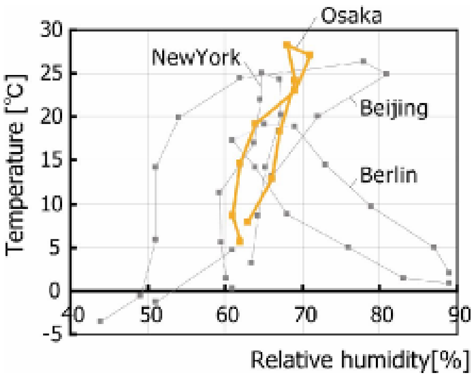
Koui, TSUKAMOTO, and Manabu TOCHIGI (2004): “Case studies on the buildings in Okinwa no 1. Itoman City hall”, Society of Heating, Air-conditioning & Sanitary Engineers of Japan (SHASE) transaction, September 2004.

Hiromasa, KATSURAGI and Manabu TOCHIGI (2004), “The new environment friendly buildings – case study on Itoman city hall”, Architectural Institute of Japan (AIJ) magazine, March, 2004.

The Kansai Electric Power Building

Name of building: Kansai Electric Power building
Type of building: Office building
Location: Osaka, Japan
Owner: The Kanden Industries, Inc.
Start of operation: January 2005
Architect: Nikken Sekkei Ltd
Engineering: Takenaka etc., Kinden etc., Sanki etc., Sanko etc
Net conditioned area: 60 000 m^2
Total energy use: 30% less than standard (estimated)

Climate, site and context

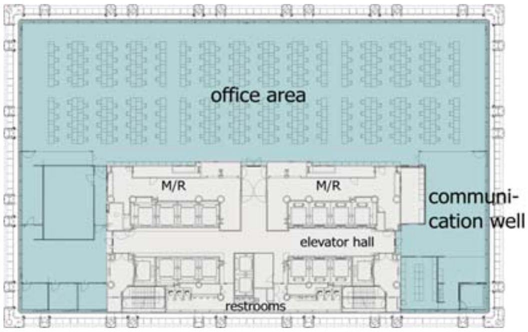


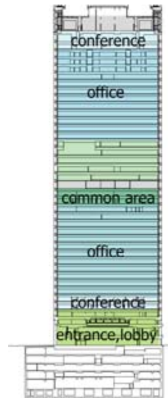
The KANDEN

Illustration showing temperature and relative humidity in Osaka and some other cities (left). Aerial view of Osaka City (right).

Type of climate: temperate climate (Relatively hot and humid area in Japan)
Heating degree-days: about 1550
Cooling degree-days: about 280

Description of the building and the integrated building concept





Plan (left) and section (right) of the Kansai Electric Power office building.

Building data:
Gross area: 106,000 (m2)
Net conditioned area: 60,000 (m2)
Number of floors: 5 basement floors, 41 aboveground floors and 1 penthouse
Construction type: (materials, insulation, window types)
Materials: Steel-frame and Steel-reinforced concrete
Window types: Low-e pair glass
Floor-to-ceiling height: 2.8 (m)

This building is a new head office building of KANSAI Electric Power Co., Inc. (KEPCO), supplying electricity in the Kansai area that is the second largest urban area in Japan including cities such as Kyoto, Osaka and Kobe. It is planned and designed with a concept, 'A model building of environmental symbiosis', to suggest a vision of new office buildings in the future. The building stands on the sandbank of the river crossing the city of Osaka from East to West. It is planned to utilize geographical advantage in the maximum. Specific plans are as follows; 1) Adoption of the 'Eaves' utilizing columns and beams to block a direct solar radiation, 2) Adoption of natural ventilation system to lead a river wind inside the building, 3) Adoption of district heating and cooling system utilizing the river water. In addition, new air conditioning and lighting system, which enable personal control to meet individual demands, are adopted to realize coexistence of energy saving and personal comfort comparing to 'uniform light and thermal environment' adopted in a conventional office.

The Construction process

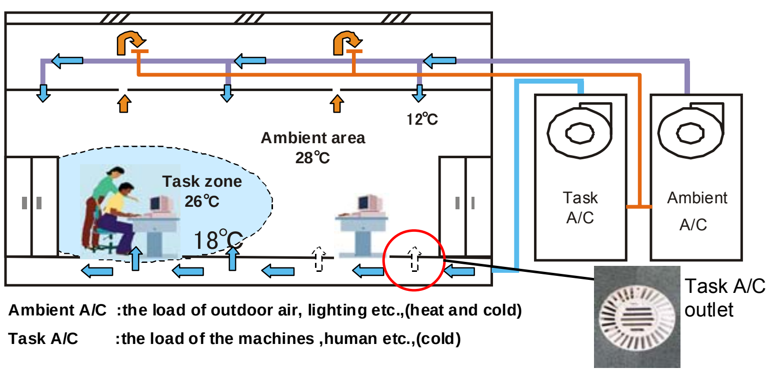
The project team was organized at the very beginning of the project and managed the project at all the stages of the project, i.e. preliminary planning, basic design, detail design, construction work, construction supervision and operation after completion. Roles of the members are as follows:

The owner, The Kanden Industries, INC. organized requirements from The Kansai Electric Power Co., Inc., the main tenant, into design conditions, and was also responsible for economy in building operation. The Kansai Electric Power Co., Inc., the main tenant, acted as a collaborator of The Kanden Industries, Inc. in the field of technology, and implemented verification of design and construction supervision at the construction site. Also, they intend to examine green building technologies installed for the building such as natural ventilation and task/ambient air conditioning, and commission Nikken Sekkei Ltd. to make necessary researches on this theme. Nikken Sekkei Ltd, designer of the building, led the design processes, and acted as a main party to propose new technologies at the design stage. Also, they are carrying out jointly with Kansai Electric Power Co., Inc. verification of building performances during operation. The contractor conducted detailed study and experiments stipulated in design documents to realize new technologies in the actual building. For these, The Kanden Industries, Inc., the Kansai Electric Power Co., Inc., Nikken Sekkei Ltd. and the contractor are in close relationship as a team member, and are jointly responsible for the performance of the this building.

With regard to window design, vertically continuous window design was also studied as an alternative of the present design with eaves. Kansai Electric Power Co., Inc. had an intention to create a flagship building of green buildings. According to a proposal by Nikken Sekkei Ltd, comparative study on life-cycle cost, and life-cycle CO2 was made and it was determined to adopt the present design, which is more effective in energy saving. The comparative study on initial cost and running cost was done for almost all the new technologies proposed and their corresponding commonly adopted technologies, and only those advantageous in economy were adopted.

Task and ambient air conditioning system

This system enables separate control of the personal environment of the office workers and the overall environment of the entire room. Indoor environment level will be reduced within the ambient area while securing the comfort of the task zone with task floor A/C outlets and ambient ceiling A/C outlets. Task A/C outlets enable changes in the 'directionality and diffusion' of air and the air volume. By adopting this system, we can reduce energy consumption.



District Heating and cooling plant utilizing river water

The district heating and cooling system is adopted in the basement of the KANDEN Building. It has two characteristics. First, it utilizes the river water as thermal source, taking geographical advantage of standing in a sandbank of the river. The River water has a smaller temperature change through the year compared to the air. Therefore, the efficiency of a heat pump system increases. The cold and warm water is produced by less energy consumption. (Reduced approx.14%) Second, the system uses a large-scale ice thermal storage tank. Foundation pits of the building are used as the thermal storage tank of approx. 800m^3. Electricity at night is used to make ice used for a daytime air conditioning, so that electricity use at daytime is restrained. This leads to electricity load levelling to raise the generating efficiency at the power station and emission of CO_2 being restrained.

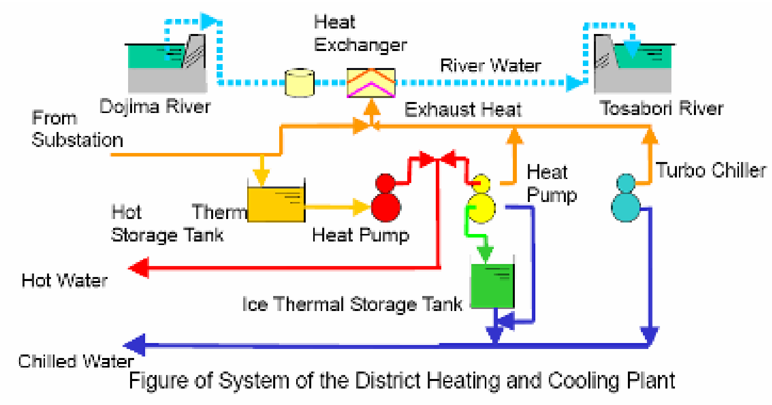
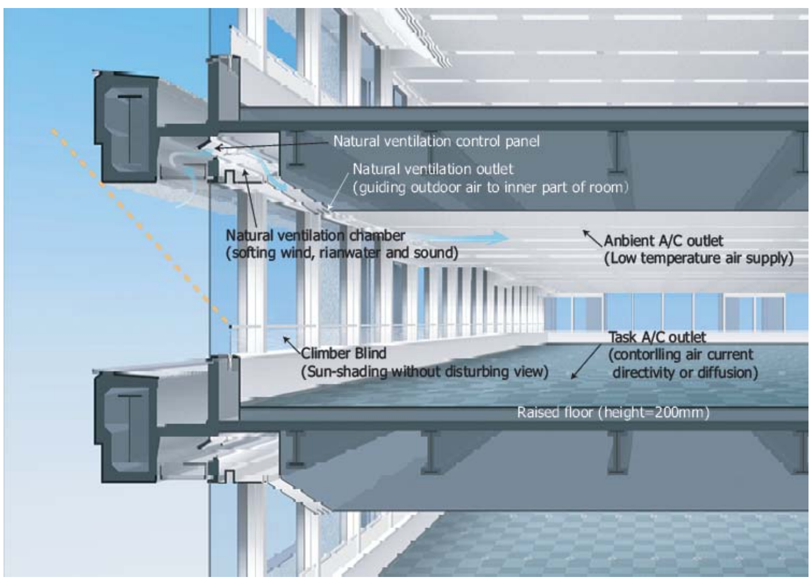


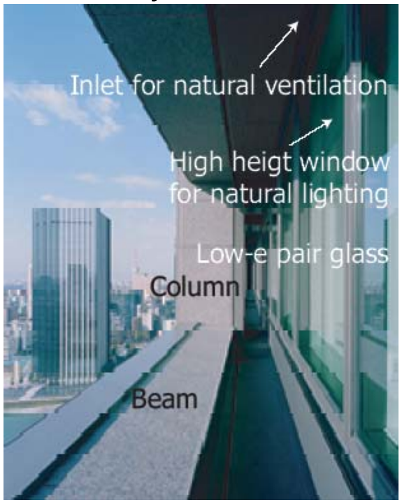
Figure of System of the District Heating and Cooling Plant

Façade design



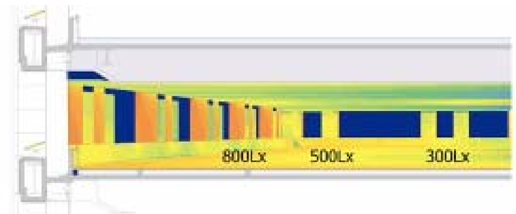
"Eco-Frame", columns and beams jutted out by 1.8m outside from the window surface, shows effects of eaves to block the direct solar radiation during 10AM to 2PM, the peak period of the cooling load in the summer time. And Low-e glass, which has a high performance in a direct solar radiation blocking and insulation, is adopted in a window to reduce an inflow of heat from exterior. By adopting these technologies, a cooling load in perimeter zone is greatly reduced (2/3 of a perimeter annual load to standard used in Japan), so that an air conditioning system for perimeter zone such as a fan-coil unit becomes unnecessarily.

Ventilation system



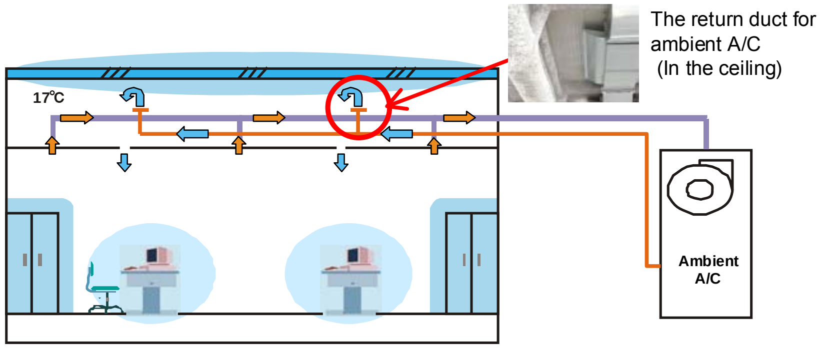
The ventilation inlet is designed to be less affected by strong wind or rain, by utilizing a shape of "Eco-Frame". Ventilation is done by wind pressure, for leading the river wind inside from the ventilation inlet under the eaves. The design of ventilation inlet is chosen by a numerical simulation and an inspection by an original sized experiment to maximize a volume and time of a ventilated air in any circumstances. In addition, opening and closing of the ventilator is automatically controlled by the conditions gained from the simulation to meet target performance (reducing 24% of cooling load). A design of ventilation outlet in the room is also chosen by the experiment to make an air current along a ceiling to send the ventilated air into the room as deep as possible.

Natural lighting



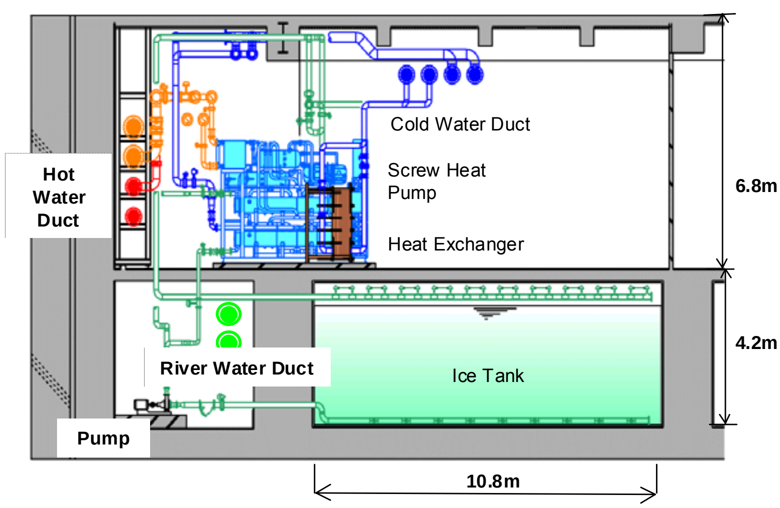
For taking in a skylight as much as possible while blocking the direct solar radiation effectively, the energy of illumination is reduced. First, a ceiling near the window is bent up to maximize a window height up to the lower part of the ‘Eco-Frame’. Second, window shades that climb up from the bottom are adopted, and these techniques are automatically controlled according to an annual schedule based on sun position and presence of the direct solar radiation measured by lighting sensors.

Building thermal storage system



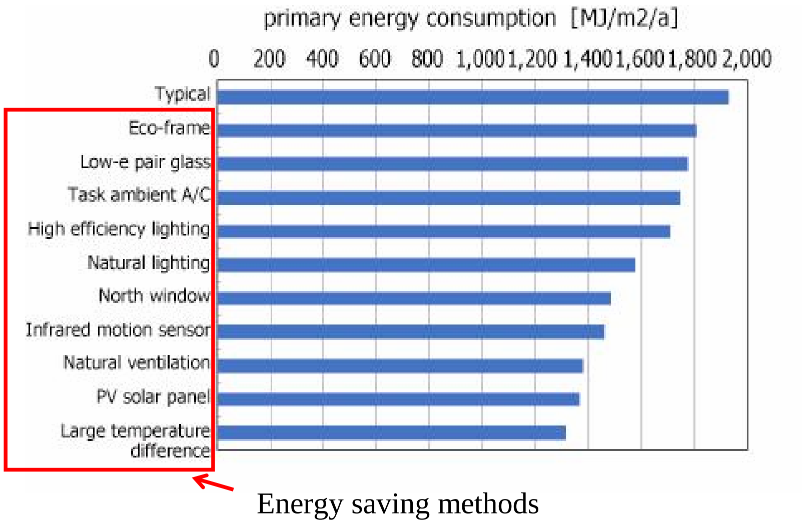
In summer, by keeping the climate control system operating at night, cold is stored in the flooring slabs, furniture and interior materials. Then this cold is released during the day-time, and we can reduce energy consumption during the peak electricity usage period by approximately 20%.

Ice thermal storage system
The usage of the 'double-slab' space as ice tanks saves a huge indoor space and the substantial tank cost of the thermal storage system. This figure shows the section of the machine room.



Performance

The figure shows the prediction of energy consumption of this building. The energy consumption is estimated to be reduced by 30% less than conventional office building. The building was constructed in January 2005, only 10 months ago, so we measure energy consumption now.



Summary of barriers

In Japan which is frequently attacked by typhoons with strong wind, there was no instance of adopting natural ventilation system widely at the full scale for a high-rise building. Major concern was a possibility that malfunction of natural ventilation system could cause inability of closing inlet openings in the wall and storm water could invade into office area. We conducted mock-up test and could confirm that storm water will not invade.

References

Masashi YAMAGIWA(2005), "The Environmental Symbiosis Technologies of the KANDEN BUILDING", SB05 TOKYO, Japan.

Kvadraturen Upper Secondary School

Name of building: Kvadraturen Upper Secondary School
Type of building: School
Location: Kristiansand, Norway
Owner: Vest-Agder county
Start of operation: September 2003
Architect: CUBUS Arkitekter
Engineering: Rambøll Unico
Net conditioned area: 9 000 m^2
Total energy use: 40% lower than a conventional building (predicted)
Cost: 250 mill NOK

Climate, site and context

Kristiansand is located at the south coast of Norway, and has a typical coastal climate. The annual mean ambient temperature is 7.2°C, and the annual mean solar radiation on the horizontal is 106.5 W/m^2. The design summer temperature is 21.4°C, and the winter design temperature is -13.3°C. The annual mean wind speed is 3.5 m/s, and the annual mean humidity is 5.7 g/kg. The school is located in the city centre of Kristiansand, with busy roads on all sides.

Description of the building and the integrated building concept

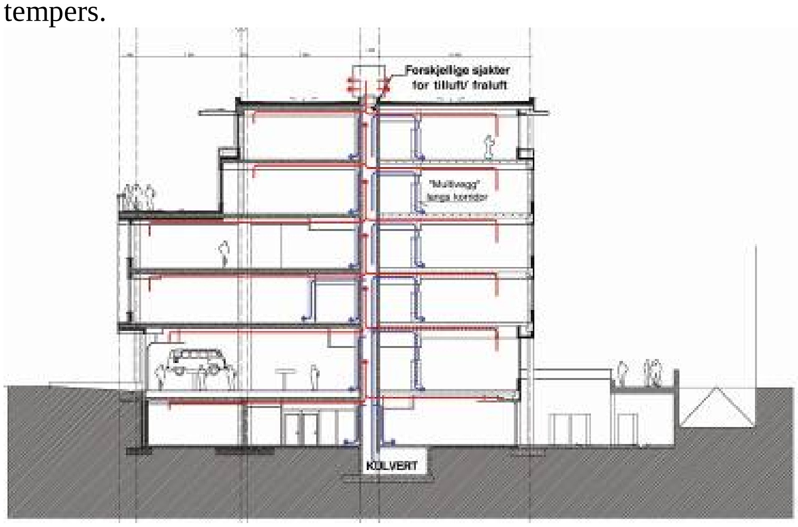
Model of Kvadraturen Upper Secondary School. Illustration: CUBUS Architects.

Conditioned floor area: 9 000 m^2 new construction (building D), 3600 m^2 retrofit
Number of floors: 5

Heating system
Water based radiators connected to district heating. Solar collector system that covers 15% of the DHW load.

Cooling system
Ventilation, shading, zoning, thermal mass

Ventilation system
Building D has a hybrid ventilation system. Total air volume 80.000 m^3/h. The air is supplied through grilles in the north and south facades (12 m above ground), then via vertical ducts in the north and south facades down to an underground concrete culvert. An internal, vertical building integrated concrete shaft was constructed to supply air to each of the 5 floors. Conventional ducts are connected to these shafts to supply the zones. The supply air is filtered and passed through a water based heat exchanger, and if necessary heated additionally by aero tempers.



Section through building D, showing the principles of the hybrid ventilation system. Illustration: CUBUS Architects.

Filter at air intake in culvert (left) – low pressure drop. Storage tank for solar DHW is place in culvert (right). The culvert surfaces are painted.

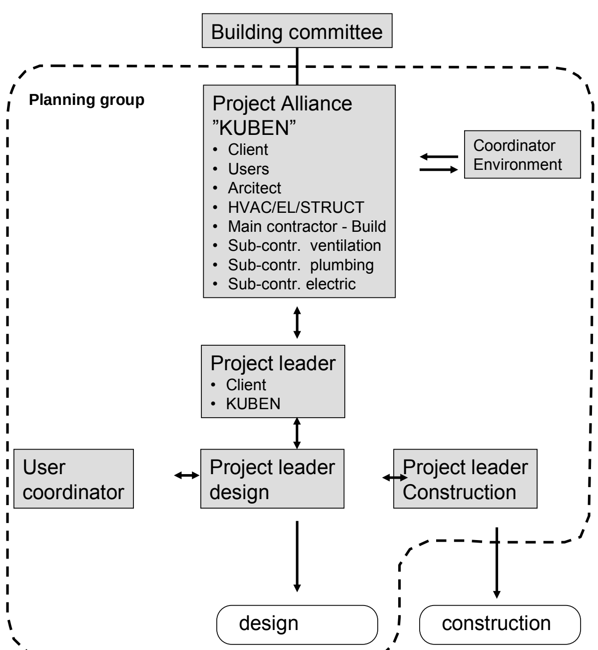
Control system
Each room has CO_2-sensors to control the supply/exhaust air volume.

Design and construction process
The contract was based on a Partnering arrangement, whereby the cost savings were divided among the client, the contractor and the design team. The architect, the consultants and the contractors established a formal joint collaboration to enter the competition. The winning team was selected based on architecture, qualifications, and price. The winning team then formed an alliance with the client and the users, and this alliance was kept until the building was commissioned. A special coordinator for environmental issues was appointed. An R&D institute (Norwegian Building Research Institute) was hired to perform a pre-study of hybrid ventilation.

All major decisions were taken in the leader group of the alliance, containing one representative from each of the partners. Smaller decisions were delegated to the project leader.

Around 40 studies were conducted to evaluate alternative technical solutions, their economy (life cycle costs) and their environmental impacts. A report and a summary sheet were produced for each of the studies.

The participants in the alliance expressed that this special form of organization was a major factor in achieving good integrated solutions. They also claimed that the extra investment in the planning process was rewarded through lower construction costs and better integrated solutions.



The model of the partnering agreement of the project.

Performance

The energy use was predicted to be 40% lower than for a conventional new school building.

The project was finished ahead of schedule and at a lower cost than estimated. The estimated cost was 279 mill NOK, while the final cost was 250 mill NOK. The discounted annual costs of the hybrid ventilation system were calculated to be 7% lower than a conventional system (with an energy price of 0.50 NOK/kWh and a discount rate of 7%). The main reason to this was reduced energy use for fans.

Summary of barriers

- Little knowledge and experience with hybrid ventilation systems with embedded culverts.
- Little experience with this kind of partnering work.

Open questions and needs for future research

- Detailed measurements and simulation of the performance of the hybrid ventilation system.

References

Buvik, K. (2003), ”Miljøvennlige skoleanlegg. 5 skoler med tilknytning til programmet Økobygg”, Læringssenteret, http://skoleanlegg.ls.no, Oslo, Norway.

Wigenstad, T. (2004). “Evaluering av Kvadraturen videregående skole – energi og miljø”, SINTEF Report STF22 A04513, Trondheim, Norway.

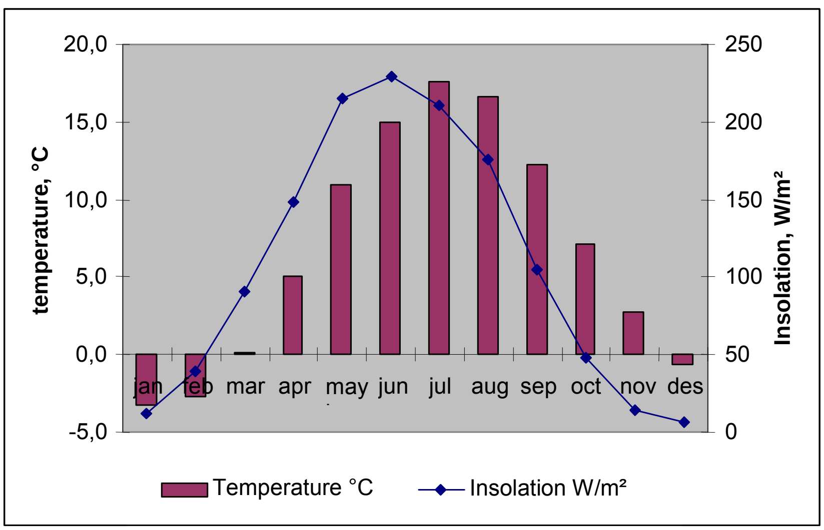
Kvernhuset Lower Secondary School

Photo: Terje Heen

Name of building: Kvernhuset Lower Secondary School
Type of building: School
Location: Fredrikstad, Norway
Owner: Fredrikstad Municipality
Start of operation: January 2003
Architect: PIR II Arkitekter
Engineering: Dagfinn H. Jørgensen AS
Net conditioned area: 5700 m^2
Total energy use: 40% lower than standard building (design)
Cost: 201 mill NOK

Climate, site and context

Fredrikstad is located at the east coast of Norway and has a costal climate with 3885 heating degree days (base 17°C). The monthly average temperatures and solar radiation is shown in the figure below Annual mean wind speed is 1.8 m/s.



Monthly average dry bulb temperatures and total horizontal solar radiation (24 hour average) for Halden (59.7°N, 11.17°E) which is the closest meteorological station to Fredrikstad.

Description of the building and the integrated building concept

Name of building: Kvernhuset Lower Secondary School
Location: Fredrikstad, Norway (59.12°N, 10.56°E)
Owner: Fredrikstad Municipality
Start of operation: January 2003
Gross floor area: 6865 m^2
Net conditioned area: 5700 m^2

Number of floors: 2
Number of pupils: 450-500
Operation time: The school is operated 5 days a week (06-22) all year around, except for 7 weeks during summer for the teaching space (2nd floor), and 4 weeks for the office space.


The main design idea of the school building was based on the active use of the site qualities: the rock, the forest and the light filtered by the trees. Wood and stones from the site were used as building materials. The first floor of the building cuts the rock. The burst rock mass is used as cladding on the facades of the ground floor. On top of the rock there are three rectangular, long and narrow wings that almost float over the ground. The wings' façades testify to the design inspiration of the surrounding trees, and each wing has a slight stain of the colours yellow, green or blue. The three wings have a light architectural expression that makes a strong contrast to the ground floor. The home bases (classrooms) for the pupils are situated in the wings.


The materials have been chosen based on a range of criteria; recycling, embodied energy, , maintenance, quality, cost and availability. Several surfaces have been constructed without any finish, or the finish consists of semi-processed materials (e.g. particle boards are used as suspended ceiling elements). The main load bearing walls are made from prefabricated reinforced concrete. The ground floor façade is faced with "gabions" of unprocessed local granite encased in stainless steel mesh cages. The mass of concrete and stone increases the building's thermal inertia. The building's «spine» has been constructed from reused brick.

The facades of the pupils' wings are faced with untreated pine wood taken from the trees which had to be cut on site in order to clear sufficient place for the building. Large areas of façade glazing and a number of skylights provide ample natural lighting.
The green roof system (sedum) requires only a shallow substrate. The plant species need minimum of maintenance and provide a green carpet with a changing of the season aspect.

The classroom wings at the second floor have a relatively large window area (40% of the floor area). In the pre-design phase, double low-E windows with wood frame and a total U-value of 1.3 W/(m^2K) was recommended (Andresen and Dokka 2001). However, the final window choice was double glazing with LE-coating and argon gas and aluminum frames, U = 1.5 W/(m^2K). The translucent wall elements inserted in the fully glazed facades are made from recycled polyethylene (ISOFLEX) inserted between two layers of glass. In the schematic design phase, these elements were specified with a total U-value of 0.5 W/(m^2K). The opaque walls have a U-value of 0.22 W/(m^2K) and the roofs and floor have a U-value of 0.15 W/(m^2K).

Heating system
A 360 kW ground source heat pump has been installed for tap water heating, space heating and heating and cooling of the ventilation air. The heat is collected from 28 wells (depth: 175m). The annual COP of the heat pump was assumed to be 3.0.

Ventilation system
Level 2 (classrooms) have a hybrid ventilation system. The ventilation air is taken in via underground concrete culverts and supplied to the teaching space via brick interior walls and through valves near the ceiling. The air is exhausted through lamellas in the vertical parts of the skylights. The airflow rates are controlled according to outdoor temperature, see table below.
Level 1 (administration) has a conventional mechanical ventilation system with heat recovery.

Section through pupils' base area, level 2. Ventilation air is led from the culvert via shafts to a distribution chamber over the secondary rooms ('spine'). The exhaust air is evacuated via the skylights (left). The air intake is through the glazed entrance of the building (middle), down to the underground culvert (right).

Ambient temperature, °C	Air flow rate, m^3/h
-20	13 200
-15	19 800
-10	21 120
-5	22 440
0	25 080
5	26 400
10	33 000
15	52 800
20	66 000

Design ventilation air flow rate as a function of ambient temperature.

Lighting systems
Daylight is used to reduce the electric energy for artificial lighting and, at the same time, enhance indoor qualities and architectural values. The classrooms have both occupancy sensors and daylight sensors.

Parametric studies were carried out to find the minimum glazing area allowing to achieve satisfactory daylighting requirements, including the best form and location of the additional window openings. The daylight simulations were made using the LesoDial computer program. The analyses showed that the simplest and the most effective alternative for the base area was a combination of large windows and skylights situated over the rear part of the class area. Large windows facing north and skylights allow achieving high daylight levels.


Skylights used for lighting and for air exhaust.

Performance

Computer simulations of the expected energy use were performed during the schematic design phase, using the computer Program SCIAQ Pro (Andresen and Dokka 2001). The simulations estimated the purchased energy use to 120 kWh/m^2/year heated floor area, of which 100 kWh/m^2/year was electricity and the rest was based on oil. This is well below experience from other similar buildings, which have an average energy use of 200 kWh/m^2/year. The benchmark for energy efficient schools in this climate is 116 kWh/m^2/year.

Estimated yearly net energy use in kWh/m^2 heated floor area, based on the schematic design (Andresen and Dokka 2001).

	Teaching wings Level 2 (3480 m^2)	Administration Level 1 (2200 m^2)	Total (5680 m^2)
Space heating	73	41	60
Heating of ventilation air	86	52	72
Tap water heating	10	11	10
Fans and pumps	5*	35*	17
Lighting	9	20	13
Equipment	12	30	19
Space cooling	0	0	0
Cooling of ventilation air	2	6	4
Sum	196	195	196

**Energy use for pumps makes up 3 kWh/m^2 of this*

Estimated yearly gross energy use (purchased) in kWh/m² heated floor area based on the schematic design (Andresen and Dokka 2001).

	Teaching wings Level 2 (3480 m²)	Administration Level 1 (2200 m²)	Total (5680 m²)
Electricity	74	122	93
Oil	35	14	27
Sum	108	136	120

The measured energy use has not been obtained. However, there are some indications that the real energy use will be somewhat higher than estimated during early design phase:

- The realized building has a large window area with higher U-values than was recommended by the energy experts.
- The heat pump has been out of operation for some period dui to leakage of cooling fluid from compressor
- The exhaust air lamellas in the skylights cause cold draft due to non-optimal operation (too few wind sensors on the roof).
- The exhaust air lamellas represent major thermal bridges.

Other problems reported include:

- Acoustic rubber panels had to be installed in the underground culverts to reduce the noise from the fans. These panels caused some smell problems in the beginning.
- The central control system had a long start-up period, and had not been commissioned on year after construction.

In general, the users of the building seem to be quite satisfied (Andresen, 2004). The interior spaces appear light, clean and attractive, and the air feels fresh. The users were particularly satisfied with the flexibility of the space – the freedom to use the space in different ways (Andresen 2004).

The project achieved large media attention and several architectural prices. It was also awarded the Eco-building of the year. Also, the school is very popular among pupils and teachers, and attracts applicants from teachers and pupils from all over the municipality.

The investment costs were 201 mill NOK, including land and infrastructure and a sports hall. This was around 15% higher than the budget. However, the cost is similar to the cost of other new schools in the area.

Summary of barriers

- Lack of integrated design of the building layout. Need co-operation between different experts on HVAC and energy, architecture, electrical engineering, acoustics, contractor from the early design phase.
- The overall liability for the energy/environmental system is difficult in these kind of integrated concepts. There are no well-established contracts for this.
- Lack of standard components for hybrid ventilation system (vents, control system).
- Lack of performance measurements, not demonstrated technology.
- Lack of computer tools to predict the energy and indoor climate in the early design phase

Open questions and needs for future research

- Detailed calculations and measurements of the heating and cooling effect of the underground concrete culvert.
- The development of cheap and reliable exhaust valves in skylights
- Fomalised method for integrated design and environmental design and performance control. Process and liability related.
- User-friendly tools for performance prediction of hybrid ventilation systems

References

Andresen, I. (2001), ”Miljøvurdering av Kvernhuset Ungdomsskole”, SINTEF Rapport STF22 A01502, 12.01.01, Trondheim.

Andresen, I. og T.H. Dokka (2001), ”Energianalyse av Kvernhuset Ungdomsskole”, SINTEF Rapport STF22 A01504, 26.02.01, Trondheim.

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Buvik, K, I. Andresen, and B. Matusiak (2002), ”LA 21 Applied to Kvernhuset Secondary School in Fredrikstad, Norway”, Paper at the International Conference Sustainable Building 2002, 22-25 September, 2002, Oslo, Norway.

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Longley Park

Photo: Ellis Williams Architects

Name of building: Longley Park
Type of building: Office
Location: Sheffield, UK.
Owner: Longley Park Sixth Form College
Start of operation: September 2004
Architect: Ellis Williams Architects
Engineering: Buro Happold Consulting Engineers, Thermodeck
Net conditioned area: 6200m^2, 4 storey
Total energy use:
Cost:

Climate, site and context

Degree Day Data for region 11 (East Pennine). Source: http://www.vesma.com/ddd/

Actual Month	Actual Degree Days	20 Year Average
July – 04	39	39
Aug – 04	18	40
Sep – 04	51	78
Oct – 04	148	171
Nov – 04	235	266
Dec – 04	305	342
Jan – 05	295	365
Feb – 05	315	323
Mar – 05	259	285
Apr – 05	203	224
May – 05	139	148
Jun – 05	55	77
Total	2062	2358

Sunshine hours for Sheffield. Source: *http://www.metoffice.com/climate/uk/stationdata/sheffielddata.txt*

Actual Month	Actual Sun Hours	20 Year Average
Mar – 04	98.1	105.1
Apr – 04	132.5	130.8
May – 04	210.7	184.8
Jun – 04	194.4	176.4
July – 04	168.0	194.4
Aug – 04	179.5	183.2
Sep – 04	168.0	131.1
Oct – 04	94.2	87.1
Nov – 04	52.2	53.1
Dec – 04	69.1	34.7
Jan – 05	48.1	43.1
Feb – 05	77.3	56.8
Total	1492.1	1380.6

The building is located adjacent to a main road (A6135) so pollution and noise is a key problem due to the required noise level of $40L_{Aeq,1hr}$ (dB) within the general classrooms etc. Derived from DfES Building Bulletin 87.

Description of the building and the integrated building concept

New build college incorporating; classrooms, laboratories, technology rooms, staff offices, meeting rooms, Learning Resource Centre and canteen. Number of occupants: 800 approx. Operation time: 0900hrs to 1700hrs.

The structure of the building utilises a steel column and beam frame. Pre caste concrete planks and in situ screed provides the structural floors. The ground floor slab consists of an in situ construction. Walls comprise of metal studs with infill insulation, behind and insulated board behind a rain screen. Windows are double glazed and utilise solar controlled glass in specific areas. The roof construction, consisting of a single ply membrane, on tapered insulation, on the structural slab. Pitched roof elements (above the 3rd floor clerestory) utilise a metal standing seam construction. The floor-to-ceiling height is 3.1 m.

Heating system
The heating to the building is provided by a gas fired stand-alone boiler system.

Two high efficiency, low NOx boilers serve the low pressure hot water circuits to:
- Variable temperature radiator circuit
- Constant temperature circuit to the air handling units and HWS cylinders.

The boilers are provided with a primary shunt pumps and secondary circuits to the heat emitters. All heating pumps are direct drive pumps offering ‘duty/standby’ facility. Secondary pumps are inverter driven and controlled to provide constant pressure in relation to the modulating 2 port control valves on all heat emitters. The heating system utilizes a package pressurization unit to maintain system pressure.

Radiator heating is provided throughout the naturally ventilated occupied spaces to offset fabric heat losses and glazing down-draughts.

In student/public areas radiators are provided with tamper proof thermostatic radiator valves. In staff areas radiators are provided with manual controls. All radiators therefore rely on occupant control.

Over door ‘air curtains’ are provided to the entrances to minimize draughts.

Heating to the toilet areas is provided via the make up supply air from adjacent spaces.

Approx 40% of the building is provided with mechanical via a TermoDeck principle. The supply air is temperature controlled to provide necessary heating to the spaces served.

Cooling system
The building is not air conditioned. The TermoDeck system and the introduction of night-time air into the building via the air handling plant shall assist the thermal comfort in the summer.

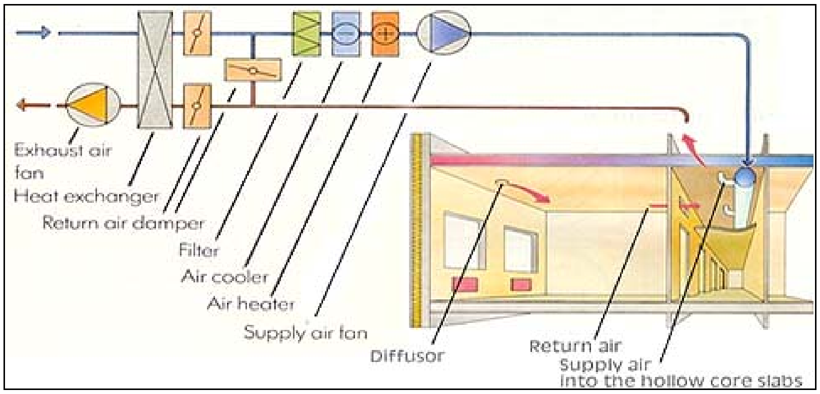
Supply air from air handling unit 2/4 is cooled when required so as to further assist the cooling of rooms with high internal loads.

A limited number of rooms, where high heat loads or high internal environmental criteria exist, are provided with mechanical cooling, by means of direct expansion refrigerant cooling systems. These rooms include:

- Principals office
- Mains Comms/Server Room
- Ground Floor Recording Room
- Second Floor Classroom
- Third Floor Conference Room

The college wing adjacent to Barnsley Road utilizes the TermoDeck system to optimize the environmental benefits inherent with the thermal mass of the hollow core precast floor slabs to reduce internal summer temperatures. In winter the thermal mass is utilized to improve heating system efficiency. The use of TermoDeck also reduces the reliance on opening windows, and associated noise pollution, adjacent to the busy road.

The mechanical ventilation system to the Learning Resource Centre and the Barnsley Road wing utilizes a system where the thermal mass of the building is optimized to reduce the running costs and minimize the summertime temperatures, with minimum need for mechanical cooling. The TermoDeck[1] system utilizes the hollow cores in the standard pre-cast slabs to supply fresh air to the rooms. The concrete slabs thereby act as heat exchangers or thermal stores and assist in creating a very stable internal environment.



TermoDeck schematic diagram. Source: http://www.termodeck.com

When days are hot, the mass of the building can absorb the ambient and internal heat gains the following day. During the night, the cooled supply air dissipates the surplus heat stored in the slab as it cools down the slab. Conversely, when days are cold the mass of the building absorbs the surplus heat provided by the occupants, light, computes, etc during the working day. At night, this stored heat will compensate for the fabric losses and keep the room warm to the morning. If necessary, it is warmed by heated re-circulated air. Irrespective of external climate conditions the TermoDeck system produces an efficient and low cost method for heating or cooling a building to the highest standard of comfort.

Ventilation system
In general Mechanical ventilation is provided to all areas within the Barnsley Road wing and the Learning Resource Centre. These areas are served by external air handling units (AHUs), each of which incorporate supply and extract fans, filtration, heating coils and heat recovery.

Air handling plant operates on a "full fresh air basis" to provide fresh air requirements for design occupancies and suitable air change rates. These AHUs supply air to the building via a 'TermoDeck' ventilation strategy.

All AHUs are provided with inverter driven fans for variable volume control. Thermal wheel heat recovery achieves a thermal efficiency of up to 75% (when heating is required). The AHUs are controlled to provide pre-heating and pre-cooling (night cooling).

The supply air from AHU 2/4, serving IT rooms, may also be automatically cooled by means of a refrigerant cooling coil, so warm outside temperatures do not cause internal discomfort.

Supply air is provided from ceiling/soffit mounted circular grilles, via the TermoDeck system and extracted at high level from central locations.

Mechanically ventilated rooms are also provided with façade openings. These windows are not necessary for ventilation purposes, but can add occupant comfort by allowing their local control of their space and connectivity to the external environment.

Electric systems

Control system
Building Management System
A Building Energy Management System is employed to control and monitor the mechanical services, internal environment and energy usage of the building. There is also the facility for remote monitoring of the BMS by TermoDeck and Buro Happold.

The main functions of the automatic controls:

Air Handling Plant
- Plant on/off, night cooling and pre-heat control
- Fan operation, speed control and monitoring
- Filter status (pressure) monitoring
- Energy management and heat recovery plant operation
- Heating and cooling coil operation for temperature control
- AHU isolating damper operation
- Supply air and room condition monitoring
- Motorized smoke/fire damper control

<u>TermoDeck</u>
- AHU control as indicated above
- Room and concrete slab temperature measurement

<u>Heating Plant</u>
- Plant on/off, frost protection and boiler sequencing

- External temperature and humidity monitoring
- Boiler operation and status monitoring
- LPHW temperature flow and return control/monitoring
- Primary and secondary pump operation, boiler interlock, status monitoring and auto-changeover
- Pump speed control, via differential pressure sensors
- Heat emitter and heating coil control via 2 port valves
- Pressurisation unit status monitoring
- Space/zone temperature control/monitoring

Metering
- Gas consumption metering to the boiler plant and main incoming supply
- Water consumption metering to the building **(not via BMS)**
- Electricity metering to each inverter driven fan (AHUs)
- Logging of internal and external conditions, for historical information
- Heat metering to the AHUs

Additional Functions
- Gas solenoid emergency isolation
- Fire alarm interface

TermoDeck Controls Description
The building is not permitted to fall below 20^{o}C at any time. Plant start optimization is therefore not employed.

Heat enable
Heating on at 20^{o}C
Heating off at 21^{o}C

Cooling enable
The requirements for night time cooling with ambient air are determined on an individual room by room basis. Only the rooms meeting the criteria below are pre-cooled at night. All other rooms have the relevant motorized dampers closed and the supply fan speed reduced via the inverters.

- Zone temp > 23.5^{o}C
- External air temp is at least 7^{o}C and is less than the average extract air temperature or average zone temperature if the fans not running
- External air temperature < 17^{o}C
- The time clock reads later than 22:00hrs

Zone 2/4 has supplementary mechanical cooling. If cooling is required, but the criteria for night cooling with ambient air are not met, then the mechanical cooling is used provided all the criteria below are satisfied.

- Zone temp > 24^{o}C
- External temp > 17^{o}C
- The time clock reads later than 04:00hrs

Architectural issues
It would be good to speak to Pablo Iglesias the project architect on this one. The log book contains the building u values etc.

Performance

The only predicted performance utilized the SEAM method (refer to BB87) which provides a crude assessment method. Refer to building log book for calculation details.

I think it would be interesting to, at some stage, summarise the issues which arose within the commissioning period and first year of operation eg

- Handover prior to complete commissioning and validation
- Client perception and aspirations
- Contractors opinions (we could solicit these)
- Obvious faults experienced during the validation (up to Sept 05)
- Lessons learnt
- External environmental conditions (summer)

Open questions and needs for future research

- Suitability (energy benefits) of Termodeck for areas with high external temperatures
- Client aspirations issues are very interesting to explore

References

http://www.longleypark.ac.uk/html/homepage.html

The Lowry

Photo: Mandy Reynolds, Buro Happold

Name of building: The Lowry
Type of building: Office
Location: Salford, UK.
Owner: The Lowry Centre Trust
Start of operation: April 2000
Architect: Jim Stirling and Michael Wilford
Engineering: Buro Happold Consulting Engineers
Net conditioned area: 23 930m^2
Total energy use: Concrete earth tube and plenum provides 4°C cooling
Cost: Within budget

Climate, site and context

Degre Day Data for region 7 (West Pennine). Source: http://www.vesma.com/ddd/

Actual Month	Actual Degree Days	20 Year Average
July – 04	44	34
Aug – 04	19	39
Sep – 04	52	76
Oct – 04	150	166
Nov – 04	235	257
Dec – 04	315	332
Jan – 05	296	352
Feb – 05	312	314
Mar – 05	257	283
Apr – 05	219	216
May – 05	154	134
Jun – 05	69	73
Total	2122	2276

Sunshine hours for Manchester. Source: http://www.metoffice.com/climate/uk/stationdata/ringwaydata.txt

Actual Month	Actual Sun Hours	20 Year Average
Nov – 03	64.4	60.6
Dec – 03	51.7	42.8
Jan – 04	34.1	49.6
Feb – 04	110.0	67.0
Mar – 04	106.7	95.2
Apr – 04	108.6	138.9
May – 04	196.3	188.8
Jun – 04	169.5	172.5

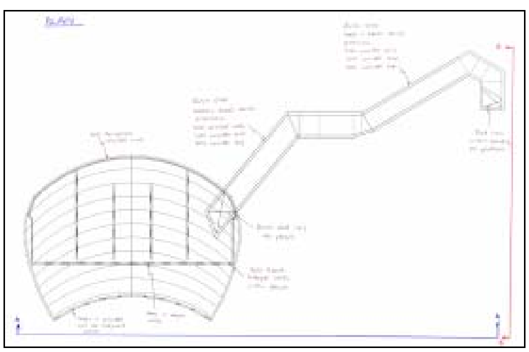
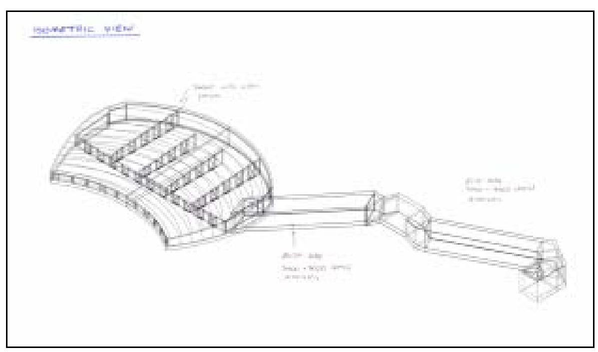
July – 04	150.4	183.8
Aug – 04	157.8	170.5
Sep – 04	148.8	127.2
Oct – 04	84.5	97.7
Total	1382.5	1394.5

The Lowry is located adjacent to the Manchester ship canal at the heart of the redeveloped Salford Quays. The building therefore has a high level of exposure, however as development continues at the Salford Quays the building will become more sheltered.

The Manchester Ship Canal was once a very busy commercial shipping route. This traffic is now much less and the water quality has improved. The River Irwell feeds into the Manchester Ship Canal and helps to improve the water quality.

Building total gross floor area 23930m^2.
Ground floor tier = 450m^2
1st tier = 165m^2
2nd tier = 425m^2
Total Theatre gross floor area is 1040m^2
Gross floor area of plenum is approx. 375m^2. Volume of plenum is approx. 500m^3
Net conditioned area (m^2):1040m2 - The whole of the theatre is comfort cooled.

Construction type: A 25m high concrete wall encloses the whole theatre. The ground floor is a concrete structure, supporting pre-cast reinforced concrete floor units. Beneath the floor units a plenum is created by the structure. The floor units are a minimum of 175mm thick and are supported by sleeper walls constructed of blockwork that are 200mm thick, the floor of the plenum is 450mm thick concrete.



Plan of Ground Floor Plenum and Earth Duct (left). Isometric View of Ground Floor Plenum and Earth Duct (right). See appendix A for larger drawings.

The supply air for the theatre stalls is supplied into the plenum via an earth duct constructed from 300mm concrete base and walls and a 200mm concrete roof. The two internal upper seating tiers are steel structures supporting pre-cast reinforced concrete floor units through which ventilation air flows from the air plenum within the steel cantilever frames. The internal steel frame and cantilever floor tier supports work compositely with the concrete wall.

Description of the building and the integrated building concept

The Lowry is located adjacent to the Manchester ship canal at the heart of the redeveloped Salford Quays. The building therefore has a high level of exposure, however as development continues at the Salford Quays the building will become more sheltered.

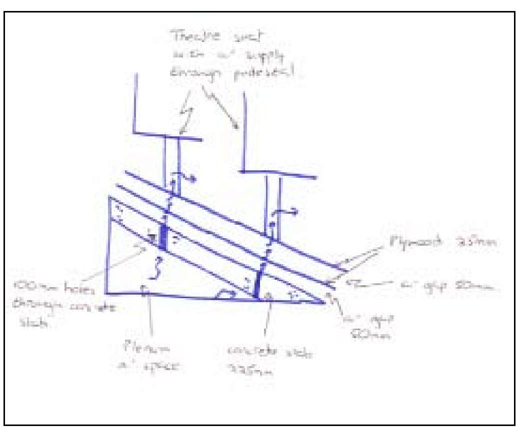
Heating and cooling systems

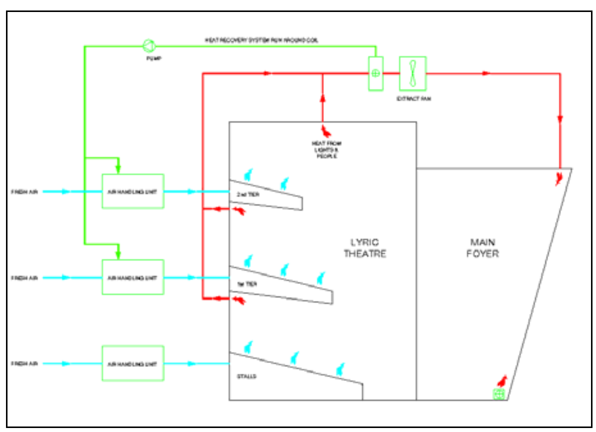
Heating is provided through the ventilation system. AHU's 1, 2 and 3 all have pre-heater batteries and heater batteries. Cooling is provided through the ventilation system. AHU's 1, 2 and 3 all have cooling coils.

The air supply plenum beneath the stalls is constructed of concrete. The conditioned air supplied from AHU 1 is passed through a concrete earth duct and then into the plenum and is then supplied into the theatre space via the pedestal diffusers. When the theatre was first opened it was found that the temperature in the stalls was cool. The temperature of the supply air coming off of the AHU was checked, and was found to be as the design setpoint. Checking the temperature of the air as it passed through the pedestal diffusers it was found that a fall off 4^oC had occurred between the air coming off of the AHU and leaving the pedestal diffusers. This cooling effect is therefore provided either by the earth tube or the concrete plenum, or a combination of both. Whilst such a fall was predicted at the design stage it needed to be quantified during commissioning so that the supply air off of the AHU could be set accordingly. Insufficient time for commissioning meant this was only quantified on the opening night. This feature is a net benefit to the energy costs of the Lowry. It is therefore of interest to look at the cooling that is provided by the thermal mass of the earth duct and plenum and to consider other active control strategies that could be used to improve the energy storage potential of the earth duct and plenum.

Ventilation system

The theatres are served by low velocity displacement ventilation – 2-2.5 m/s for supply, 3-3.5 m/s for extract. The supply air is passed into the plenum and then the air is injected into the space though diffusers beneath the seats. For the stalls the air passes through an earth duct before it enters the plenum, whereas the 1st and 2nd tier plenum is supplied via conventional ductwork.





Theatre displacement ventilation (left). Lyric Theatre Ventilation Sketch. Source: Buro Happold Project Drawings (right).

The stalls are supplied by AHU 1, the 1st tier is supplied by AHU 2 and the 2nd tier is supplied by AHU 3. This was done to allow flexibility in the ventilation strategy to meet the needs of

the theatre e.g. when a matinee performance is on in the theatre and the 2nd tier is not used AHU 3 can then be turned off.
Air is extracted at high level above each of the stalls, 1st tier and the 2nd tier. This air is then extracted to the main foyer, providing heating to this space in the winter, and ventilation in the summer. Heat recovery is provided from the extract air to AHU's 2 and 3 via a run around coil.

Control system
Each AHU is controlled independently according to the readings provided by the temperature and carbon dioxide sensors in each space.
<u>Heating</u>
Pre heater battery provides frost protection to the air handling unit – 5^{o}C off coil
Heater battery provides heat to control the space temperature – 22^{o}C space temperature
<u>Cooling</u>
Cooling coil provides cooling to control the space temperature – 22^{o}C space temperature
The Lowry has a Building Management System (BMS) that allows readings to be monitored remotely via a head end computer located in the Facilities Managers office (Buro Happold also have a remote connection).

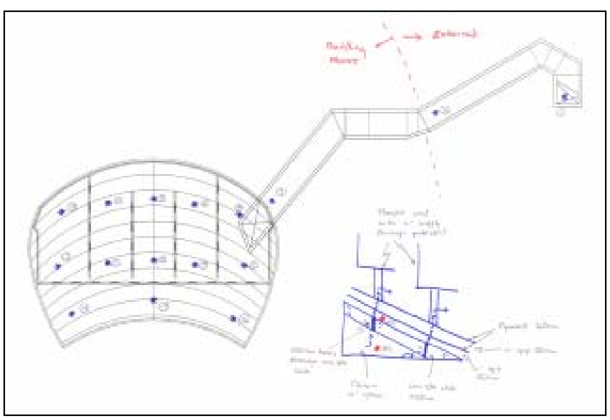
The BMS monitors:
- Temperature and CO2 content of each space
- The supply air temperature off of each AHU

The BMS also allows the set points to be changed easily and allows the facilities management team to turn the systems on and off as required to suit the times of the performances in the Theatre.

Architectural issues
The Architecture was influence by requirements made by Theatre Project Consultants and the need to accommodate seating arrangements and sight lines.

Performance

The performance will be tested by measuring the temperature of the air at various points throughout the earth tube and plenum, see sketch below.



Temperature sensor locations. Source: Buro Happold Project Drawings.

This will be done for both for a period in summer and a period in winter (at least a month for each). It is also intended to measure the temperatures of the slab at various locations and, if possible, depths. This data will then be used to validate a computer model of the earth tube and plenum constructed using IES Virtual Environment and simulated using the dynamic thermal modeling element of the software.

Summary of barriers

Cost could potentially have been a barrier. The project was within budget, but due to the use of the space as a theatre the budget was larger than that for other more standard projects.

Open questions and needs for future research

To determine the cooling provided by the thermal mass of the earth duct and the concrete plenum beneath the theatre. This will be done by monitoring the conditions within the earth duct and the plenum.

Control strategies that can be adopted to improve the cooling potential of the thermal mass of the earth duct and concrete plenum beneath the theatre. This will be done through computer modelling of the earth duct and plenum using IES software.

References

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http://www.thelowry.com

Mabuchi Motor Corporation Headquarters

Name of building: MABUCHI Motor headquarters office building
Type of building: Office
Location: Chiba, Japan
Owner: Mabuchi Motor Corporation
Start of operation: October 2004
Architect: Nihon Sekkei Ltd
Engineering: Nihon Sekkei Ltd
Gross area: 4782 m^2
Total energy use: 25% reduction in CO2-emissions (design)
Cost: £ 15.7 mill

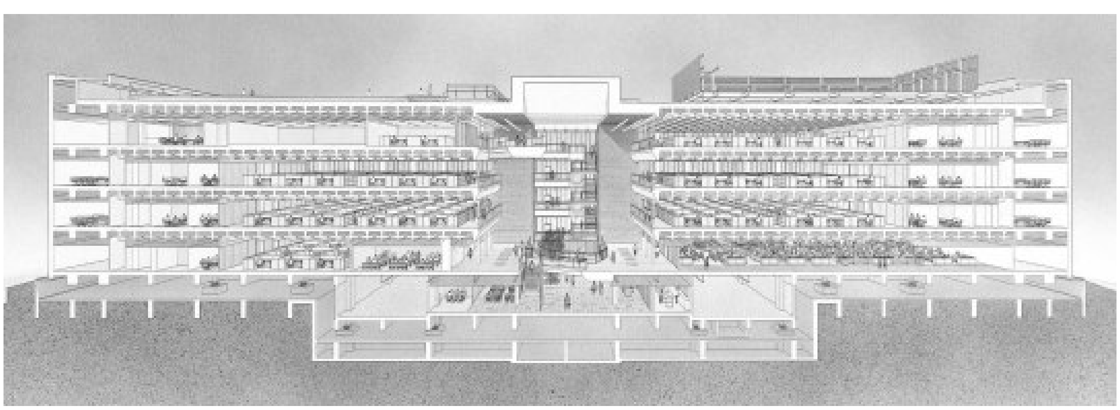
Climate, site and context

The climate is moist and mild, the highest ambient temperature is 33.4°C (design assumption value), while the lowest ambient temperature is 0.0°C (design assumption value). The building is located in the suburbs of the city area. The site is comparatively large, and has active forestation and pond work for the regeneration of the natural environment.

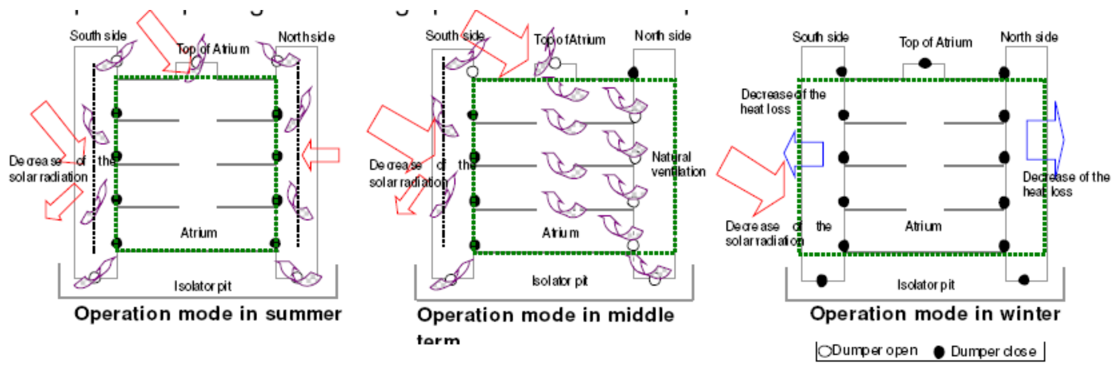
Description of the building and the integrated concepts

The energy consumption of the air conditioning system shows a big ratio of that of the whole building. So it's very important to reduce the air conditioning load with the building design from the angle of the passive method as well as making the active mechanical systems more efficient. This report shows a summary of the actual building which adopted the both of passive and active design and the air conditioning load reduction method integrated with the building environmental design.

The design of this facility tries to satisfy the client's demands for a comfortable and efficient work space with long life span, and for high design reliability and safety that also cares about the environment. The typical floor plan of the project is a space without columns with flexible spans of 33.6m (one wing has an area of 1500m2). Four floors are piled up towards the East-West wing and the central atrium is arranged in order to have an effective vertical floor communication, natural lighting and natural ventilation.

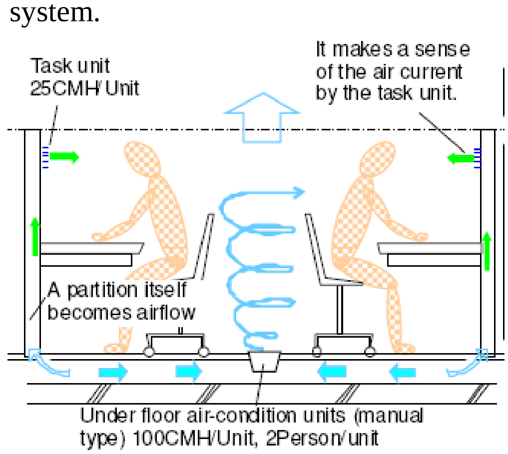


Double glass skin on the outer walls
The double glass skin has many functions which is necessary for outer wall in Japanese climate, like the heat insulation in winter, the exhaust heated air in summer, the natural ventilation in spring and autumn. These functions are realized by the automatic controlling ventilation dumpers at double glass skin (dumpers installed at top, bottom and each floor).



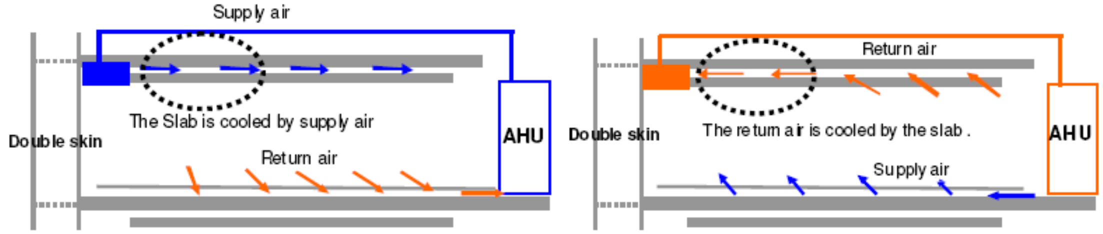
Partition panel air conditioning system.
The task and ambient air conditioning system which has supply openings for under floor air supply on the frequently-used partition panels was adopted to create the efficient air-conditioning system in the large scale and high ceiling office. The system outline is shown in the figure below. Productivity and amenity of occupants gain by using this panel air conditioning system that the volume and direction of supply air are adjustable by an individual. On the assumption that it is a combination system with under floor air-conditioning system of pressure type, a goal for design in the panel air conditioner is shown in the following.

1) The air-condition capacity (the amount of air conditioner volume) in the task zone and ambient zone in total becomes less than plan capacity value (75CMH/person).
2) Using the pressure difference control (pressure difference between underfloor and room, ΔP=15Pa) with under floor air-conditioning system.
3) Using supply temperature set point (19-20 degrees) of underfloor air-conditioning system.



Thermal storage on the building frame with the void slab
Air flow switching system: In this system, the void slab which becomes the structure of the building is used for a function as an air conditioning duct. At the usual air conditioning time

(at the daytime),the cooled air is supplied by under floor air conditioning system, and warmed return air passes through this void slab from the ceiling side. And the other way round, the void slab is used for air supply route at night. The void slab is cooled with supply air from AHU at night, and this thermal storage is recovered with warmed return air from the room at the daytime. In summer, the peak load of electric power can be shifted by using both this thermal storage and the ice storage system installed as a heat source of this building. Furthermore, in middle term, the cooling air conditioning load in the daytime can be decreased with this thermal storage system using out air cooling at night instead of using chilled water from heat source.



The void slab used as an air conditioning route consists of two kinds of forms. One is the form that ten circle ducts were installed in the slab which is close to perimeter zone. These circle ducts are used as an air conditioning supply and return route, and these aim for thermal storage and radiation mainly. This form is arranged on northern and southern 4 zones per floor of the building. And the other is that has big midair layer in the slab installed in the interior zone. And the openings for an airflow connected with the midair layer are installed on the bottom side of a slab to face the inside.

At day air conditioning time, the air from AHU passes through this midair layer first, and then it passes through the zone where circle ducts are installed. And finally it goes back to the AHU.

Performance

Double glass skin on the outer walls

It is very difficult to figure out the effect of the passive-design techniques like this double skin quantitatively with the existing heat load calculation. Because it depends on many parameters such as the weather condition, the buildings form, air conditioning systems and these operations. And there are few study cases about the relativity between the heat transfer model and the air ventilation model and about state change in the airflow and dumpers by temperature and pressure condition for whole building. In consideration of these backgrounds, it’s possible to figure out the effect with the thermal and air flow network model.

PMV distribution

The PMV distribution in perimeter zone was predicted by the rustles of simulation (using the dates of room and surface temperatures). In summer during air conditioning time, inside glass surface temperature is 30.2 degrees on the 1st floor, and 31.4 degrees on the 4th floor. The differences of the temperature and that of PMV are small. A similar tendency is shown even at the middle term. In winter air conditioning time, the PMV of the middle floor is 0 and it becomes a little low on the 1st floor and 4th floor which faces the out air.

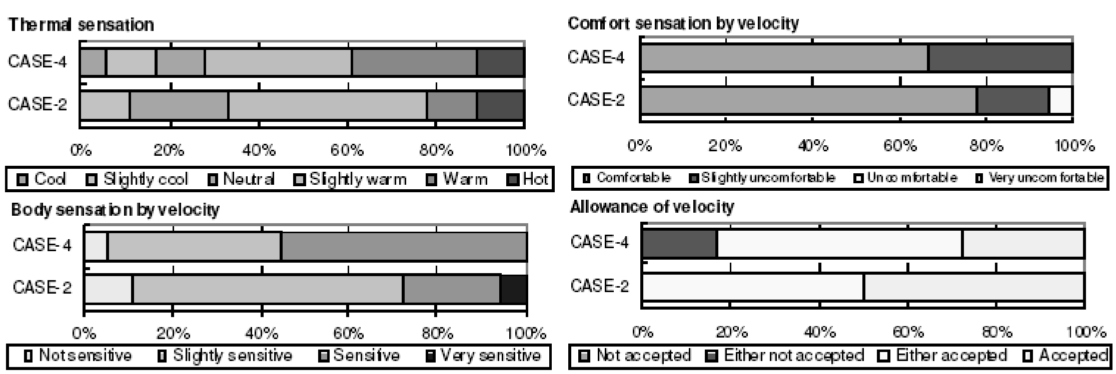
Thermal load distribution

In summer, the thermal load distribution of every floor with double glass skin shows lower tendency than the low-E glass and reflective glass. But on the north skin with low solar radiation, it shows lower effect than the south skin though it is expected to show the big effect with cooling in the seismic isolation pit. In the middle term, the heat load of low-E glass and reflective glass shows 2 times larger than the double glass skin on the south side.

Partition panel air conditioning system.
A performance experiment by the use of a mock-up was carried out. The temperature of ambient zone was set up higher than usual set point to confirm. The experiment was performed with the booth mock-up which is same as planning. The experiment pattern is shown in the table below.

	CASE-1	CASE-2	CASE-3	CASE4
Ambient Temprature set point	27°C	28°C	27°C	28°C
Ambient Humidity set point	47%	45%	47%	45%
Air supply temprature of Task unit	19°C	20°C	19°C	20°C
Air supply velocity of Task unit	1.0m/s	1.0m/s	2.0m/s	2.0m/s
Cloth insulation	0.6clo	0.6clo	0.6clo	0.6clo
Metabolic rate	1.2met	1.2met	1.2met	1.2met

A result of an experiment and examination of saving energy
A sensitivity experiment was conducted on 8 women and 10men only with CASE-2 and CASE-4. In this experiment, people who declare "It's warm" shows high ratio when the air velocity in the task unit is fast. It is grasped that broadening occupant's options with adjustable air direction, volume and wind velocity improves individual comfort.

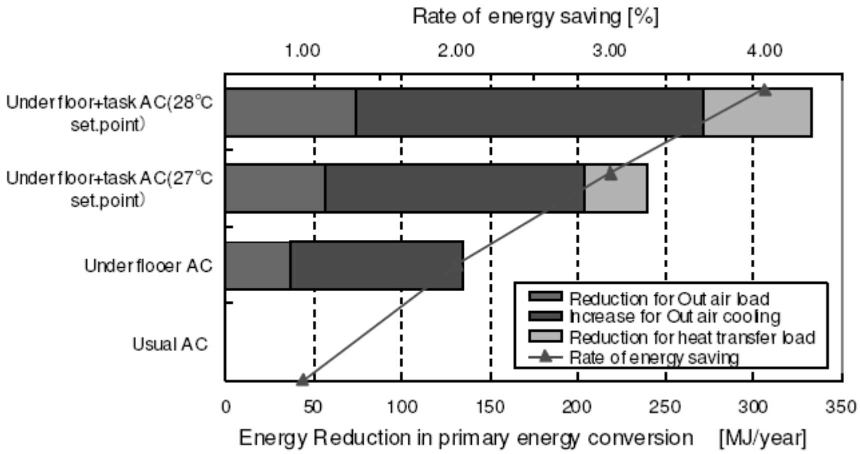


The result of PMV measurement shows less than 1.0 at all points on 27 degree. And it shows 0.5 at point A just like normal air conditioning. But it shows less than 1.0 only at point A on 28 degree with an effect of wind velocity, so the room temperature set point is supposed to be much better on 27 degrees than 28 degrees.

From the above results, the task unit was designed with following specification:
1) Air supply velocity from task unit is about 1.0m/s.
2) Air supply volume and velocity direction can be adjustable.

The examination of saving energy
The usual air conditioning system is planned as 26 degree room temperature, 16 degree supply air and the return air is same as the room temperature on the assumption that the indoor air is diffused equally. But the task and under floor air conditioning system is planned as 18-20 degree supply air, 28-30 degree return air on the assumption that it's possible to raise

the temperature level. The effect of energy saving with the task air conditioning shows the highest value with the improvement the conditioning of the outside air cooling. It shows 2.4% saving from the whole building energy consumption on 27 degree room temperature, and 3.3% saving on 28 degree room temperature.



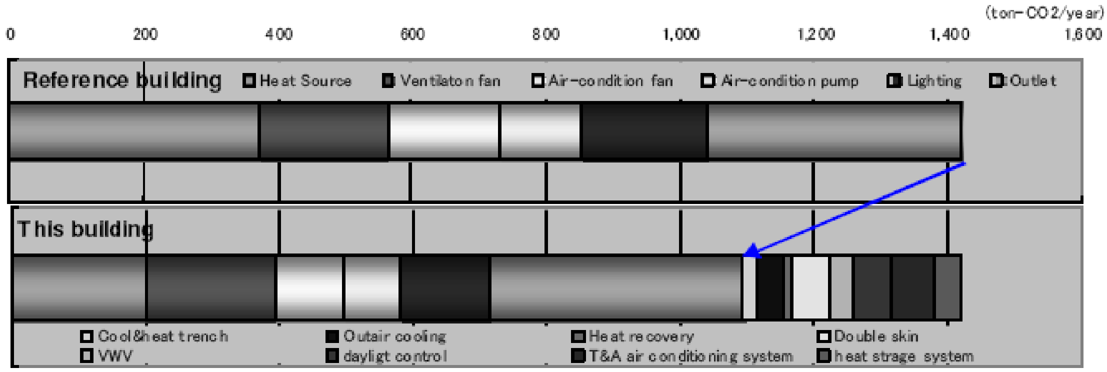
Thermal storage on the building frame with the void slab-a result of thermal performance prediction.

The energy consumption of the thermal storage system using the thermal and airflow network simulation model in summer and the middle term could be reduced about 5% from the primary air conditioning energy consumption in both summer and a middle term. There are several conditions of thermal storage time and supply air volume to void slab (maximum=4800CMH, minimum=2000CMH). And the simulation was done with 9 cases. In both summer and the middle term, the energy consumption for air conditioning fans at thermal storage (at night) was increased remarkably. When the supply air volume is at maximum, the primary energy consumption is increased bigger than the one without thermal storage system. And the effect of the heat recovery and the heat source load reduction with the void slab became low because of the outdoor air cooling. The following tendency could be grasped by this simulation:

1) In summer, supply air volume should be setting in minimum in a short time. (4 hours storage is the best in this simulation)
2) In the middle term, supply air volume should be setting in minimum in a long time. (8 hours storage is the best in this simulation)

CO_2

It is the result that about 25% of CO_2 can be reduced by both introducing the techniques and the high efficiency equipment systems by the energy simulation of the design stage.



Predicted CO2-values.

Design and Construction Processes

The project stage: The decision of the design requirement book were examined by analyzing needs in the future with the grasp of the situation of “work style” in owner’s PJ team. The design phase: PJ team's (owner, Consultant, and designer) design reviews were done, and the policy was decided from the aspect of LCC. The environmental adjustment technology confirmed a prior performance of the simulation by the designer. The construction stage: The research section of the construction team also participated, and about the environmental adjustment technology, a special advisory committee was formed and examined. The mock-up was made, and the task air-conditioning confirmed the inspection certificate, and fixed the specification by the PJ team. Moreover, it confirmed the performance, and the control mode was selected by the simulation in double-skins and the building frame thermal storage air-conditioning. The maintenance management stage: The follow-up team is formed as a building performance evaluation after it completes it, and it investigates jointly with the specialist such as universities.

Summary of Barriers

- The construction of Void slab which reaches 40m.
- A functional assignment in the task air conditioner with the equipment and the furniture.
- An uniformity-ization of the air flow distribution in the raised-floor of the under-floor air conditioning system.

Open Questions and Needs for Future Research

We will reflect to facilities operation with confirm of the Occupied person's evaluation by POE. Moreover, development schedule in double-skin, task air-conditioning, and building frame thermal storage to operation improvement like control judgment setting value etc. based on result of detailed verification every each season.

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Marzahn low-energy building

Name of building: Marzahn low-energy building
Type of building: Residential
Location: Berlin, Germanu
Owner: WBG Marzahn mbH
Start of operation: 1997
Architect: Assmann, Salomon & Scheidt and Partner.
Engineering: Ove Arup and Partners
Net conditioned area: 4243 m^2
Total energy use: 20% reduction compared to new code (design target)
Cost: 2664 DM/m^2

Climate, site and context
The climate is temperate, with mean temperatures of 17-18 degrees in summer and 0 to 1 degrees in winter. The area around the building contains a large amount of 6 to 8 storey residential buildings, which means that the building is quite sheltered. A large amount of consideration has however been given to the shape and the orientation of the building in relation to sunlight and the heating load in the building. The building is placed in a suburban area of Berlin, which means that the air quality should be very good on this site due to less traffic in the area because of the suburban placement and a good transportation network in close proximity to the site. The suburban placement and the transportation network should also lead to a low level of noise in the area, which eases the use of natural ventilation in the area.

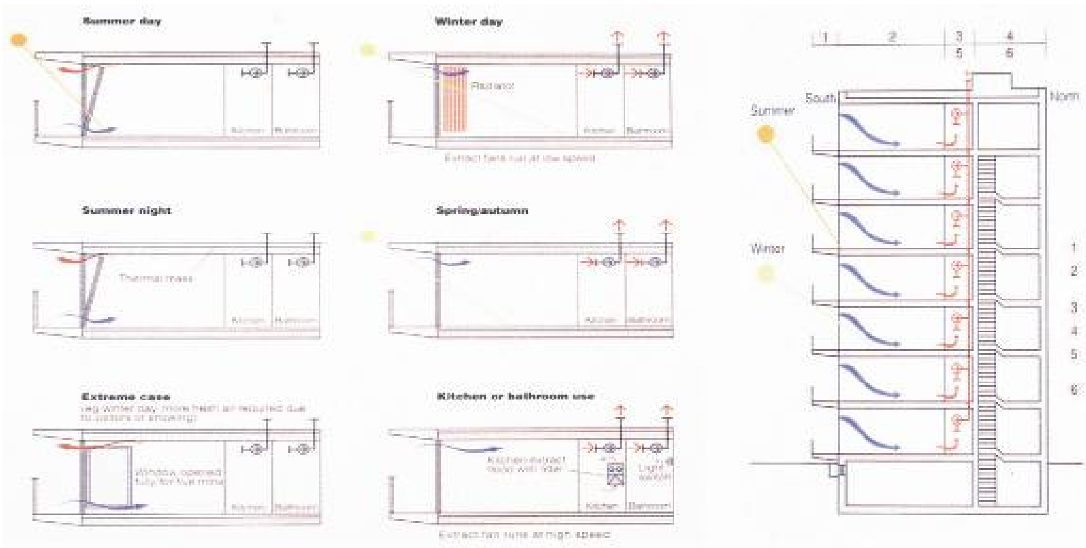
Description of the building and the integrated concepts
This project is interesting from an architectural and process-oriented point of view. Architecturally the project breathes life into a suburban area of Berlin characterized by the cheep and old modernistic concrete buildings erected in the DDR after World War II. Inspired by the modernistic context, the architects have transformed the modernistic architectural language by applying a process aimed at achieving a low-energy apartment building by focusing on the volume to surface ratio, seasonal ventilation strategies, building orientation, day lighting and other passive techniques.

Construction type: Concrete. Insulation: Outer walls: 120 mm (U-value: 0.25 W/m^2*K), Roof: 200 mm (U-value: 0.2 W/m^2*K), All floors: 120 mm (U-value: 0.3 W/m^2*K) Window types: wooden frames with low-transmitting glass, U-value (k-value) = 1.1 W/(m^2*K). Window area facing north: 25%, facing south: 75%

Heating system: “The heating system uses hot water supplied, via a heat exchanger, from a local district heating network. The rooms are heated by conventional radiators.” [4:81]. The heating system is supplemented with solar heat gain from south facing windows and internal heat gain.

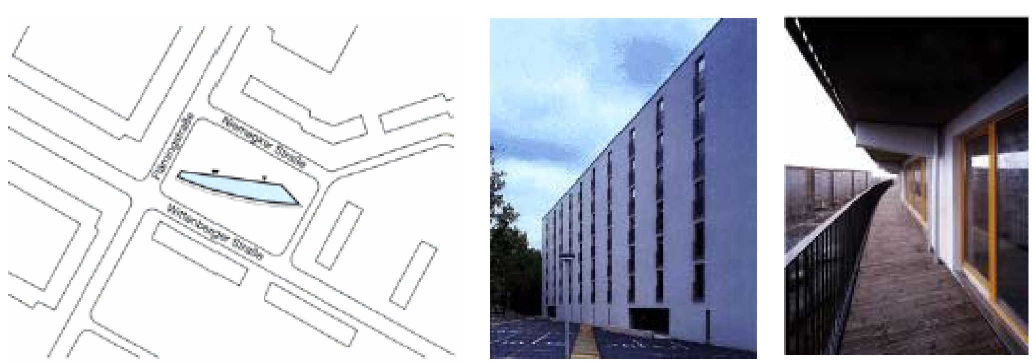
Cooling system: Natural ventilation, Thermal mass, Night cooling.

Ventilation system: Seasonal strategies, Natural ventilation during the summer season and some of the transitional seasons, Mechanical ventilation during the winter season and some of the transitional seasons.



The illustration shows the seasonal ventilation strategy. Need permission

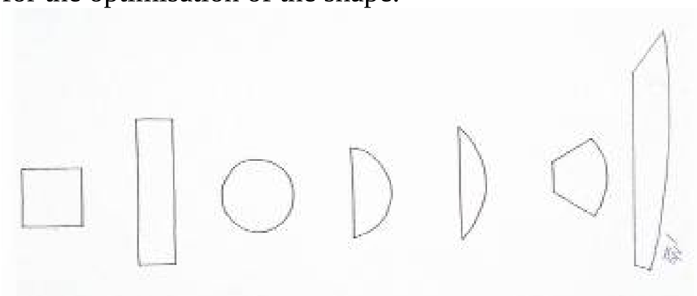
Control system: The building is controlled by a computer-controlled building management system, which guides the user of the building via a touch screen. The system ensures that the mechanical ventilation system and the heating system are shut down when the windows are open in the apartment, just as it contains information about room temperatures, external temperatures, wind speeds and wind directions. The control system also enables the user to minimise the energy consumption, as the “system provides a visible warning to the occupant at times when the windows could provide more effective ventilation than the mechanical fans” situated in the kitchen and bedroom.



Site plan (left) and north facade (middle) and the outside of the south facing balcony (right) – need permission.

Responsive building elements applied and their integration

- Volume to surface ratio: The volume to surface ratio was determined for five geometrical shapes based on a number of basic assumptions which made the results for the heating demand for the five shapes comparable. The cylinder proved to be the shape with the smallest heating demand, the results of this calculation was thus used as the target value for the optimisation of the shape.



The illustration shows the shapes investigated in relation to the volume to surface ratio. The five on the left side are the investigated shapes and the one on the right is the final shape. Need permission

- Thermal zones: The plan is divided into thermal zones. The living room and the other primary rooms are placed facing south, as these are the rooms which require the highest comfort temperature. The kitchen and the bathroom are placed in the centre of the building, while the bedroom is placed facing north in the largest apartments, as this room usually requires a lower comfort temperature than the other primary rooms.

- Thermal mass and Night cooling: Thermal mass absorbs the excessive heat in the summer and keeps a steady temperature both in summer and winter. This is a large part of the cooling strategy in the building combined with night cooling.

- Seasonal ventilation strategies: The ventilation strategy varies over the year in order to minimise the heat loss to the ventilation air. See the section entitled “ventilation strategy”.

- Daylight: The building has a narrow plan (7 m) which eases the penetration of direct daylight. Furthermore the internal walls are equipped with internal sliding doors in order to ensure even further penetration of daylight, as this enables the user to open up the rooms facing south, thus making one long room along the southern facade.

- Electronic user manual. See the section entitled “Control System”.

Performance

Energy consumption

The target value for the energy consumption of this low-energy building was a 20% reduction in comparison to the 1997 Berlin building codes. There is no report on what the actual energy consumption of the building is.

During the design process the target value for the heat energy demand was to achieve match 35 KWh/m^2, which was the calculated energy demand for the cylindrical shape, which had the lowest heat energy demand of the 5 investigated shapes. (see “responsive building elements applied and their integration”.

Economy

Investment cost 2664.15 DM/m^2 = approx. 5328.3 EURO/m^2.

Cost per apartment: 2141 DM = approx. 4282 EURO, Funding: 1500 DM per apartment = approx. 3000 EURO.

Architectural issues
The architectural vision in relation to the technical solutions:
This project is an example of how technical solutions can be integrated from the beginning of a project. The ventilation strategies, daylight strategy, the heating system, the cooling system and the control system are all integrated into the architectural expression of the building in a recommendable way due to the choices made in the design process. What makes the project interesting is the way the overall building shape and the energy consumption were interconnected in the design process and the way the architectural disposition of the rooms are based on climatic considerations.

The north façade of the building, however, is rather closed of and monotonous which is a shame from an architectural point of view. It would be interesting to see what effect it would have on the architectural expression of the north façade and the energy consumption, if the entrance area was more accentuated. This is where the downside of the choices made in the process shines through. Most of the rooms facing the north façade are unheated, which means that the impact of a larger percentage of windows in this façade only will have a small impact on the energy consumption in the apartments. On the plus side more windows placed in connection to the staircase will enable a reduction in the energy consumption used for electric lighting in the staircases, which might provide a larger reduction in the energy consumption than the reduction in the heating demand gained by removing all windows from the unheated staircase.

Elements in the building providing architectural quality:
The primary architectural quality of this building can be found in the original shape of the building and the south facing façade. Plan wise the building possesses some qualities, such as the sliding doors providing daylight further into the building. There are, however, a few issues in relation to the disposition of the plan in relation to the hallway area and the rooms facing the east and west facades. The hallway takes up a large percentage of the net conditioned area of the apartments. By placing the doors leading into the bedroom and the bathroom differently the hallway area could be reduced providing more space for the primary rooms of the apartments.

Design and construction processes
The environmental considerations have been integrated from the beginning of the project, beginning with the investigation of the heating demands of the five different shapes. After determining the shape with the smallest heating demand the calculated heating demand of this shape was chosen as the target value for the generation of the shape. The fan shape was chosen as the outset for the generation of the shape, probably because of the guidelines chosen for the shape:

- A large south facing façade with a high window to wall ratio
- As small a north facing façade as possible with a low window to wall ratio
- The east and the west façade were determined by a systematic experimentation with the lengths in relation to the overall heating demand of the entire building.
- Southern orientation of all apartments.
- Thermal buffer zone facing north and thermal zoning with in the apartments.

After determining the initial shape of the building the plans were made for the building resulting in a final shape and plan. In the process of finalising the plans the construction of the building was determined and the insulation thickness was decided just as the different systems were decided.

Summary of barriers

The project presents a number of aesthetic decisions made based on a series of technical calculations and considerations, which to some extend is very successful. There are however a number of aesthetic issues such as the improvement of the aesthetic expression of the north façade and the experience of the room in the staircase, just as there are issues of crocked rooms in the corners of the floor plans.

Due to the fact that the majority of the energy optimising decisions are focusing on the heating demand in the building a number of decisions are made, which in most cases improve the energy consumption of the building. But because the project only focuses on the heat demand and the daylight it does not take the all electric energy consumption into considerations, which in some cases, as in the case of the staircase, seem to result in solutions which lead to an increased consumption of electric energy.

A barrier to the implementation of this type of process is the exclusion of the electric energy, the energy embodied in the materials used for the building, transportation etc. So when one bases aesthetic decisions on calculations, one needs to at least consider both the energy consumption used for heat and electricity, whilst keeping a comfortable indoor climate with a satisfying room temperature and satisfying daylight-levels.

Open questions and needs for future research

It would be an interesting experiment to repeat the calculations used for the existing project, including the electrical energy consumption and a life cycle assessment of the building. This may prove a justification of adding windows to the unheated staircase, which would improve the experience of the inside and the outside of the building.

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Menara Mesiniaga

Name of building: Menara Mesiniaga
Type of building: Office
Location: Selangor, Malaysia
Owner: IBM's Malaysian Agency
Start of operation: 1992
Architect: Ken Yeang
Gross area: 12345 m^2
Total energy use: N/A
Cost: 20 mill RM

Climate, site and context
The climate is hot and humid, with mean ambient temperatures of around 26-27°C year around. The building is 14½ storeys, which means that a large part of the building will be exposed to the wind and sun. Recessed terraces (sky-gardens) with vertical greening provide shade and shelter.

Description of the building and the integrated concepts
This project is interesting because of the method applied in the design process and because of the architectural expression. The Malaysian architect Ken Yeang has been engaged in bioclimatic design in connection to Skyscrapers since 1981. He is interesting because of his methodological view on bioclimatic design as he also works in a way that differs from traditional architects. Yeang has devoted his career to creating ecological responsible architecture for the 21st century. To develop his designs Yeang performs research to update his knowledge during every project thereby improving the architecture. Over time he, thus, integrates more and more sustainable measures in his architecture, which also enables him to reflect on the effectiveness of his solutions. He calls this method RD+D (Research Design and Development). The application of this method has over the years resulted in the development of more and more sustainable principles used in his buildings. Even in Yeang's early projects one sees a particular working method which through climate theory achieved innovative results for commercial clients. Menara Mesiniaga is a good example of one of these projects, as it belongs to the second series (1989 – 1994) of Yeang's experiments with reinventing the skyscraper.

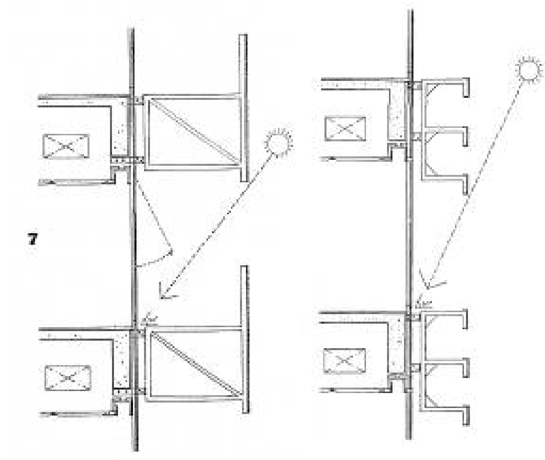
Heating system: None

Cooling system: Thermal mass placed in the service core, minimal exposure to the morning sun, open able windows. Shading; The windows facing east and west are shaded by external blinds which reduces the cooling load in the building.

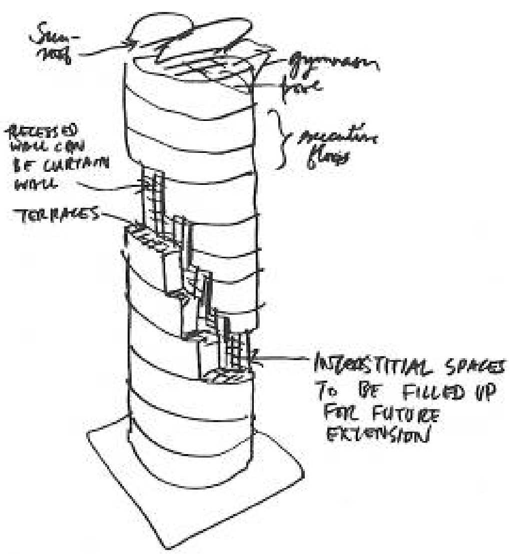
Ventilation system: Natural ventilation is used where it is possible, in connection to the terraces (‘sky’-courts), the lift lobbies, stairwells and toilets.
The building employs a range of automated systems to reduce energy consumption by equipment and the air-conditioning plant. Building Automation Systems (BAS) are used for this purpose. The lift lobbies at all floors are naturally ventilated and are sun-lit with views to the outside. These lobbies do not require fire-protection pressurisation (ie. low-energy lobby). All stairways and toilet areas are also naturally ventilated and have natural lighting.

Control system: The building is controlled by a Building Automation System (BAS). The users are permitted to open the windows in the office area.

The picture shows one of the sky-gardens.



The two illustrations show the solar shelves integrated in the facade



The illustration shows a principal sketch for the building

Responsive building elements applied and their integration

- Vegetation:
  ”"Vertical Landscaping" (planting) is introduced into the building facade and at the "skycourts". In this building the planting starts by mounding up from ground level to as far up as possible at one side of the building. The planting then "spirals" upwards across

the face of the building with the use of recessed terraces (as skycourts).” These provide shade and a oxygen-rich atmosphere (also works as dust reduction)

- Plot ratio (1:6)
  In order to minimise the building’s footprint and thereby it’s impact on the ecological systems in the area

- ‘Sky’-courts:
  Work as open atriums, channelling a cool flow of air through the building (the recession from the façade also enables the use of curtain walls (shading from the sun and excessive heat)

- Sun paths (window orientation)
  ”A number of passive low-energy features are also incorporated: All the window areas facing the hot sides of the building (ie. east and west sides) have external louvres as solar-shading to reduce solar heat gain into the internal spaces. Those sides without direct solar insolation (ie. the north and south sides) have unshielded curtain-walled glazing for good views and to maximise nautral lighting.” A core of functions is placed on the east-side of the building, because this is the hottest façade in this region, thus the core works as a thermal absorbent reducing the cooling load.

- Hybrid ventilation: see “Ventilation System”

- Daylight:
  Working stations are placed by the window, while internally enclosed rooms are placed as the core in the buildings east-side.
  The building has a circular shape there are no dark corners which also ensures a good volume to surface area ratio

- Views to the outside from all working stations

- Shading:
  Small windows are placed on the east and west side of the building. These windows are shaded by external blinds.
  The roof-top sun terrace is covered by a sunroof, which shades and filters light on to the swimming pool and at the roof of the gymnasium. The sunroof also provides space for future fixing of photovoltaic cells.

- Recyclable energy
  ”The sunroof is the skeletal provision for panel space for the possible future placing of solar-cells to provide back-up energy source. BAS (Building Automation System) is an active Intelligent Building feature used in the building for energy-saving.”

Performance

Operation and maintenance related issues

There appear to be no maintenance related issues to any of the systems in the building. All problems with maintenance have been related to the choice in materials, as some of the materials started leaking and rusting due to the humidity.

Economy
Investment cost: Total cost: 20,000,000 RM, Interior Design 3,000,000 RM Euro, Grand Total 23,000,000 RM

Architectural issues
The architectural vision in relation to the technical solutions:
The building has a high-tech feel to it, which is correspondent with the image of the client (IBM). The technical solutions were integrated into the aesthetic solutions in the building, such as the service core, thermal mass, natural ventilation, sky-gardens, construction etc.

Elements in the building providing architectural quality:
- Flexible and open plan
- The sky-gardens; provide green areas close to the work station, while clearing up the air and enabling the ventilation strategy and the vertical greening.
- The concept for the building is very much in the spirit with the image of the client.
- The service functions in the building, such as the swimming pool on the roof and the gymnasium provide a quality for the employees.

Design and construction processes
The general objectives for the project were:
- "Control of fresh air and air movement
- Access to operable windows
- Potential for natural ventilation
- A good view
- Access to green space
- Access to transitorial spaces
- Receiving natural sunlight.
- Control of lighting level
- Greater comfort in furnishings
- Ability to move furniture
- Provision of interior and exterior area for relaxation
- A greater feeling of spaciousness
- Better heating and cooling
- Adjustable temperatures
- Less noise and distraction
- Better amenities
- Provision of recreational facilities
- Awareness of place
- Awareness of seasons of the year
- Recreation of ground condition in the sky through elevated gardens
- Bioclimatic functioning of the building
- Interaction with nature, sunlight and shadow"

Open questions and needs for future research
It would be interesting to see if the principles Yeang has developed since 1979 will work in a different climate or to develop similar principles to fit other types of climate.

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MIVA Office Building

Name of building: MIVA Office Building, “Christophorus” House
Type of building: Office
Location: Stadl-Paura, Austria
Owner: MIVA
Start of operation: 2003
Architect: Bill Dunster Architects
Engineering: AEE INTEC, Gleisdorf
Net conditioned area: 1215 m^2
Total energy use: 20 $kWh/m^2/yr$ heating, 6.4 $kWh/m^2/yr$ cooling
Cost: 1205 EUR/m²

Climate, site and context
The climate is temperate, typical for Upper Austria, with 3923 heating degree days. The building is located in a rural area.

Description of the building and the integrated concepts
This project describes the new built office building of the Catholic Church association “MIVA”. The association is active in development cooperation and mission work. One of their activities is to prepare all kinds of vehicles for developing countries. During the last 10 years has the MIVA association also worked with providing mobility through ecological means, in energy and water supply. With this background, it was a natural step to build their new office building from an ecological point of view.

The office building with 1,215 m² is a work place for 40 persons. The remaining building area is used for parking of the company’s cars (325 m²) and basement (550 m²). The building has a basement, a ground floor and two upper floors.

Coefficient of heat transmission for the construction parts are listed in the following:

outer walls	U ~ 0.1 W/m²K	foundation	U ~ 0.1 W/m²K
ceiling	U ~ 0.1 W/m²K	glazed areas /atrium	U ~ 0.8 W/m²K

Energy concept
The goal of the planning team for the construction were:

- Multi functional application of the building (offices, events, mini shop, exhibition facilities and logistic central).
- Wooden construction
- Heating load < 15 kWh/m²a
- Pressure test air change n50 < 0,6 h^{-1}
- Primary energy consumption < 80 kWh/m²a (including electricity for the domestic use)
- No compressor cooling machine
- Covering the remaining energy demand with renewable energy sources to a maximal extent
- Highest possible comfort for the employees with lowest possible running costs
- Building certified as “passive house quality” by the passive house institution in Darmstadt, Germany

These high ambitions were a challenge for the planning team and could be reached due to an integral planning process.

The essential components for the energy supply system are listed in the table below.

Components for the energy supply and technical thumb figures.

Energy supply		
	Application	**Technical data**
Deep sonds	Heating (heat pump) and Cooling (“direct cooling“)	8 x 100 m Duplex – deep sonds, (Double-U-pipes DN 32)
Heat pump	Heating	Nominal power 43 kW at COP 4,03
PV – system	Covers the yearly electricity demand of the heat pump	10 kW_{peak}
Solar thermal system	Domestic hot water supply	5 m² collector area
Energy demand		
	Application	**Technical data**
Ventilation system for the office building area	Fresh air supply Heating, Cooling	Nominal flow volume 2,800 m³/h, heat recovery rate 78%
Ventilation system for the seminar rooms	Fresh air supply Heating, Cooling	Nominal flow volume 1,000 m³/h, heat recovery rate 86%
Heating and cooling surface area	Heating, Cooling	“direct cooling“ ~ 25 W/m²

Load reduction measures / Optimisation process

The reduction of the energy demand for heating and cooling was a requirement to build a sustainable and also a cost efficient energy supply system. An optimisation process was carried out by the planers and the first calculations resulted in very hot indoor climate during the summer (approx. 50°C in exposed areas) but rather low heating demand for the winter (approx. 30 kWh/m²a). With this as base were further calculations carried out for two reference years, one with an extreme hot summer and one with an extreme cold winter. This was optimised with the dynamically simulation program TRNSYS. A thermal mass of 100 tons was integrated into the house, as results from the simulations, which showed a need for additional storage mass.

The optimisation calculations of the building considered improvements in the U-values of the glazed areas, application of thermal building mass, reduction of glazed areas in the atrium (up to 50%), application of solar protection glass and heat protection glass, avoidance of thermal bridges, reduction of infiltration, optimised lighting concepts, optimised shading concepts, high efficient heat recovery application, application of night ventilation and optimisation of all HVAC equipment.

Implemented energy concept

Since there is a significant cooling demand in the building, the solution for a sustainable cooling concept played an important role. The energy supply should be both based on renewable energy sources and be cost effective. A monovalent system for both heat and cooling supply was planned to achieve these guidelines.

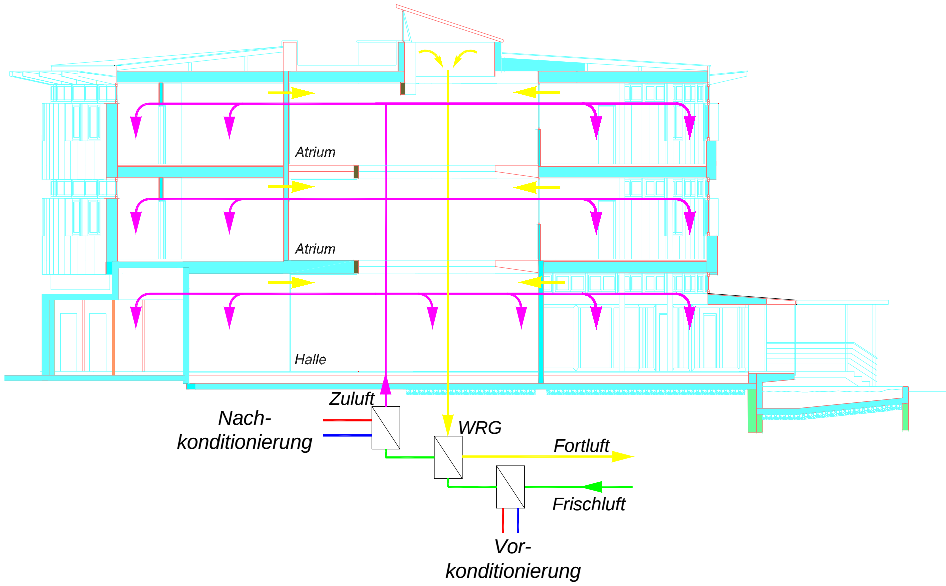
Responsive building elements

The main cooling concept for this passive office building is the application of deep sonds. The temperature of the water, which is lead to the water-circulated earth heat exchanger is evened out and is relatively stable in comparison to the fluctuations in outside temperature.
Deep sonds are used both for the heating and cooling period. They serve as both heat source (heating period) and cooling source (cooling period). The sonds are used as heat source for a

heat pump (43 kW and COP = 4.03) during the heating period. Heat is extracted from the ground and a beneficial temperature profile is thereby established for the summer cooling period. The energy supply during the winter is coupled with a highly efficient air ventilation system with heat recovery. The deep sonds are used as so-called “direct cooling”. This direct cooling is realised through panels, which are flown through with cold water and integrated in the building components. It is thereby possible to have a cooling without the application of a compressor cooling machine. The cooling capacity of this concept is approximately 25 W/m². The same panels are also applied for the heating system during the heating season.

Heating and cooling panels, which are flown with cold water (cooling period) or warm water (heating period), product “RCS“

This cooling concept is supported by a natural air flow through the atrium during the night. The stream of air is the result of the difference in density of the warm inside air and the cold air outside as well as from the cross section area of the inlet and outlet openings.
The figure below shows the concept of this passive cooling for the MIVA office building.



The air stream from deep sonds into the building

The ventilation of the office building is carried out with the means of two separated ventilation systems with heat recovery systems (78% recovery rate and 2,800 m³/h nominal air flow) through a rotation heat exchanger. The ventilation of the seminar remises have a 86% heat recovery and a nominal air flow of 1,000 m³/h.

The storage mass of the building is the stabilising element of the room temperature. The higher the storage mass, the more even are the inside temperatures. The function of the storage mass is based on that the heat, which is gained during one day is stored and then released during the night. This creates a balance in the room temperature between day and night. If the storage mass is encircled by cold air during the night, the cooling effect can be realised during the following day. The cooling period at night should be at least 5 hours to reach enough capacity to remove the gained heat. The pre-requisite for an effective thermal day-night balance is suitable material with a high thermal conductivity and good heat storage capacity (concrete, heavy-duty walls etc.) of the construction parts foreseen for thermal storage. The upper 10 cm in the room are decisive for this effect. 100 tons of storage mass was included in the MIVA building.

The office building was constructed following the passive house standards, with the goal to reach 15 kWh/m²a. The heating is carried out through the ventilation system and the active components (applied for cooling in during summer) are also used distribute the heat during winter. This brings the advantage of a sense of a higher comfort level. Further is a floor heating system is installed in the atrium area for winter operation.

The project included alternative ways for the generation of the electricity demand of the pumps and ventilators. The photovoltaic system has a peak load of 9.8 kW (from which 3.6 kW_{peak} was integrated in the façade and 6,2 kW_{peak} with an angle of 40° on the roof). Further, the building has a solar thermal system with a collector area of 5 m², which supply the building with domestic hot water.

Performance

Thermal comfort and humidity

The monitoring results show that the comfort parameters indoor temperature and humidity show extraordinary good and constant values. Also the supply during the transition time function well and almost without any auxiliary primary energy supply (heat pump). This means that the heat recovery from the ventilation system and the “direct cooling” concept with the deep sonds are enough to keep the room climate at a comfortable level.

Energy consumption

The heating demand was measured to 20 kWh/m²a and the maximal heat load was 13 W/m² for the winter operation. During the cooling period was the measured cooling demand 6.4 kWh/m²a and the maximal cooling load was 11 W/m².

Maintenance and operation of the systems

The operation of the building is of high satisfaction and the occupants are very pleased. The shading devices and the lighting is operated through sensors at the work area, which results in an optimal daylight utilisation. The conference rooms are equipped with CO_2 sensors via which the ventilation is regulated and is activated when the CO_2 level is higher than a set value (1000 ppm). The ventilation and heating deactivated on the weekends to enable a high efficiency of the systems are. The energy supply is supervised via 24 hours running monitoring of all the systems. In addition to information over this particular building, the monitoring serves as learning of the highly innovative applied systems. The person in charge of the operation on site is contacted, should there be an error message.

Costs
The establishing costs for the entire building complex were 1,205 EUR/m², without royalties. The running costs for the heat pump (7,5 kWh/m²a) and for the HVAC equipment operation (42 kWh/m²a) can be calculated in total with an electricity price of 0,14 €/kWh (+20% sales tax) and a total yearly electricity consumption of 108,742 kWh. This results in running electricity cost of 15,224 € (+20% sales tax).

Design and construction processes
This project is of best practice character because of the very early integrated planning process with the planning team (architectures, energy engineers, civil engineers). With this expertise working team could lower running costs be achieved and the CO_2 emissions are 80% lower than those for a conventional office building. The energy systems and the application of the building have worked in an optimal way ever since it was taken into operation in 2003.

The initiative of the project was the building owner, who contacted AEE INTEC and asked for an expertise consultation before the project was started. AEE INTEC coordinated the entire planning process and carried out the energetic calculations and optimisations. It was shown that such coordination with one partner acting as “energy party in charge” was of great importance of such innovative construction project. This coordinator not only dealt with the conventional energy processes, but also keep the overview of the energy relevant areas and acted as the link between the project partners (building owner, architecture, planner, engineers engaged in static calculations, constructional physicist etc.).

It is of high importance that the planning of the building operation coincides with the use of the building as far as possible to get good operational results, i.e. the planed use of the building has to be as realistic as possible. The financial planning of the project was done by the building owner, who’s wish was to apply sustainable energy technology and reach a passive house standard

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M+W Zander

Name of building: M+W Zander
Type of building: Office
Location: Stuttgart, Germany
Owner: M+W Zander
Start of operation: 1998
Architect:
Engineering:
Net conditioned area: 10 000 m2
Total energy use:
Cost:

Climate, site and context
The climate is temperate (middle Europe), with 3390 heating degree days 3390. The building is situated in an urban area, with light industry, surrounded by buildings of approximately same height, place close to the green area.

Description of the building and the integrated building concepts
The global concept utilize the passive solar energy using a winter garden, the light stream architecture, the Thermo Active Building System (TABS) is used in one of the buildings in the complex (further described in detail) in the association with the supply of the fresh air.

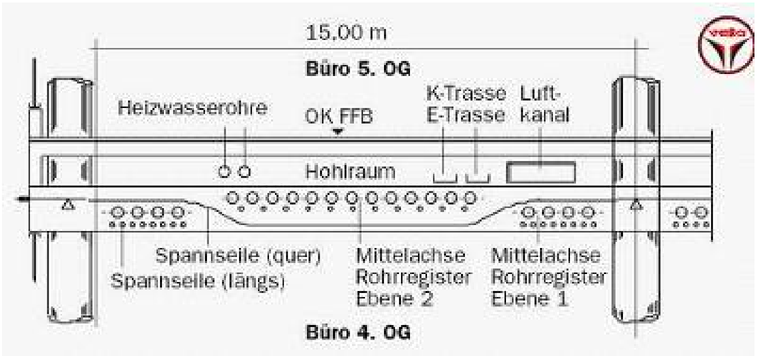
The energy supply concept consists of the following elements:

- Thermal Solar collectors
- Photovoltaic (shading elements)
- Free night cooling
- Rain water buffer tank
- TABS with Fresh Air Conditioning

The complex of M+W Zander includes four buildings. They are called as follows: Production Hall, round shaped building with offices - “Tower”, Link Building which connects old and new part of the complex, newly built Annex Building. Time of the occupancy is from 8am to 5pm, from Monday to Friday.

Gross complex area: 10.000 m^2, Net conditioned area: 10.000 m^2 (6.500 m^2 heated/cooled by TABS - annex building).
Number of floors: ground floor + 5 floors (6-storey building)

Construction type: The load bearing skeleton in reinforced concrete consists of pillars (columns) with a distance of 15 m and flat concrete ceiling slabs of 300mm.



Typical cross section of the responsible building element/TABS-ceiling slab (Wiercioch 2001)

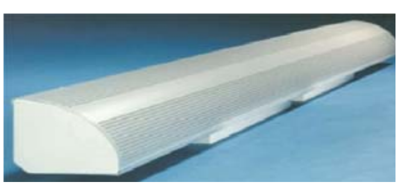
Heating system / Cooling system

The main idea was to create (build) a modern, an ecological and an economical building, which will provide the appropriate indoor climate for the office workplace and the team work of employees. The cooling/air-conditioning was designed with regards to the huge electronically equipped offices and thus increased cooling loads, and not exceeded the maximum allowed air velocity in occupied zone based on DIN_1946 T 2/1. The Thermo Active Building System (TABS) is used for integrated cooling/heating (tempering) in the Annex building (6500 m^2), which will be described in more detail.

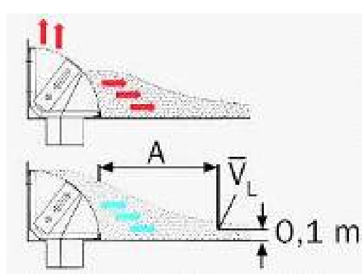
Ventilation system:

The TABS is associated with the air conditioning system using fresh air plinth (close to the facade) and floor (building core area) inlet units. These units (with possibility of an individual control) allow additional and warm air heating, using built in water heat exchanger (300W). Their position under the glass surfaces helps to avoid the down cold draft from windows, formation of moisture on the surface and avoid the unwanted cold/warm radiation from windows. Four air handling units are installed in Annex Building. The ventilation provides 100% fresh air, the individual room humidity control, and covers the part of peak cooling/heating loads.

The majority (90%) of the exhaust air is exhausted through the gap between the floor and slab surface. This air goes directly to the air handling units equipped with a heat recovery. The rest of the exhausted air (10%) is used for ventilation of the rest rooms and adjacent rooms. A plate cross countercurrent heat exchanger is used for the heat recovery.



a)



b)

a) Plinth air supply unit, b) fresh air pattern heating / cooling

Control system

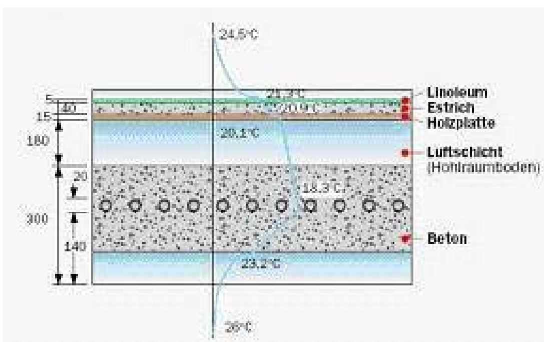
The mean water temperature in the activated slabs is controlled depending on the outdoor temperature during the whole year. Thus the supply water temperature varies between 19-

23°C. The operation showed that using this strategy, in cooperation with ventilation system, the room temperatures are kept between 22-26°C in summer and 21-24°C in winter. As the TABS performs as a buffer, its thermal inertia is utilized. Thus, in the summer time, the heat carrier circulates during the night (18:00 - 10:00) in intermittent operation. Utilization of the cheaper electricity night tariff slightly shifts the peak power demand to the nighttime.

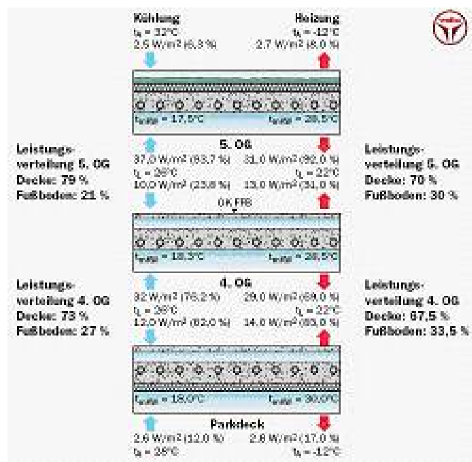
Responsive building elements applied and their integration

For integrated heating and cooling in new Annex building, the TABS is used. Heat exchange between surface and the space performs by two physical principals; radiation 65% and convection 35%. Heat carrier circulates in meander-shaped pipe coil (VPE pipes, 20 mm diameter), which is embedded into the load-bearing 300 mm concrete ceiling slab. Total length of embedded pipes is ca. 49.000 m and 9.750m^2 of ceiling is activated.

An air gap 180 mm thick is left between the slab surface and the floor construction, it significantly affects heat fluxes going upwards from the slab. The gap space is also used for installation of IT and electricity cables, water pipes for the coils, water distributors and air duct system.

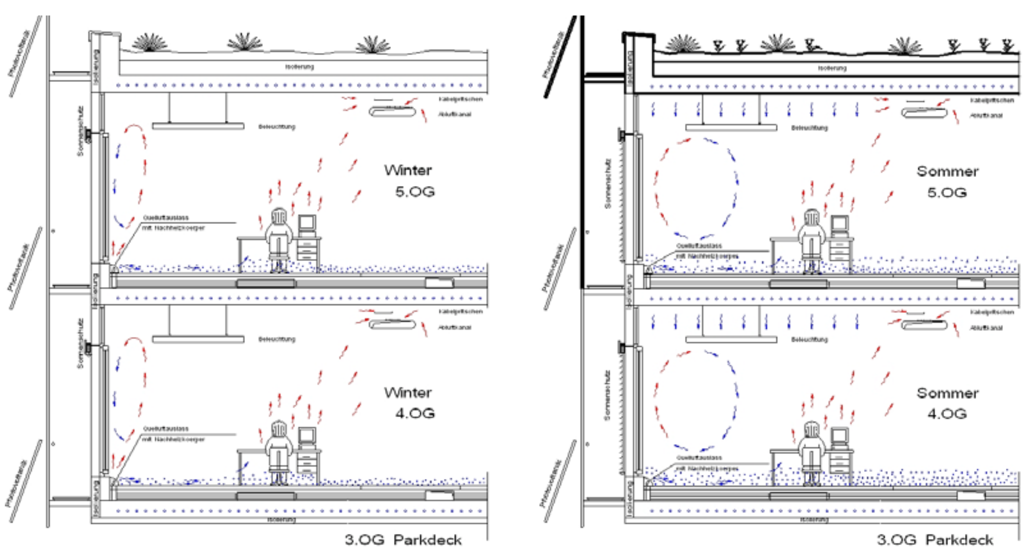


a)



b)

a) Temperature distribution in the concrete slab during the cooling mode; b) Thermal output rates from the activated slab for different floors of the building

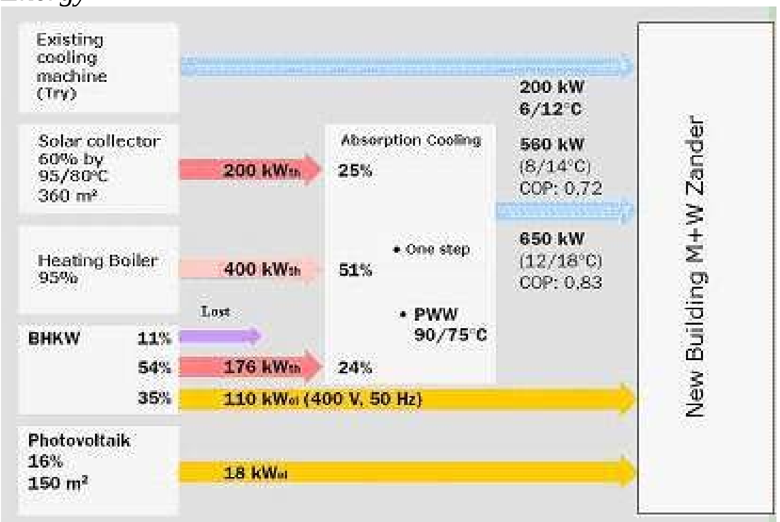


a) b)
Winter and summer operation modes of the TABS in the Annex building. Heating/cooling operation, reference room.


Installation of the TABS on site

Performance

Energy



Energy sources used for a complex of W+M Zander buildings

Thermal performance of the W+M Zander building complex

	Area m^2	Cooling [kW]	Heating [kW]	Electricity [kW]
Total:	10 000	1047	6210	**780**

Thermal comfort

Generally, the owner is satisfied with the operation of the system. The temperature is kept 21-23°C (winter)/22-24°C (summer) and relative humidity between 45-60% (for closed windows). The fresh air inlet units are set to provide adequate 80-100 m2/h/person. Indoor smoking is prohibited. The air velocity achieves 0.11 m/sec in 0.6 m distance from the inlet units.

Summary of barriers/ lesson learned

- VPE pipes were used instead of commonly used PE-Xa: As the construction columns' distance was 15 m (significant stress/strain in the concrete) the plastic pipe supplier suggested to use unusual VPE material instead of PE-Xa.

- After starting the operation it appeared, that the design value of the inlet temperature gave the system higher capacity than need. Next optimization showed the supply water temperature range of 19 – 23 °C was sufficient, while it is controlled in dependence on the outdoor temperature during whole year.
- The system was not designed to cover 100% of the thermal loads. Installation showed that using TABS is suitable to provide specific thermal output of 45-50 W/m^2. If this is insufficient to provide thermal comfort, additional heating/cooling by plinth air supply units is used.
- The temperature difference supply/return was 3K, however according to the experience from the system operation it can be shifted to the 4-5 K
- Summer night operation utilizes thermal inertia of concrete slab as the thermal buffer, and thus save expensive electrical energy (day tariff). The results of the measurements show that this operation does not affect (impair) the thermal comfort. The measured daytime temperature drift on the lower surface of the ceiling was 1.5K (21-22.5°C).

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Nikken Sekkei Tokyo Building

Name of building: Nikken Sekkei Tokyo Building
Type of building: Office
Location: Sakai City, Japan
Owner: Nikken Sekkei Ltd
Start of operation: May 2003
Architect: Nikken Sekkei Ltd
Engineering: Nikken Sekkei Ltd
Net conditioned area: 15 500 m^2
Total energy use: 145 kWh/m2/yr (about 50% reduction compared to reference)
Cost:

Climate, site and context

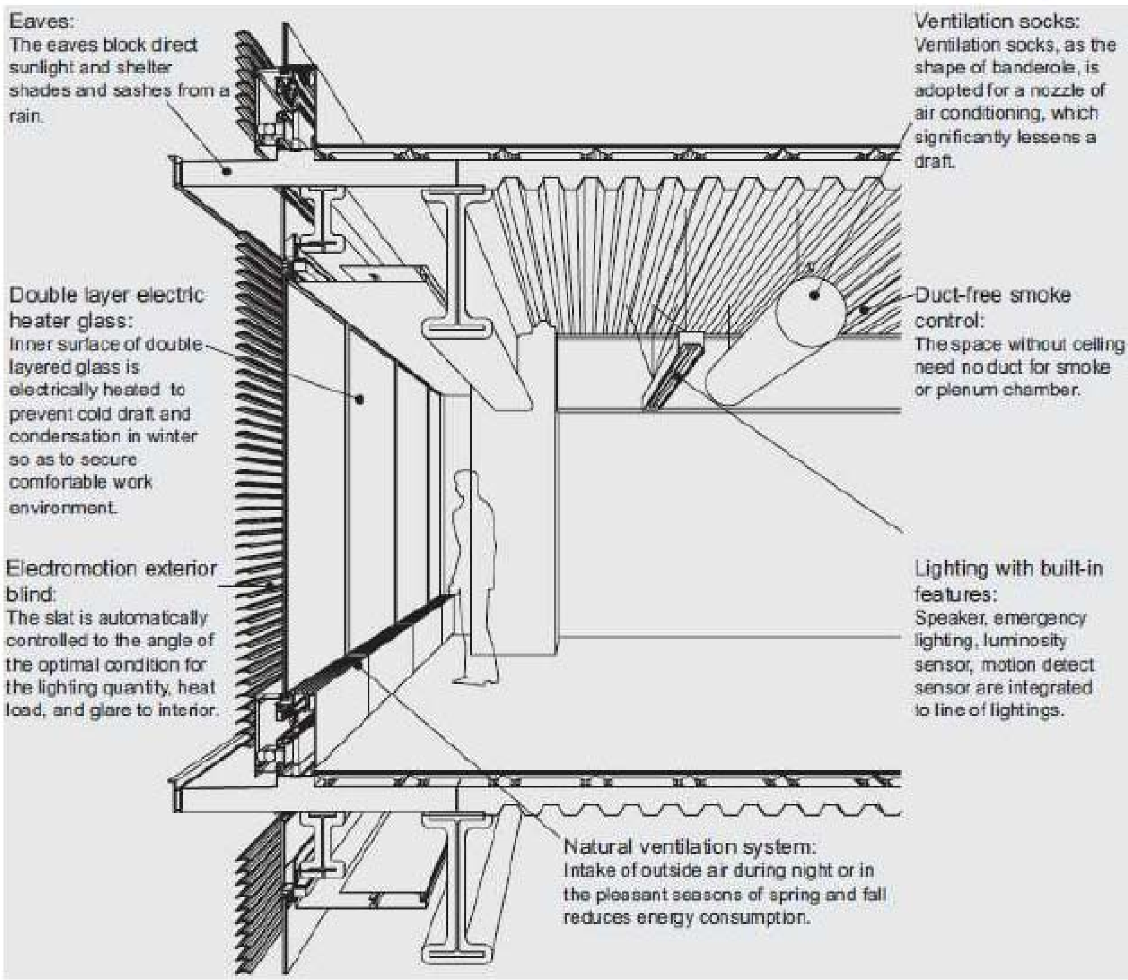
The climate is mild, with 1609 heating degree days and 232 cooling degree days. The Nikken Sekkei Tokyo building is located in the heart of Tokyo. The building is built in the redevelopment area, faces the Kanda river on the east side, and has the unoccupied land of opening to the public of about 10m on the west side.

Description of the building and the integrated concepts

This 14-floor building is not only simple and practical but genuine at every aspect such as facade, plan, details and engineering, to be appropriate to a design office. Working area and meeting area are laid out to further enhance the communication between the staff, which is considered important in a workplace environment. A typical floor without ceiling allows extension of sectional space and enhances the inspiration of the staff. The space also helps smoke control and allows a safer workplace. Ventilation socks are adopted for a nozzle of air conditioning, which significantly reduces draft. Outside electromotion shades, natural ventilation system, double layer electric heater glass, and balcony at the east and west ends reduce inside heat load and assure pleasant environment. Viscosity damping wall as well as steel frame damping brace is in place to secure the earthquake resistance performance of S grade, the high level structural grade. The damping walls and braces absorb most of vibration energy and prevent almost all the columns and beams from any damage under big earthquake and typhoon.

Responsive building elements applied and their integration

This building will arrange the main opening on a very disadvantageous east and west side in the environment because the south north is placed in the adjoining building and it is located on a long from east to west site. The development of "Window system responding outside environment" started from the redesign of old Japan "Bamboo blind" as sun shade from strong west sun of summer under such a condition. The architects and the engineers achieved coexisting of securing the flexibility of the design and the energy saving by the collaboration, and aimed at the construction of "Integrated system of “construction” and “equipment”. Solar insolation has an extremely big influence on the indoor environment and the energy consumption. Increasing the number of buildings of the glass facade, it is so important to control solar insolation appropriately. The design of this building aimed at the construction of the technology that had high generality that was able to become one of the choices in the general office building plan for the future. This system combines the electromotion exterior blind and the double-layer electric heater glass, and has controlled these automatically by the open network system.



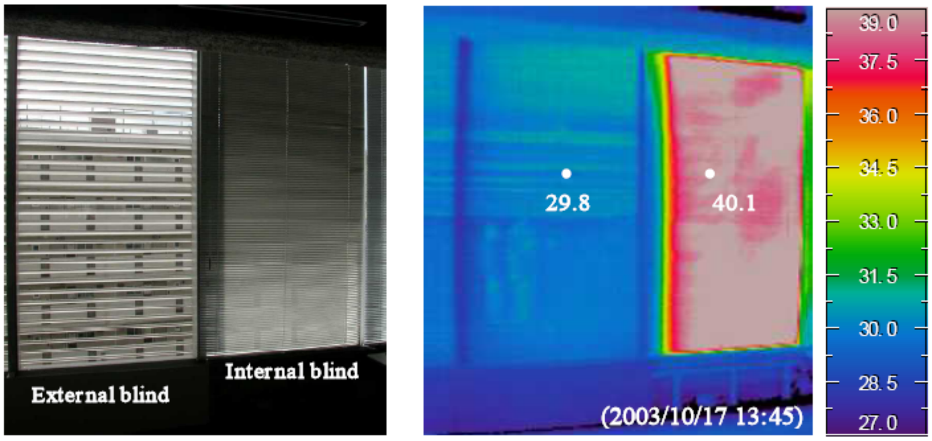
This window system can achieve the energy saving while securing the view and the open plan in response to the change of outside environments of shooting and the outside temperature, etc.

Performance

Blocking solar isolation by electromotion exterior blind

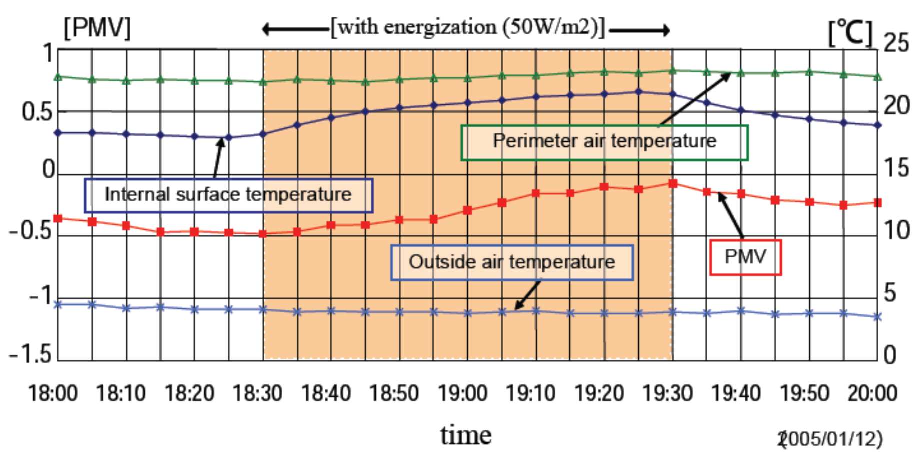
The external blind greatly decreases the insolation load compared with the internal blind. To understand the insolation blocking performance of this window system, thermal environment at the window were compared by the difference of the insolation blocking position.

The figure below shows the measurement result of the western window surface temperature in situation that one window is blocked with external blind, the next window is blocked with internal blind in the same color.



Comparisons of a surface temperature of western windows (at a typical floor)

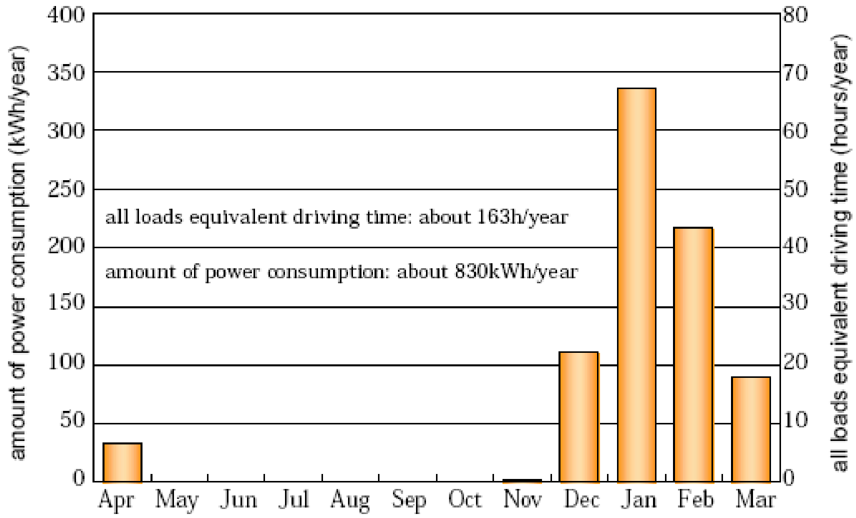
Improvement of perimeter environment by the double-layer electric heater glass
1) Thermal comfort
In order to understand the effect of the improvement of perimeter thermal environment by the double-layer electric heater glass, the thermal environments by the presence of generation of heat were compared on the western window side of night time in winter.
This window has high adiabaticity according to the midair layer and the Low-E characteristic of a metallic transparent film. Therefore, the internal surface temperature in the window shows about 18°C without heat when the outside temperature is 5°C or less. When the electric power of about 50W/m2 was turned on, the window side temperature rose about 4°C every about 40 minutes. The PMV value (see figure below) in that case rose with generation of heat on the window side, and the value became about -0.5 to -0.1. The improvement of perimeter thermal environment by this window system was able to be confirmed from these measurements.



Usage condition of heater glasses (in fiscal year 2004)

2) Energy saving
The figure below shows the usage condition of this heater glasses in fiscal year 2004. The amount of the generation of heat electric power has contributed to the improvement of the

thermal environment by about 163 hours a year at all loads equivalent driving time (by a very little about 830 kilowatt-hour/year) in the standard floor. The amount of power consumption of the glass in fiscal year 2004 was about 1% against the cool & heat production calorie in the entire building and about 6% against heat production calorie.

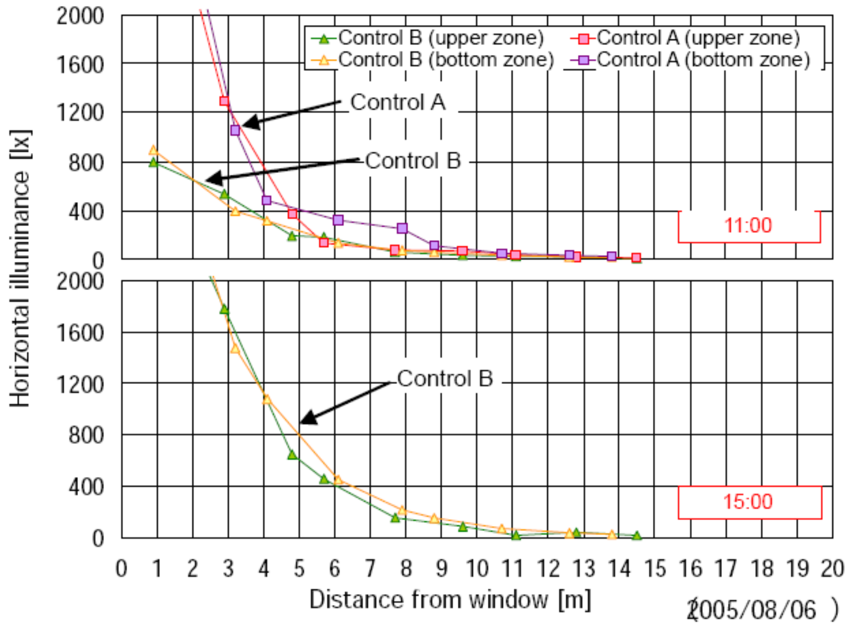


Usage condition of heater glasses (in fiscal year 2004)

High level lighting control by occupant sensor, brightness sensor, and optimal slat control of external blind

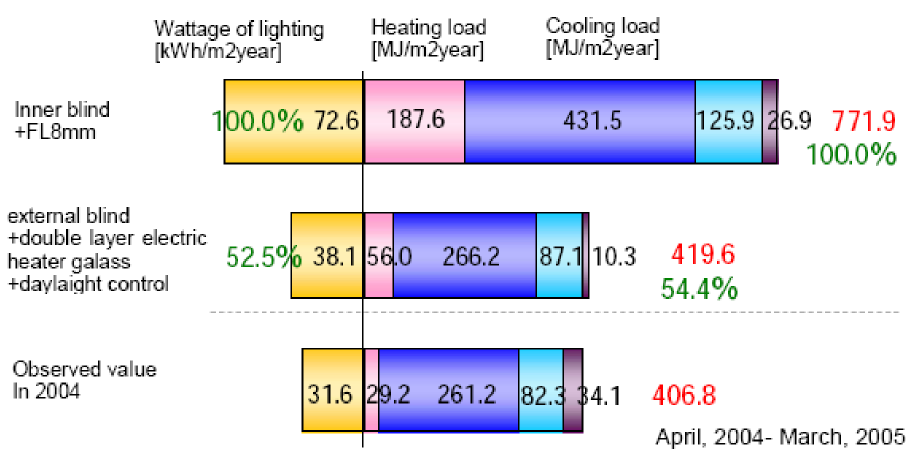
The field measurement of the horizontal illuminance distribution only of natural light with an illuminance meter was done in order to examine utilization of the daylight linked control, (August 6, 2005). The measurement performed in the height of the partition (above the floor level 1,200mm) with the lighting turned off. The figure below shows the horizontal illuminance under two control states, stored control (A control) and slat angle control (B control). A control achieves a big effect within the amount of the daylight introduction and the range of the daylight use compared with B control in the morning. In the afternoon, the daylight introduction is effectively done by automatic angle control in both control method.

The rate of the output of the electric power of the lighting (left: perimeter, right: interior) is shown in the figure below at each month of working hours on the weekday. The output rate is small in the perimeter (section 1) by appropriate illuminance adjustment, occupant sensor control, and the daylight-linked control with about 46%. This value was about 14% smaller than the interior (section 2-4), and the effect of the daylight use was shown.



Horizontal illuminance under slat controls

Energy consumption
The energy consumption of air-conditioning is greatly reduced after considering the thermal comfort. The energy consumption of lighting has been reduced by adopting the daylight use control at the same time.



Energy saving effect in western perimeter area in typical floor (110m2)

Summary of Barriers
Nikken Sekkei LTD, are researching and developing a regulating system that selects automatically whether the effect of reducing the cooling load by an external blind or the effect of reducing the electric power of the lighting by letting in light contributes to the energy conservation of the building as the future problem.

Open Questions and Needs for Future Research
It is necessary to do the examination that considers two or more of energy conservation, the environment, and productivity, etc. factors continuously aiming at the office building plan for the future.

Passiv Hauptschule Klaus-Weiler-Fraxern

Name of building: Hauptschule Klaus – Weiler – Fraxern
Type of building: School
Location: Klaus, Austria
Owner: Gemeinde Klaus Immobilienverwaltungs GmbH & Co
Start of operation: 2003
Architect: Dietrich Untertrifaller Architekten
Net conditioned area: 4522 m^2
Total energy use: Less than 15 $kWh/m^2/yr$ for heating and less that 120 $kWh/m^2/yr$ total primary energy
Cost: 8.3 million Euros

Climate, site and context
The climate is temperate, typical for Austria (Zürich area). The area around the building is open and green. The passive house school building was built as an extension to an existing school from the 1970s. The building is situated in a small town in a mountain area.

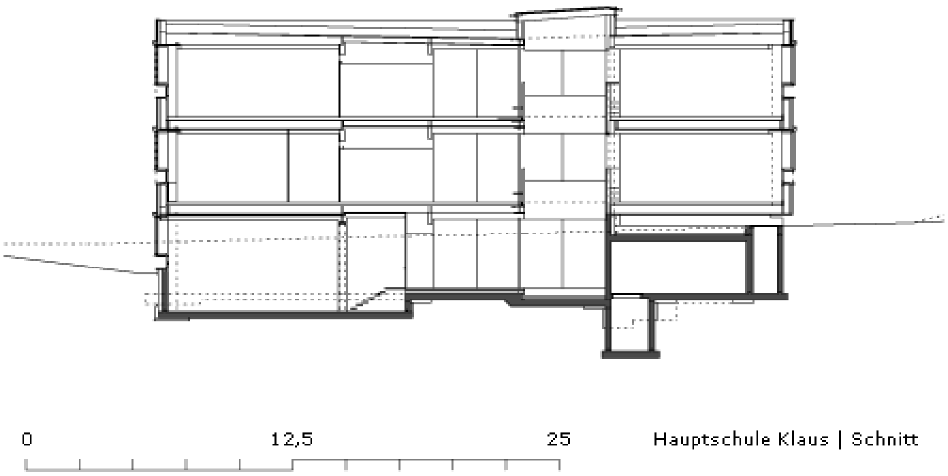
Description of the building and the integrated concepts
This school building in Austria is a good example of a passive approach to architecture, which lives up to the low energy consumption demanded by the passive house standard.
Besides being a passive school building, the building also provides architectural quality as well as comfortable indoor conditions for its users. The school is a good example of how for instance shading devices and acoustic solutions can be integrated into the overall architectural expression of the building. The building has a very comfortable atmosphere and indoor climate for a building living up to the passive house standard.

Heating and cooling system via mechanical or hybrid ventilation system, with an inlet air temperature of 18^oC, this system supplemented by earth coupling in the basement (see pictures on page 7). The heating strategy is furthermore supplemented by a biomass (wood chips) heating unit.

Ventilation system. Mechanical or hybrid ventilation system with heat recovery supplemented with earth coupling which preheats or cools the inlet air. Air-change in the classrooms: 100m^3/h pr. person. The inlet and extract openings are placed in the ceiling in the 12 classrooms. The rooms which needs a high air change are placed in the basement, close to the aggregate.

Responsive building elements applied and their integration
- Hybrid ventilation (natural ventilation supplemented with mechanical ventilation when necessary, the mechanical ventilation system uses heat-recovery)
- Earth ducts (see pictures on page 6)
- Shading (different types; external blinds in classrooms, internal screens in atrium, external cobber screen in library and assembly room)

- Materials (wooden construction, thermal mass in floor)
- Visibility of energy consumption in the circulation area (provides consciousness with the users)
- Use of daylight (every room, except the bathrooms are daylit), it does however seem that the daylight design is not sufficient, as the electric lights were on when we visited the building on a sunny day around noon in September 2005.



http://www.dietrich.untertrifaller.com/projects_d.html date: October 26th 2005

The energy consumption and the savings in $C0_2$-emmisions are visible to the users (children and teachers) in the cloak area adjacent to the atrium.

Picture taken of the inlet opening to the earth cooling.

The picture shows the ducts through which the air is let into the basement area where the air is preheated or precooled.

Picture of the façade in the classrooms. The external shading is automated, the automation can, however, be overruled by the users. Inlet openings are placed in the bottom in order to allow shading and ventilation simultaneously. The classrooms are also mechanically ventilated through inlet and outlet openings in the ceiling.

This picture shows the internal shading device in the atrium. The shading is activated when the temperature in the cavity is 40^{o}C.

Performance

Energy

The school buildings performance lives up to the passive house standard, which means that the total energy consumed for heating must not exceed 15 kWh pr. m^2 pr year and the combined consumption of primary energy must not exceed 120 kWh pr. m^2 pr year for heat, hot water and household electricity. Furthermore the passive house standard demands an evaluation of the energy consumption in the building after completion, to ensure the finished building lives up to the standard.

Usually the hard surfaces in the assembly, atrium and cloakroom would cause acoustic problems. The wooden surfaces in the building decreases problems with long reverberation times, furthermore, acoustic absorbents are integrated in the furniture and the ceiling and the floor in the basement is made in a perforated and uneven surface.

Adaptability issues
The building has so far been used as intended, there does, however, seem to be fever students in the school, than initially intended.

The architectural vision in relation to the technical solutions
There is great accordance between the vision for the project and the technical solutions, as the technical solutions in the building are well integrated into the architectural expression, which makes for a very harmonious building without large visual technical installations.

Elements in the building providing architectural quality
There are a lot of elements in the building providing architectural quality. First of all there is a great coherence between the difference rooms in the building, which comes through in the materials, colours and scale of the rooms.

Every room is day lit (except the bathrooms); even the staircases have great visual qualities caused by a symbiosis between the daylight levels, the concrete material, the shading and the décor in the stairway. The ceiling in the classrooms and the cloak area is painted black in order to hide the installations and make the acoustic ceiling (in wood) stand out as the ceiling. This however reduces the daylight level in the room, which can be considered a problem for the perception of the light in the room. This can, however, be a conscious decision made by the designers, in order to reduce glare or brightness in the room. If this is the case it would be interesting to see whether a different window design would solve this problem. A further indication of problems with the daylight perception in the classrooms is the fact, that the electric light was turned on, when we visited the building on a sunny September day around noon.

The building is very well designed with respect to the users and thus the building seems to be in great harmony with its function.

Summary of barriers
Overall this is a really good example of passive architecture. The quality of the indoor climate is good and the architectural expression is complete and focused on the functionality of the building.

Problems encountered in the project are related to the daylight perception in the classrooms. There seems to be sufficient daylight in the classrooms, but in spite of this the electric lights were turned on, on a sunny day, this is, however, difficult to be sure of, as the building was not visited on an overcast day. The ceilings in the classrooms play a large role in this problem, because of the colour of the ceiling, the installation and the acoustic plates. It would be interesting to see a simulation of the daylight conditions in the building compared to the actual daylight conditions.

Barriers in relation to the passive house standard, which are not present in this project, have to do with the air quality and the comfort conditions in the buildings, as designers or users are tempted not to ventilate as much as they should or not to heat the building as much as they should in order to save energy.

Open questions and needs for future research

In relation to this project there seems to be a need for research in the area of the relationship between the daylight solution and the energy consumption in the building, but in fields of research relating to the perception of the light in the rooms compared to the daylight levels. This will reveal that the daylight levels do not necessarily ensure a good evaluation of the daylight conditions in a room.

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http://www.passivhaus-institut.de November 9th 2005

Photo-Catalytic Material Building

Name of building: Experimental Building with a Photo-Catalyst material coated facade
Type of building: Experimental
Location: Noda-shi, Chiba, Japan
Owner: Tokyo University of Science
Start of operation: June 2004
Architect:
Engineering:
Gross area: 165 m^2 (experimental part)
Total energy use:
Cost:

Climate, site and context

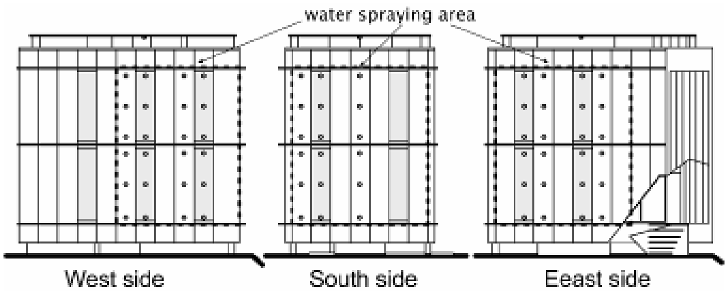
The climate is mild and moist, the highest temperature is about 32°C. The building is located in the east part of the campus of Tokyo University of Science (Chiba, Japan). There is no building at the front of the east side and a building, which has two stories, at the front of south and a flat (low height) building at the front of west side.

Description of the building and the integrated concepts

Evaporative cooling is a way to be able to make ‘coolness’ in summer in Japan. Roof spraying cooling system is an architectural method using evaporative cooling effect to reduce cooling load and improve thermal environment of a building (Ishikawa, Y., 1991, Kimura, K. et al 1993). There is possibility to use evaporative cooling effect more effectively if spraying outdoors surface of a building wall and glass pane because an area of wall and glass pane are usually larger than that of roof. There were almost no buildings that spraying building outdoor surface of wall and glass panes for cooling. One reason is that it is not easy to wet whole surface of wall and glass pane uniformly because most of the materials used for building outside facade repels water and sprayed water on it flows down like some strings.

A photo-catalyst titanium dioxide (TiO_2) material being developed in the field of material science in Japan has a specific feature that sprayed water on a surface coated with a photo-catalyst material spread as a thin layer with absorption of ultraviolet radiation. Applying this material for building wall and glass pane, it would be possible to do efficiently water spraying on outdoors surface of a building and also possible to reduce solar heat gain trough building envelope during summer season. An experimental building was constructed at Tokyo University of Science and a measurement of temperature of outdoor surface and indoor thermal environment during summer season in Japan.

The building has a steel frame structure. The exterior wall consists of 5th layers, the 1st layer was aluminum (or steel) wall panel (3 mm), the 2nd and 5th layer were air space (85 mm and 300 mm), the 3rd layer was cement board (6 mm), the 4th layer was urethane blowing (25 mm) and the 5th layer was particle board, and the U-Value of the exterior wall was 0.676 W/(m^2·K). Floor-to-ceiling height: 2.4 m.



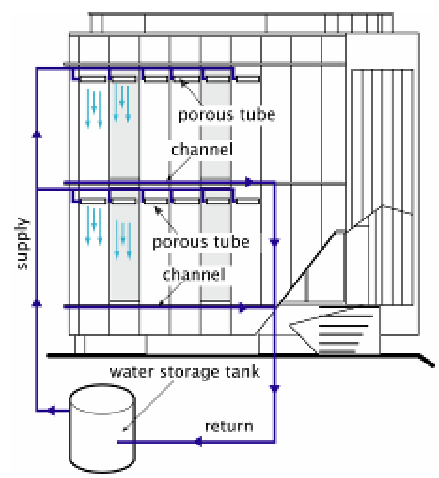
East-south view of the experimental building and west, south and east view of it. The outer surfaces of the exterior walls and glass panes were all coated with photo-catalytic material. Water was sprayed on the wall and glass surfaces at west, south and east.

Photo-catalytic material coated walls and glasses

A photo-catalyst titanium dioxide (TiO2) material is a material being developed in Japan these years. One of the specific features of the material is so called 'Photo-catalytic super hydrophilicity', it enables water on the surface to spread as a thin layer with ultraviolet radiation incident on the surface. A building wall panel and a glass pane coated with photo-catalytic material are being developed in Japan. The building wall panel was a aluminum or steal panel, the thickens was 3 mm, with fluorine paint and photo-catalytic material coated on the paint. A glass pane was clear single glazing also with photo-catalytic material coated on the exterior surface.

Water spraying system

Outdoor surface of exterior walls and glass panes were sprayed with water spraying system installed in the building. The figure to the right schematically shows water flow of the water spraying system. Water was supplied by electric pumps from water storage tanks installed at the underground floor of the building and sprayed on the outer surface of exterior walls and glass panes by a porous tube installed at the top of the wall panel and glass pane. A part of the supplied water was lost by evaporation and the rest were gathered by a channel installed at the bottom of the exterior wall panel and sent back to the water storage tanks. There were four water storage tanks, one of it was for water spraying for roof and N/A for this measurement, for east, south and west side and each tank has ca. 300 litter capacity. The water spraying system was designed to be able to spray walls and glass panes at 1st floor and that of 2nd floor individually and also able to spray east, south and west side individually.



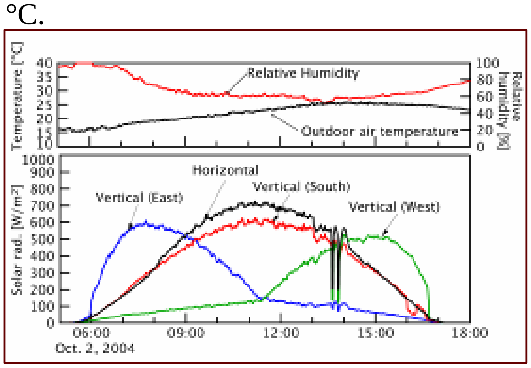
Water spraying system installed at the experimental building. The same water supply and return system shown above was also installed at the east, south and west facade.

Performance

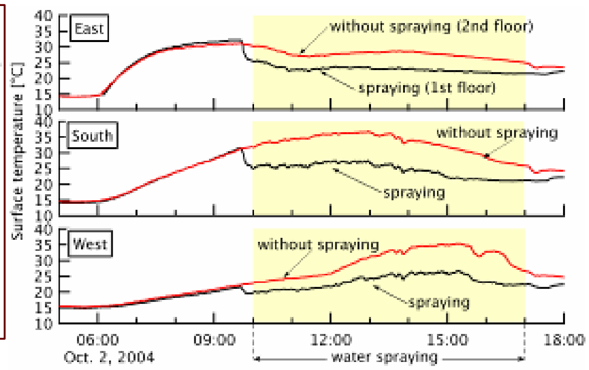
Cooling effect on outer surface of exterior walls and glass panes

To discuss evaporate cooling effect of water spraying, we show the results of a case that the outer surface of 1st floor was sprayed and that of 2nd floor was not at October 2, 2004. The figure below shows the outdoor environment of the day. It was fine weather day and almost no clouds and outdoor air temperature around noon was about 25 °C, horizontal solar radiation around noon was about 700 W/m^2.

The figure below shows outdoor surface temperature of exterior wall on the middle of the wall panel at east (top), south (middle) and west (bottom). The wall at 1st floor was water sprayed and that at 2nd floor was not. Surface temperature of the sprayed exterior wall of 1st floor at south was about 27°C around noon and it was about 10°C lower than the 2nd floor wall without water spraying. Surface temperature of sprayed exterior wall at east side and west side were also 5 to 12°C lower than the walls not sprayed. Almost the same results were shown for the other cases. This fact shows that water spraying on outdoor surface effectively removes solar heat on the surface and outdoor surface temperature goes down about 8 to 10 °C.



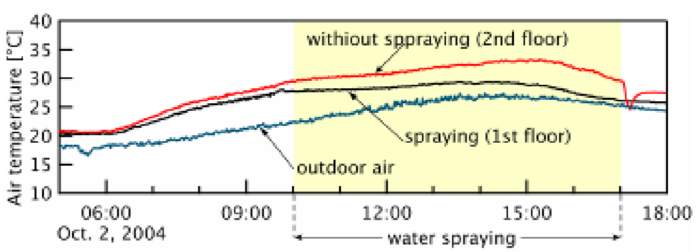
Outdoor climate of a day used for discussion



Outdoor surface temperature of exterior wall

Interior thermal environment

The figure below shows time history of air temperature in the room whose outer surface of exterior wall was sprayed, 1st floor, and that in the room without water spraying, 2nd floor. Before water spraying system operation, room air temperature was ca. 28 °C, with and without water spraying. Thereafter, the effect of water spraying on room air temperature became more noticeable. In the room with water spraying (black line), room air temperature remained relatively constant until the water spraying system turned off at 17:00. In the room without water spraying (red line), room air temperature rose and reached 34 °C at 15:00.



Room air temperature time history in the room with and without water spraying on the wall surface

Barriers

We had done a measurement to reveal cooling effect of a water spraying cooling system that spraying water on outdoor surface of exterior wall coated with photo-catalytic material during summer season in 2004 in Japan. The result of the measurement shows as follows:

1. Sprayed water on a photo-catalytic material coated wall surface flows like a thin layer on it by the specific feature of a photo-catalytic material.
2. Outdoor surface temperature of the exterior walls with water spraying was about 8 to 12 °C lower than that of walls without water spraying.

3. Air temperature of the room at the floor whose exterior wall was water sprayed was about 2 to 4 °C lower than that of the room at the floor not water sprayed.

Open Questions and Needs for Future Research

- Spraying water on the outer surface of a building effectively reduce solar heat gain from outdoor surface but contribution for reduction of cooling load and for energy conservation effect for HVAC system were very small. There, so, needs to develop a method for efficiently removing heat from room interior.
- Water spraying system consumes about 200 litters in a day for when whole of the facade were sprayed. We are discussing to use rainwater for the system.

References

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Porous-Type Residential Building

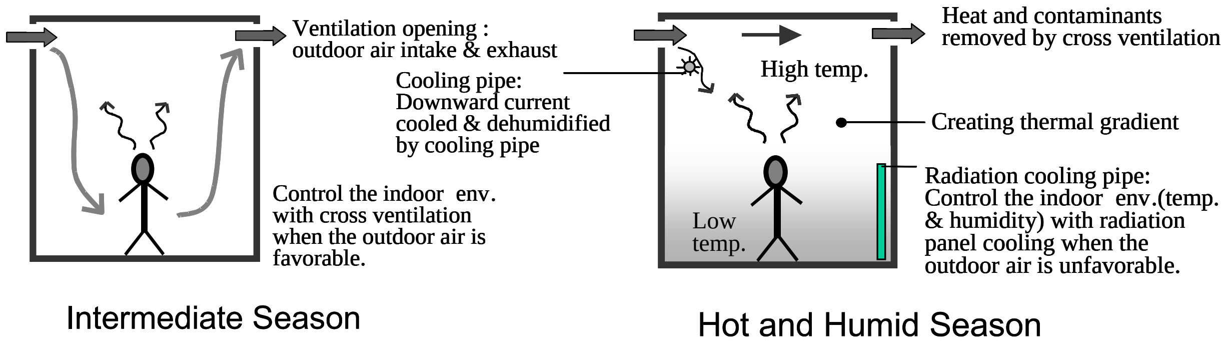
Name of building: An Experimental House in Hanoi
Type of building: Residential
Location: Hanoi, Vietnam
Owner: Hanoi University of Technology
Start of operation: March 2003
Architect:
Engineering: Shinsuke Kato, the University of Tokyo, Japan
Gross area: 500 m^2
Total energy use:
Cost:

Climate, site and context
The building is situated in the hot and humid regions of Asia, where population increases and concentrations in cities are intense. There are problems related to the heat island effect and air pollution along with deterioration in dwelling conditions.

Description of the building and the integrated concepts
Living environments in hot and humid regions of Asia, where population increases and concentrations in cities are intense, have some problems. For example the heat island effect and air pollution along with a deterioration in dwelling conditions. In order to solve these problems, it is imperative to develop a new form of city planning and new building models, and an indoor-environmental control strategy that takes the regional characteristic of Asia into consideration. It is proposed an environmental load-reducing porous-type housing model that effectively exploits the potential of the outside environment under hot and humid climate conditions using voids. And Natural ventilation, radiation panel cooling, solar shading and some devices of cooling system are proposed to form an energy-efficient indoor-environment control strategy.

Cooling and ventilation system
The hybrid cooling system aims to introduce outdoor air to the indoors by cross ventilation and thus achieve comfortable indoor thermal conditions using the power of nature as far as possible. Even though it is impossible for higher-temperature outdoor air to cool the room by cross ventilation, outdoor air can still be introduced and pass through the upper part of the room, sweeping out the heat and contaminants generated indoors. In the meantime, making use of the vertical thermal gradient, the lower part of the room can be well cooled by a radiation cooling panel. This strategy is expected to be energy-efficient and to provide people with adequate thermal comfort in hot and humid regions.

Control system
- Air Temperature Control System: If room air temperature exceeds 27°C, the air conditioner is operated.
- PMV Control System: If PMV is more than 0.5, the air conditioner is operated.



Responsive Building Elements Applied and Their Integration
This building controls the indoor environment using the power of nature by introducing voids into the building interior. Void spaces are formed by the space block design method. Facilitating natural ventilation, enabling the indoor air quality to be controlled as well as the indoor thermal environment, and providing a source of indirect light are achieved. The effects of promoting natural ventilation, introducing a double-skin roof, the PMV control system, and radiation panel cooling system on reducing the air conditioning load (in house unit C of this model building) are examined by running a thermal and airflow network simulation program

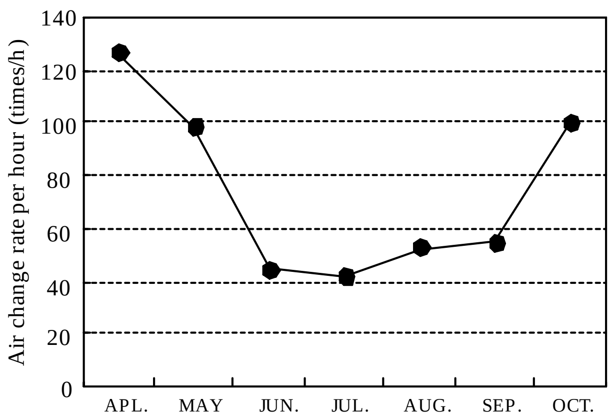
Design and construction process
The performance of a porous-type housing model was analyzed with Computational Fluid Dynamics (CFD) and network simulation in terms of building ventilation rates and energy saving effect. Various combinations of a few cubes, called BSBs (Basic Space Blocks) were studied.

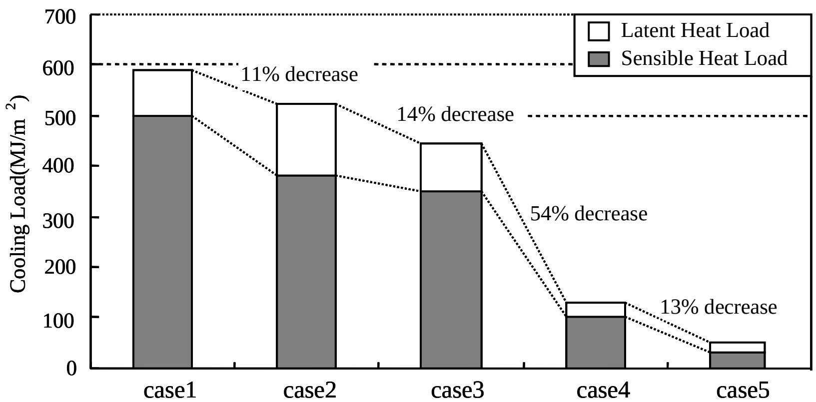
Performance
An environmental load-reducing porous-type housing model are proposed, and the performances of the porous-type housing model in terms of building ventilation rates and energy-saving effect using CFD and network simulation are analyzed. A porous-type building model (building model introducing voids) constructed based on the space block design method is proposed as a model of high-density neighborhood unit, and a solution which is appropriate for hot and humid regions of Asia where there are high population densities. The ventilation properties of the experimental house were evaluated by using ventilation efficiency indices.

This experimental house, a prototype of porous-type housing model for hot and humid climates, makes it possible to reduce the cooling load by 1/10 by introducing various building and air conditioning devices, such as natural ventilation, solar shading, a PMV control system and radiation panel cooling.

Thermal comfort, acoustics and lighting conditions were considered good. However, the operation of the natural ventilation system was difficult to control, which led to negative user reactions.

case	summary
case1	Without Natural Ventilation Openings are always closed. (Number of air change rate is 0.5/h by ventilation machine) Air Temperature Control System
case2	With Natural Ventilation Air Temperature Control System
case3	case2 + Double Skin Roof
case4	case3 + PMV Control System
case5	case4 +Radiation Cooling Panel





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RWS Terneuzen

Name of building: RWS
Type of building: Office
Location: Terneuzen, The Netherlands
Owner: the Ministry of Transport at Terneuzen
Start of operation:
Architect:
Engineering:
Net conditioned area: 1350 m^2
Total energy use: 70-80% of a standard new building
Cost:

Climate, site and context

The building site is on a small island without natural gas supply (only connected to electricity grid). The outdoor conditions are free from pollutions, and it is quite windy.

Description of the building and the integrated concepts

The building has a spherical triangular shape in which the floor levels rise like a snail-shell. In the centre of the building is an atrium with a glazed roof. The building houses 60 employees and has a gross area of about 1350 m^2. The building is constructed of sustainable materials, well insulated, utilises maximum daylight and is equipped with a minimum of building services. Passive and natural sources have been utilised as much as possible. An advanced natural ventilation system provides fresh air and controls the thermal comfort in summer. A heat pump on canal water as heat source delivers heat supply for the low temperature wall and floor heating system. DHW is produced by a solar collector system and 54 m^2 of PV cells generate part of the electricity.

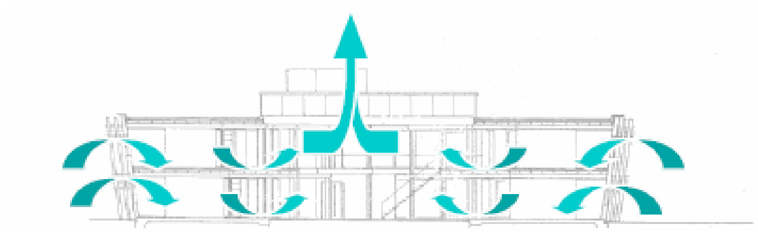
Cooling

The program of requirements described for the thermal comfort a maximum of 120 h above 25°C and a maximum of 20h above 28°C, based on a reference climate year.. The goal was to avoid a mechanical cooling system. The internal heat load is 33 W/m^2. Calculations indicated that with adequate solar shading, sufficient internal mass and a good operating ventilation system the required targets could be reached. The addition of internal mass to the wooden building was necessary to smooth peak temperatures during summer period. An additional 30 mm layer of loam plaster to the walls and the ceiling brought the solution.

The exterior walls have small windows of 30% of the facade area, with an overhang above the window. The size of the overhang is designed in relation to the orientation of the facade. Specific attention has been given to temperatures in the atrium. Direct solar incidence through the glazed roof is mainly prevented by the PV-cells, which are placed directly above the glazing (facing south). Moreover an internal solar shading screen under the roof combined with automatically controlled ventilation valves above this screen reduces solar gains. The absence of the internal screen in the atrium during the first summer period of the building proved the necessity.

Design calculations indicated that the ventilation system is important for controlling overheating during summer. Fresh air supply needs a ventilation rate of n=1.5 h^{-1}. The assumption is that above an interior temperature of 23 °C occupants open the windows. In that case the ventilation rate is estimated to increase to n=6 h^{-1}, which is necessary for effectively avoidance of overheating. Conditional night ventilation must be applied.

Ventilation



A natural ventilation system involves the risk of insufficient performance in case of no wind or no thermal stratification. Using a multi-zone ventilation model various scenarios such as winter/summer, with and without wind was examined. The results showed that, due to a good wind profile on the site at the Dutch coast, during approx. 95% of the time the ventilation would function in a proper way. The calculations also showed that normal inlet grills result in cross ventilation and an unequal distribution of airflow's throughout the building. The application of electronically controlled constant flow inlet grills improved this effect significantly. The opening of the grills is constantly adjusted as function of the air velocity through the opening. This also prevents an overshoot of airflow. During winter the grills, controlled by the BEMS, are closed after working hours. The occupants also have the possibility to manually overrule the system.

From the office rooms the airflow is led to the central atrium via overflow openings in the internal separation walls. These overflows were custom-made. Acoustical absorption in the opening provides a good sound insulation. The polluted air is extracted from the atrium by a large chimney with a 1 m diameter. The 7 m height of the chimney was needed to discharge in a suitable under-pressure area. The chimney is opened and closed by a controlled grill at the inlet side. Climate room measurements showed that the incoming air in the office rooms during wintertime could cause thermal comfort problems, due to a fall of cold air just behind the facade. The flow of cold air at floor level would cause draught complaints. Based on extensive tests the addition of a perforated shelf with 100 mm borders under the inlets was added to the design.

Daylighting

The reduction of energy consumption by artificial lighting and a good visual comfort were the driving forces to create a good daylight situation. For energy conservation during winter and avoidance of solar gains during summer the glazed area in the facades was limited to 30%. Via the atrium additional daylight is provided through the glazed roof and large windows in the separating walls. First calculations with a simple design tool showed a daylight factor of 3% on the working surfaces and 1% in the middle of the room. Detailed daylight calculations with the ray-tracing model Radiance confirmed the expected outcome.

Performance

Within the framework of the EU Thermie program extensive measurements have been carried out to the performance of the building and its services. Shortly after the housing at the end of

January 2000 commissioning measurements have been carried out (air tightness, capacity of ventilation system, infrared photography and inertia of the heating system). During the summer of 2000 and the winter of 2001 a monitoring program was conducted.

Air tightness
The air tightness of a single office room, determined by a blower door test, showed a significantly bad performance. Extra losses from infiltration have to be expected in the order of 200 - 300 % above the design starting point. In-between measures have been carried out to improve the air tightness.

Thermal insulation
Infrared photo's showed a good thermal performance of the building envelope in general. The heating system performed very well and showed a quick regeneration of set point temperatures after a 2 hour cooling down period from open window venting. Overheating during wintertime occurred due to the control of interior temperatures with air-temperature based thermostats. Users can individually control their room temperatures (+/- 3 °C) but need

Indoor Air Quality
CO_2-levels were measured on six locations (3 offices, 2 positions in the Atrium, exhaust air and outdoor air) during 4 weeks in the winter of 2001. The indoor air quality was found to be satisfying

Thermal comfort
Thermal comfort measurements have been carried out in 3 office rooms, the entrance desk and three locations in the atrium. During summer, due to the moderate conditions (Te = 10-15 °C, clouded sky) no overheating was found. Under low activity and light summer clothing, discomfort occurred in one room. In general for higher activities and warmer clothing all PMV's were found in the range of -0.5 < PMV < +0.5 such resulting in an ideal thermal comfort situation. From the middle term temperature measurements overheating was found in the south orientated office rooms during the afternoon. This occurred only in a restricted period of time while the shading device in the atrium was not installed. During winter under medium activity and average winter clothing all office room and the atrium show PMV values between -0.23 and +0.02 (except one office room PMV=-0.99). At lower activity, all office rooms exceed PMV=-0.50. These values seem quite low, asking for special attention. An explanation for these values is that most employees are outdoor workers, who spent only part of their time in the office. Due to their outdoor tasks most workers are warmly dressed and turn their thermostat on a low value. Some complaints have been about the inertia, indicating that the heating up period should start earlier on the day.

Humidity
The Relative Humidity levels showed a good performance in summer. During winter it varies from 20 to 50 %. The lower values could cause discomfort. On the long term plants in the Atrium are planned to regulate the humidity.

User inquiry
The perception of the users was interviewed by setting out an inquiry under all employees. The questions in the inquiry were similar to earlier conducted inquires in a large stock of office buildings (reference stock). During winter draught and temperature fluctuations need special attention. Additional measurements were planned to tackle the background of these complaints.

Energy consumption
The energy consumption appears to be in the order of 70 to 80 % of a reference new office building. This is a good result for a regular building concept but far from the expected savings on primary energy of about 50 %.

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Sakai Gas Building

Name of building: Sakai Gas Building
Type of building: Office
Location: Sakai City, Osaka, Japan
Owner: Sakai Gas Co.
Start of operation: October 2003
Architect: Nikken Sekkei Ltd
Engineering: Nikken Sekkei Ltd
Net conditioned area: 5000 m^2
Total energy use: 33% of a standard new building
Cost:

Climate, site and context
The climate is mild with an average yearly temperature of 16.1°C, 1672 heating degree days and 266 cooling degree days.

The Sakai gas building is located from the Osaka bay to the east in 300m, and the building faces the south of the Main Street. The wind in this region is comparatively strong and the wind direction is limited in the northeast and southwest in the middle period to which natural ventilation can be done.

Description of the building and the integrated concepts
This building, as a harmony-with-environment type office building located in an urban area, was planned with a concept of aggressive energy-saving promotion and environmental load reduction while maintaining sufficient functions and living comfort. For this building, a hybrid air-conditioning system was planned combining three (3) subsystems integrated with the architecture, namely natural ventilation as the main role player, ceiling fans generating a sensual feeling of air stream, and floor outlets supplying air from under.
To be specific, the ceiling fan installed in the rectangular section square recess provided in the centre of the ceiling type lighting fixture and the natural ventilation using the staircase as a ventilation tower are utilized to the maximum extent. In the mild interim season, air conditioning starts basically on the natural ventilation sub-system only as long as outdoor air condition is normal, and as the load increases, the ceiling fan and floor outlet air conditioning sub-systems will be superimposed, and as the load decreases, such subsystems will retire in the reverse sequence. A drastic energy conservation was realized by elongating, as long as possible, the duration of air-conditioning wherein the operation of the heat-source facilities and air-conditioners is not required. Further, in high summer, a comfortable environment with a "cool feeling" was realized with soft air stream generated by ceiling fans though the room temperature is set for 28 C.

The East Wing of the Sakai Gas Building was designed and constructed under the three previously described design concepts in order to positively save energy and reduce environmental load while pursuing economic efficiency. In practice, a cogeneration system

was installed as the base machine for efficient use of energy, with a supplemental means for effectively using natural energy sources such as wind, sunlight and rainwater.
The BEMS optimizes the building facility operations to create comfortable office room conditions at 28°C in summer while minimizing total energy consumption.

The following energy-saving systems were installed in the Sakai Gas Building:
A cogeneration system consisting of two micro gas turbines (50 kW each) generates electricity to cover part of the electrical needs of the building. Most of the high-temperature exhaust gas of the turbines is sent to absorption chillers/heaters (two sets with 100 RT each) to cover part of the energy demand. The remaining exhaust gas is supplied to heat exchangers (which transfer heat from high-temperature exhaust gas to water) to produce hot water. Part of the hot water produced in the heat exchangers is supplied to a desiccant dehumidifier (in summer) to dehumidify the outside air introduced into the building, while the remaining hot water is used as a heat source for hot water supply. In winter, except during the coldest periods, exhaust gas bypasses the absorption chillers/heaters to the heat exchangers to enhance energy-saving efficiency. Hot water produced in the heat exchangers is used for room heating.

The Sakai Gas Building introduces exterior sunlight into the building to save lighting energy, uses a natural ventilation system to save air-conditioning energy, and stores and reuses rainwater to protect water resources. Among these energy-saving measures, the natural ventilation system is described here in more detail.

In office buildings, each room generates a large amount of heat even in spring and autumn. As a consequence, each room needs to be cooled in response to the heat load even though the outside air temperature is lower than the room temperature. It was expected that taking outside air into the building would help reduce the air-conditioning load. We installed natural ventilation passages in the building to establish an open-air cooling system that controls the air intake rate automatically in response to the enthalpy inside and outside the office rooms. The open-air cooling system works as follows:

(a) Outdoor fresh air is directed into the building through air dampers installed on the north and south sides of each standard floor.
(b) The fresh air is fed into each office room through an air chamber located under the floor.
(c) After the heat load is reduced in each room, the fresh air passes through an automatic transom window located above the entrance door. The air then passes through the corridor and enters the always-open staircase.
(d) The staircase is a tower with a stairwell in the centre. The daylight opening provided in the tower's ceiling accumulates solar heat and creates a stack effect, helping the air to move upward along the stairwell. The air is then released from the building through the exhaust port on top of the tower. This system is also used for night-purge ventilation in summer, spring, and autumn.

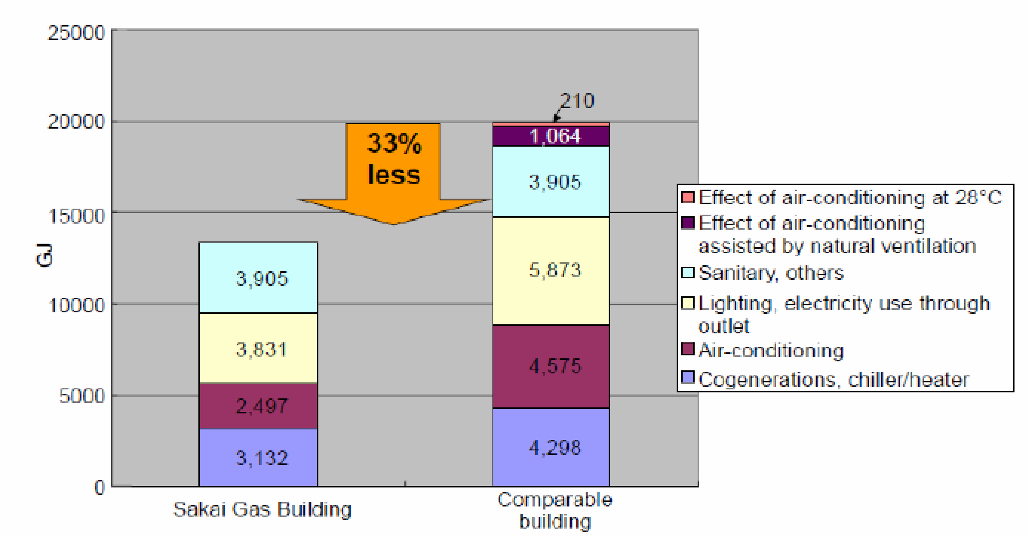
The Sakai Gas Building is equipped with an air-conditioning system designed to create comfortable office room conditions at 28°C in summer, and thereby save energy during work hours without enforcing any undue burden on employees. Human feeling of heat or chill is influenced not only by the temperature but also by heat radiation, humidity and air current, as well as by clothing and each person's individual metabolism. In the Sakai Gas Building in summer, three factors (heat radiation, humidity, and air current) are controlled to assure comfortable office room conditions while maintaining the office room temperature at 28°C, using values calculated by Predicted Mean Vote, or PMV, index. In practice, the following equipment and devices have been installed:

(a) A desiccant dehumidifier that enhances the comfortableness of the office rooms in summer by reducing humidity
(b) Floor blow-offs that blow cool air into each office room to capture the heat radiation effect from cooling the entire office automation free access floor
(c) Ceiling fans that create an indoor air current

The data on clothing and metabolism were obtained from questionnaire surveys of employees. The Sakai Gas Building introduced a BEMS to collect, process, and evaluate data on the status of facility operations, energy consumption, environmental conditions inside and outside the building, etc. and to use these data for assuring energy-efficient operation of the building, as well as to disclose the energy consumption status to tenants. In spring and autumn, the BEMS controls the open air-conditioning system and ceiling fans to assist the conventional air-conditioning system with natural ventilation.

Performance
As has been described, the Sakai Gas Building employs various advanced energy-efficient systems controlled by various pieces of innovative software. As of September 2004, these systems had been in operation for one year with many data collected and analyzed by the BEMS.

Energy
The total amount of energy consumed in the Sakai Gas Building during the first year of operation from October 2003 to September 2004 was approximately 14,000 GJ (on a primary energy basis). In order to calculate the energy savings achieved by the Sakai Gas Building, an estimation of the amount of energy that would be needed for a comparable office building that does not employ any energy-efficiency measures was carried out, and compared that amount with the results that was actually obtained. The analysis revealed that the Sakai Gas Building used 33% less energy.



PMV index in air-conditioning at 28°C and the amount of energy saved

Osaka Gas has drawn up a company-wide policy to control the temperature of all offices at 28°C from the middle of July till the middle of September. In the Sakai Gas Building, the air-conditioning system is set at 28°C during the above period. Each office room in the building is mounted with a thermometer, hygrometer, radiometer, and air velocity meter. Using the data obtained from these instruments, as well as data on clothing and metabolism obtained through questionnaire surveys, the PMV indexes were calculated. The figure below shows the relationship between the temperature and humidity inside and outside office rooms and the PMV index for one day in the middle of August. As can be seen from the figure, the PMV index gradually decreased with time after the air conditioning system and ceiling fans were turned on.

The index finally stayed in a range of +0.7 to +0.8, indicating that the room temperature was slightly higher than the level at which people would generally feel comfortable. As already discussed, these data were acquired when the office room temperature was controlled at 28°C. Another method for assuring comfortable office room conditions is to control the air-conditioning system so that it assures a preset PMV index. To make the room conditions more comfortable, employees' opinions and suggestions will be implemented into the air-conditioning system control conditions in and after the next fiscal year. During the period from the middle of July till the middle of September 2004, the savings were approximately 200 GJ.

Barriers

BEMS Review Meetings were held once a month to analyze the data obtained from the BEMS. Employee representatives, the building operation staff, design engineers, and principal contractors attended the meetings. In the course of the meetings, the facility control conditions were improved in cooperation with related personnel. Also, the various valuable data useful for further improvement of the systems, were collected. The improvement items that were performed according to the results of the meetings are listed below.

Improvements already completed:

- Night purge in response to indoor and outdoor conditions in room-heating period
- Intermittent operation of secondary pump of air-conditioning system for anti-freezing
- purposes
- Modification of wintertime starting logic of heater
- Review of outside air temperature conditions for starting up natural ventilation
- Control of cafeteria ventilation fans by inverter
- Reconsideration of cafeteria air-conditioning zones and time
- Stoppage of air-conditioning in the entrance hall on 1st floor in spring and autumn in
- response to outdoor conditions
- Change in night purge control scheme

Open questions and needs for further research

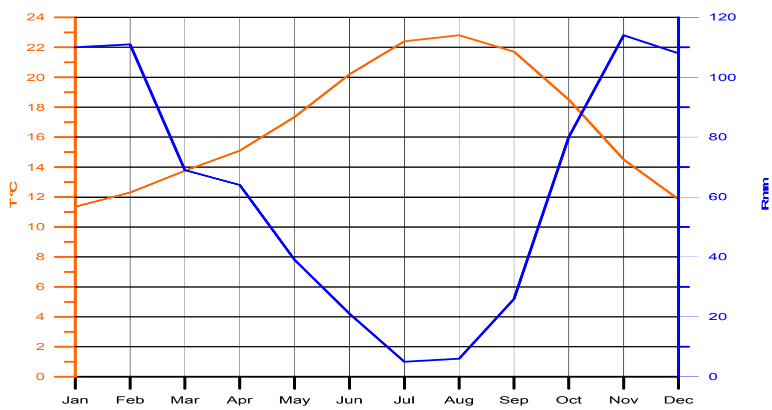
- Monitoring indoor PMV index, temperature and humidity to control heater startup in spring and autumn
- Adding intermittent operation and start/stop conditions to air-conditioning system controller for spring and autumn
- Reviewing heat exchangers and desiccant dehumidifier operating conditions to further enhance efficiency of waste heat recovery.

SOLAR XXI Building

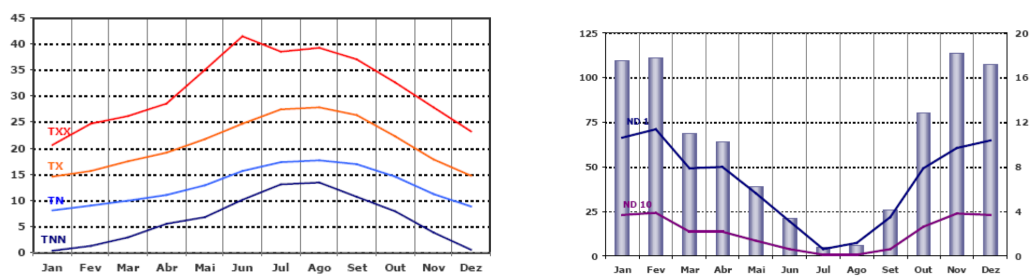
Name of building: SOLAR XXI
Type of building: Office and laboratories
Location: Lisbon, Portugal
Owner: http://www.ineti.pt/
Start of operation: 2006
Architect: Pedro Cabrito & Isabel Diniz
Engineering: INETI
Net conditioned area: 1500 m^2
Total energy use: 14 $kWh/m^2/yr$ heating, 32 $kWh/m^2/yr$ heating 7 $kWh/m^2/yr$, cooling: 25 $kWh/m^2/yr$
Cost: 800 EUR/m²

Climate, site and context

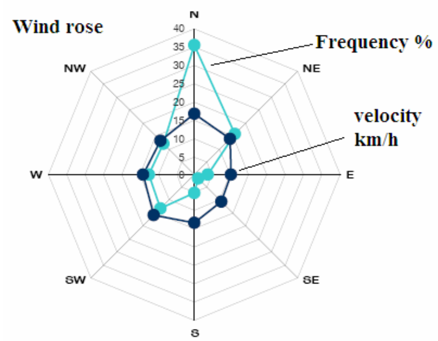
Lisbon is situated at 38º43´N – 9º9´W, its altitude rising from sea level to approx. 115m. It has a mild and temperate climate with a range of 900-1500 ºC day and an irradiation of 500 $kWh/m^2/yr$ for the heating season, and 2800 hrs/yr of sunshine.

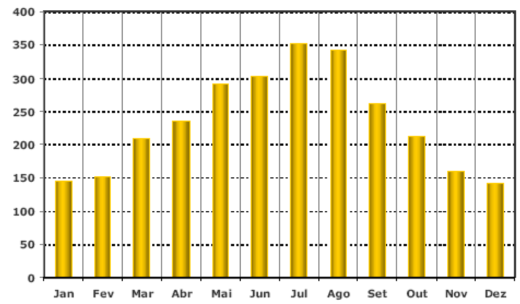


Lisbon mean temperature and rainfall.



Lisbon absolute max. (Txx) and min. (Tnn); mean max. (Tx) and min. (Tn) temperatures; rainfall (mm) and number of days above 1mm (nd1) and above 10 mm (nd10).





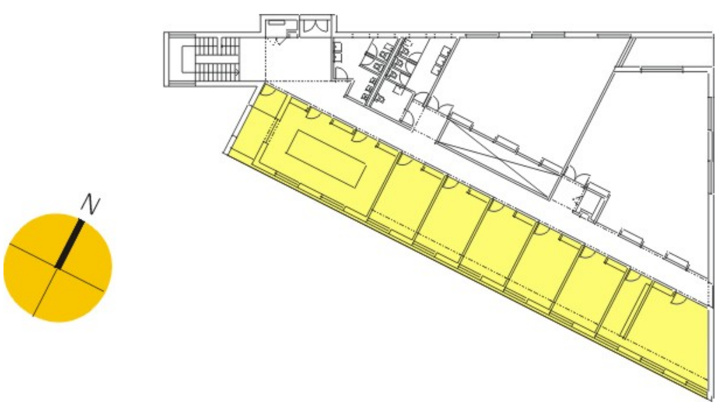
Lisbon wind rose and sunshine hours bar chart.

The building belongs to an R&D institution *campus* sited on quiet environment with low density of construction, low levels of noise and pollution. The buildings next to SOLAR XXI are of the same height.

Description of the building and the integrated building concepts

The building is the new headquarters of the Solar Energy and Building Thermal Unit of INETI's Department for Renewable Energies and was designed as an example of integration of renewable energies in a services building through the use of active and passive solar energy, natural ventilation and daylighting, together with responsive technologies. It also aims to be an example of a low energy efficient building. Among the solar active systems is a set of vertical PV panels (100 m^2) allowing to produce power for the building's use (12 kWp) and to recover heat on its back within the gap formed between the panels and opaque walls. SOLAR XXI has a mix of offices and laboratories connected to its activity (PV, Biomass). The foreseen number of occupants is 20-25 persons, and main operation time is business hours.



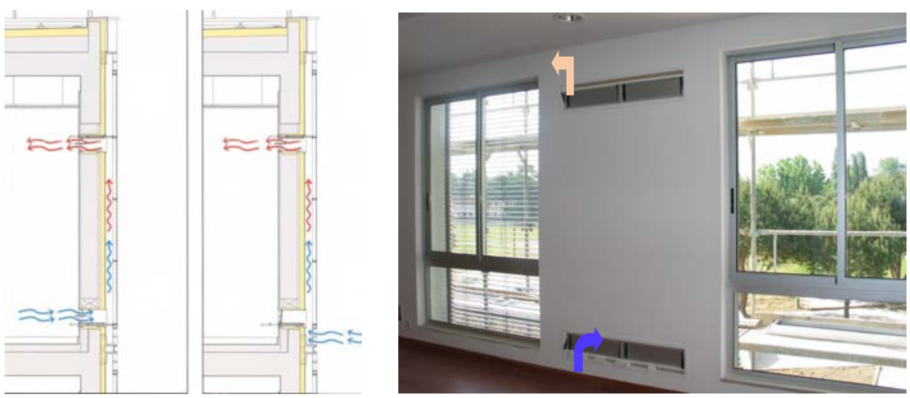


South, East and North façades and floor plan

Heating system
The majority of the glazed surfaces is placed on the South façade to allow a maximum solar caption in the heating season. For long periods with no solar radiation the building uses a set of hot water convectors supplied by a boiler supported by a set of CPC type solar collectors, and hot water tank, sited on the roof.

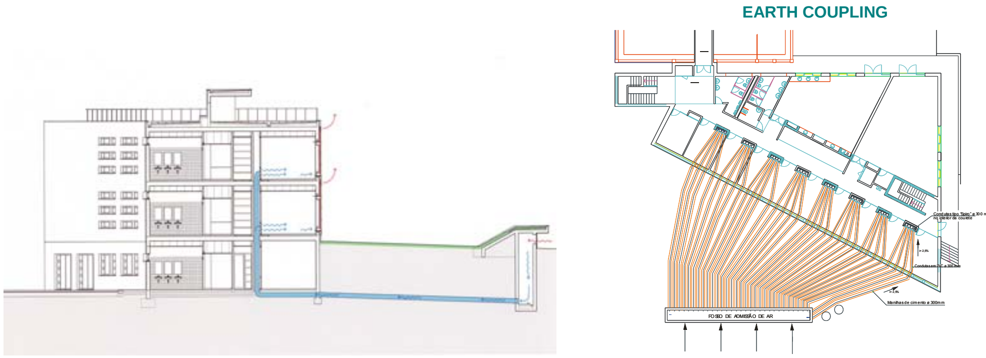
Roof window for ventilation and daylight and set of CPC solar collectors

Also in the South façade and between the windows the building is equipped with a set of vertical PV panels forming a gap between the panels and the opaque part of the external wall. Within this gap (a translucent double skin façade - DSF) the heat is used, in the heating season, to introduce hot air to the rooms via two openings top and bottom placed.
The user can chose to open both the ventilation openings recirculating and heating indoor air (mixed with outdoor air) or just allowing heated outdoor air in the room.



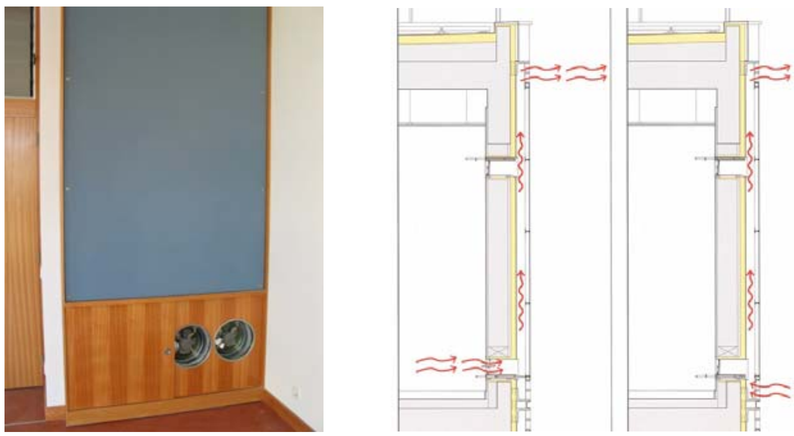
Heat recovery from the DSF (back of the PV panels) and room ventilation openings

Cooling system:
Cooling is be provided by natural means, where shading blades play an essential role preventing direct solar gains, and indoor heat removal is obtained by an hybrid ventilation system based on ground coupling. A set of 32 concrete pipes with 300 mm diameter were buried 4.6 m deep connect the supply well (15 m from the South façade) to each room on the two upper floors.



Earth coupling system and cooled air supply.

A pair of pipes is available in each room and the users can chose among one or two cool air inlets, the air being supplied by natural means or by small fans. The DSF contributes for the cooling process removing heated indoor air using the gap stack effect.


Cooled air outlets in each room and heated air removal using DSF stack effect

Ventilation system
Natural ventilation plays an essential role in this building. In one hand managing heat distribution from southern rooms to the northern ones in the heating season. In a second hand for the night free cooling strategy. As stated before room cooling during business hours uses a hybrid system operated by the users.
Ventilation openings (roof window, stair wells and room doors) allow vertical and horizontal cross flows.

Control system
Manual

Responsive building elements applied and their integration
- Advanced Integrated Façades – DSF with a translucent external pane made of PV cells and a opaque inner pane provides with user operable ventilation openings. It occupies half of the South façade area between the double glazed windows.
- Thermal mass activation – Night free cooling
- Earth coupling – A set of buried ventilation pipes 15m long and 4.6m deep connects a supply well to each office. Ventilation may be natural or mechanically assisted.

- PV panels – An area of 100 m^2 on the South façade delivers energy for direct use in the building. The estimated production is of 12 MWh/yr corresponding up to 70% of power consumption (lighting and informatics).

Performance

Not yet available.

References

"A Passive Solar Office Building in Portugal", *Helder Gonçalve, Pedro Cabrito,* PLEA2006 - The 23rd Conference on Passive and Low Energy Architecture. Geneva, Switzerland, 6-8 September 2006

"Um Edifício Solar Passivo com Integração de um Sistema Fotovoltaico na Fachada." Helder Gonçalves, ENCAC - ELAC 2005, Maceió- Brasil 5 a 7 de Outubro de 2005

"**Edifício Solar XXI- Um Edifício Energéticamente Eficiente em Portugal"** Helder Gonçalves, Pedro Cabrito, XII Congresso Ibérico de Energia Solar – Vigo, Setembro de 2004

W E I Z

Name of building: W E I Z
Type of building: Office
Location: Stuttgart, Germany
Owner: Weizer Energie Innovation Zentrum GmbH
Start of operation: 2003
Architect:
Engineering: AEE - Institute for Sustainable Technologies
Net conditioned area: 1561 m^2
Total energy use: 80 kWh/m^2
Cost:

Climate, site and context

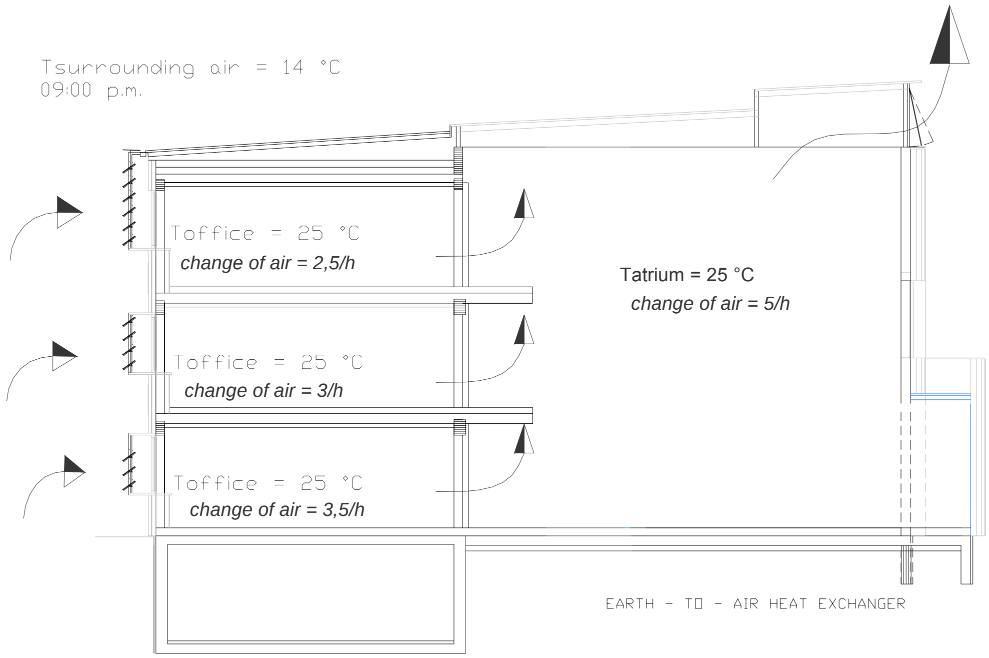
The building is located in the city of Weiz, which has a temperate climate with 4767 heating degree days and 104 cooling degree days (measured 2003).

Description of the building and the integrated concepts

The Energy and Innovation Centre Weiz (W.E.I.Z.) is a future oriented business centre. It offers office spaces to innovative companies with focus on energy and provides management consulting to SMEs in the region and abroad. In addition, conference, media and meeting rooms with full technical equipment are offered. The innovative focus of the building is supported by its architecture and energy concept. The goal of the Weizer Energie- und Innovationszentrums (Weiz Energy and Innovation Centre) building project was to erect an office building in the passive house standard for around 100 employees. The three story office building consists of an atrium and offices arranged in a U and L shape around the atrium. This arrangement allows a high flexibility in size and depth of each individual office and light entering from both sides of the building. The main hall is the communication area for the whole building and encompasses the space for infrastructure such as staircases, corridors and elevator, and the general spaces such as conference, media, meeting rooms, and tea kitchens

Heating, cooling, ventilation and daylighting

An overall air rate of 3,200 m^3/h was estimated for an occupancy of around 100 people with a fresh air flow rate of 30 m^3/h and person, which is required for hygienic reasons. The heating and cooling distribution is carried out with the means of the ventilation system. There are no water carried energy distribution nets. Additional heat during the heating season is supplied by the local district heating net. Cooling during the summer season is carried out via an underground heat exchanger.



Cross section of the office building with principle diagram, showing the heating and ventilating system.

Since the building was constructed in a compact way, it was possible to build with a passive standards and 15-20% of the costs could be saved. Coefficient of heat transmission for the construction parts are listed in the following:

outer walls	U = 0.185 W/m²K	foundation	U = 0.19 W/m²K
ceiling	U = 0.124 W/m²K	glazed areas atrium	U = 0.7 W/m²K U = 1.1 W/m²K

The low U-value for the glazed areas is necessary in a passive house for the energy requirements as well as for the comfort. It is important to have good quality of the glazed areas since a heating system based on outside air cannot counter-act a drop of the air temperature in the area over the windows, which is the operation mode for a conventional heating system with radiators under the windows. The size and compactness of the W.E.I.Z. building, which results in a very good surface-volume relationship were the prerequisite for certain compromises in the outer wall of the building.

Skylight window hinges in the office partition walls to the atrium allow indirect lighting via the large-scale reflection walls, which helped to realise a regular situation with regard to daylight in the room depth of the offices. The internal loads are reduced with the aid of the lighting regulation, which depend on the daylight at the working places. Apart from its elementary functions, the atrium interacts with the building as a whole in terms of energy and ventilating techniques and is thus an integral part of the overall concept. It was possible to reduce the costs for the ventilating since the atrium itself is used for the return air from the offices.

Already at the beginning of the planning phase was the declared goal to apply conventional cost-intensive air conditioning in the summer. The undesirable increases in temperature as a result of passive solar gains were reduced as a result of the variable elements for shading mounted outside on the office windows. The approximately 40% transparent parts of the outside building-cover of the office building were kept to a moderate scale for administrative building conditions. Further were lamellae integrated in the building roof, which are regulated throughout the day, following and blocking the radiation of the sun. Construction parts with higher thermal storage abilities were used in the atrium than what was originally planned. This because the first results from the simulation indicated the need for more thermal masses. The high outside wall as well as the inner functional rooms were given a reinforced concrete structure.

The cooling is realised via night ventilation and the earth to air underground heat exchanger, which was placed below the foundations of the cellar. The underground heat exchanger is also applied for preheating the incoming air in winter. This concept allows an avoidance of ice on the side of the outgoing air of the ventilation heat recovery (recovery rate of 80%, reheating from a biomass local heating network). The incoming air is also preheated with heat recovery from the exhaust air during winter operation and a connection to the district heating net work serves as a last step to heat the ventilation air in a water to air heat exchanger. The local district heating grid is operated on biomass.

The diagonal ventilation can be generated with outside air temperature levels by opening the skylights and the excess current openings to the atrium in the early evening and during the night. The engine for this is the buoyancy of the warm masses of air in the atrium. A build-up of hot inside temperatures during longer hot periods can be damped in this way and the temperature can be kept at an acceptable level. Night cooling with the help of the atrium doubles the exchange of outside air for the offices compared to only window ventilation without the need for additional required power for the ventilating fans.

The storage mass of the building is the stabilising element of the room temperature. The higher the storage mass, the more even are the inside temperatures. The function of the storage mass is based on that the heat, which is gained during one day is stored and then released during the night. This creates a balance in the room temperature between day and night. If the storage mass is encircled by cold air during the night, the cooling effect can be realised during the following day. The cooling period at night should be at least 5 hours to reach enough capacity to remove the gained heat.

The pre-requisite for an effective thermal day-night balance is suitable material with a high thermal conductivity and good heat storage capacity (concrete, heavy-duty walls etc.) of the construction parts foreseen for thermal storage. The upper 10 cm in the room are decisive for this effect.

Design and construction process

This project is a best practice project since it was possible to build this office building with passive building energy standards and was the first office building in Austria to be built with this standard. The planning integration process was applied in the very beginning of the project and there was an early and effective team work between active parties (builder, planners etc.). It was further possible to optimize the construction in relation to the building site and thereby reach optimal heating and cooling loads. The energy concept was simulated at an early stage with the planning program TRNSYS. What also makes this project a good example is that the energy, which is needed for heating is covered by environmental energy (heat stored in the ground and biomass from the local district heating supply).

Performance

Heating

The heating consumption was measured for 2000 and 2001, divided in the office facilities on the ground, first and second floor and the conference room. The underground heat exchanger supplied 12,300 kWh heat during the year 2000, leaving the district heating demand to 19,100 kWh. The total heat demand for 2000 was 31,400 kWh and 43,200 kWh for 2001.

Cooling

The monitoring results from the period 2000 to 2001 show a cooling yield from the underground heat exchanger of 18 kW. This yield in combination with the utilisation of the night cooling (night flush with cold outdoor air) cover the entire cooling demand for the summer of 2000. Calculations of the office building ("massive" construction mode and specific cooling load of 50 W/m²) show that the cooling energy demand can be reduced by up to 60% with a 3.5 times night ventilation air change. Further, the window ventilation show a reduction of more than 50%.

Electricity

The electricity consumption during year 2000 was 88,500 kWh (=57 kWh/m² office area), the electricity for the ventilation systems excluded (which was 6,000 kWh/a).

Lessons learnt

Lessons learnt from this project regard the planning of activities and the occupancy of the building. The rate of occupancy was planed much lower and one company with their offices in this building have much different working hours as what was calculated with. This has lead to unexpected high internal loads. Further was a layout temperature of 20°C used in the calculations and 23°C is applied in reality. The norm DIN 1946 is applied for definition of the comfort criteria. But since the tolerance temperature level tend to increase with the outdoor temperature, can this only be used limited as an estimation standard.

References

Herkel S. (2003), "Thermische Komfort im Sommer in Bürogebäuden mit passiver Kühlung", Fraunhofer Institute for Solar Energy Systems, Freiburg, Germany.

ZUB

Name of building: The Centre for Sustainable Building (ZUB)
Type of building: Office
Location: Kassel, Germany
Owner: Zentrum für Umweltbewusstes Bauen e.V.,
Start of operation: Spring 2001
Architect: Arbeitsgemeinschaft Jourdan & Müller – PAS, Seddig Architekten
Engineering: Ingenieurbüro Prof. Hauser
Net conditioned area: 1347 m^2
Total energy use: 32 $kWh/m^2/yr$ (measured), 20% of standard
Cost: 1766 EUR/m^2

Climate, site and context

The climate is temperate (middle Europe), with 3317 heating degree days and the mean annual horizontal radiation is 1027 kWh/m^2. The building is situated in an urban area, surrounded by buildings of approximately same height.

Description of the building and the integrated concepts

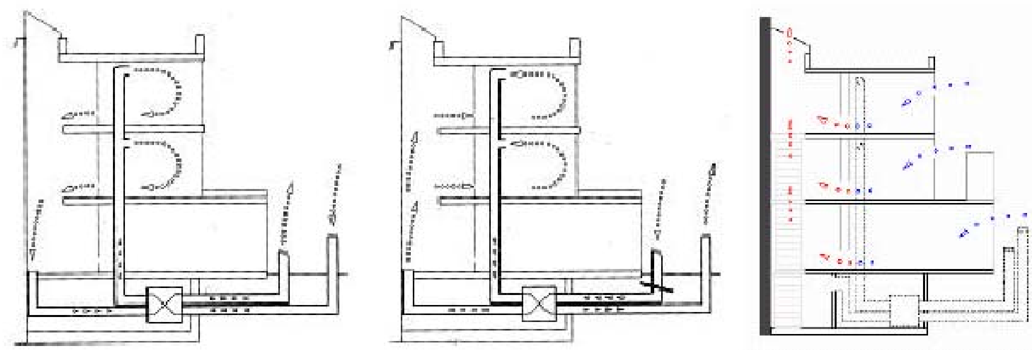
The new building of the ZUB closes a gap between an ensemble of old houses. An atrium, used as a light gap, which contains the entrance zone and the staircases, joins the old brick building to the modern concrete construction. The ZUB office building consists mainly of three different parts: one part for exhibitions and events, one part for offices and an experimental part for different kinds of research.

Heating / Cooling system

All office rooms and the lecture hall of the building are equipped with a surface heating and cooling system, with thermally activated building constructions. On all floor slabs, conventional floor heating has been installed in addition to activated ceilings. This has been done for research purposes. Each office is equipped with separately regulated heating/cooling circuit in the ceiling and in the floor slab. Demand controlled heating and cooling is done via a regulation of the mass flow of the heat carrier (water).

Ventilation system

A combination of natural and mechanical ventilation is used. In summer conditions, the offices are ventilated by natural means. During wintertime, windows and the balanced mechanical ventilation with heat recovery is used for low outdoor temperatures. For mechanical ventilation, one central air handling unit with heat recovery (two cross flow heat exchangers) is used. Maximum design airflow is 4000 m^3/h. In the normal operation mode, fresh air is supplied directly to the office rooms and exhaust air is extracted from the atrium, and then transferred to the heat recovery unit. For research purposes, the fresh air can be supplied to the central atrium and extracted from the offices. When the lecture hall is fully occupied, the mechanical ventilation system is employed only for the air-change of this room, while for the offices natural means are used. To allow natural ventilation in offices, fresh air is supplied through the open windows and the exhaust air leaves the rooms through particular air outlets, which are set in the clay wall near the doors. In this way the exhaust air is sent into the atrium and leaves the building through openings at its top, thus avoiding the installation of fan systems. The ventilation system works from 6 a.m. to 8 p.m., and at night and during the weekend it is turned off.



Operation modes of the ventilation system (Hausladen 2000)

Control system

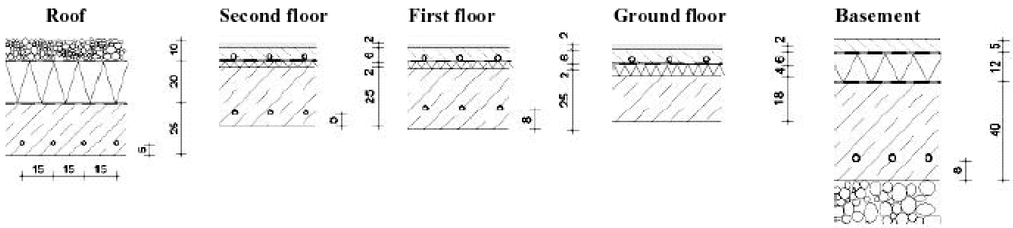
- *Heating:* The indoor temperature is set at the lower value of 19°C and the upper value of 21°C for the offices and approximately at 18° C in the experimental room. To achieve these conditions the inlet temperature of the radiant systems depends on the outside temperature, thus avoiding the heating system working continuously at the highest temperature. Then, after 8 p.m., the indoor air temperature is set at 19°C.

- *Cooling:* The temperature of the rooms is set at an upper value of 26°C and the water mass flow rate is cooled by the ground heat exchanger. In this way, the inlet temperature of the water depends on the ground temperature. Furthermore, the building structure can be cooled during the night by a flow of external air.

- *Ventilation:* The ventilation system is regulated by the actual demand and air quality. The sensors measuring the content of volatile organic compounds (VOC) in the air are installed in the offices. Increasing levels of VOCs mean increasing speed of the air supply fans (increased airflow). The office with the worst air quality guides the ventilation system. The CO_2 sensor is installed in the lecture hall. In case of CO_2 concentration above 600 ppm the lecture room is ventilated in parallel to the offices. If the concentration rises above 1000 ppm the system ventilates the lecture hall only and the offices have to be ventilated by windows.

Responsive building elements applied and their integration

In the ZUB building, radiant systems for heating and cooling have been installed. They include both activated thermal slabs and conventional floor heating. The pipes are embedded in the upper concrete layer on the floor and in the centre of the slab. Pipes are made in polyethylene with a diameter of 20 mm and a distance of 150 mm, except in the basement where the diameter is 25 mm. The distribution has a coil shape and an individual circuit for each room; in this way, each room has its own control system.



Position of the different pipe layers in the concrete slabs of the ZUB building (De Carli 2003)


Installation of the pipes on the reinforcement grid of the future concrete floor slab (Hauser 2002)

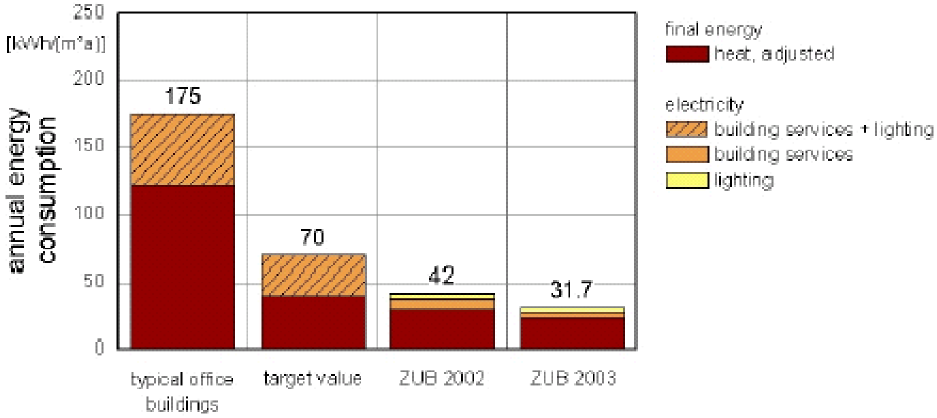
Each circuit of the floor radiant system and the active thermal slab system is supplied by about 600 kg/h water mass flow rate, thus allowing to keep the difference between supply and return temperature lower than 4-5 °C. In the heating mode, the radiant system is connected with the district heating supply system. It is divided in two different circuits to supply the traditional floor system and the system of activated thermal slabs.

As for the cooling system, the hydronic pipe circuits employed are the same as the heating system, but, for investigating the possible use of renewable energy sources, an additional circuit of pipes in the slab construction of the basement has been installed to exploit ground coolness to cool the water. Thus, the ground heat exchanger replaces the installation of a mechanical cooling machine. Measurements have shown that the ground heat exchanger works with a COP of 23, in comparison to a normal mechanical cold production with COP of about 3.5.

Performance

Energy

Measured annual energy consumption of the ZUB building is depicted in the figure below. Calculated energy demand according to the EnEV (the new energy code) is 21.3 kWh/m^{2}a. Implementing the demand controlled ventilation strategy decreased electrical power consumption for the ventilation by about 50%. The use of natural lighting strategies in combination with demand controlled artificial lighting ensures very low electricity consumption of the ZUB building. The annual energy consumption for lighting in the ZUB building is 60 % lower than the Swiss guideline SIA 380.



Specific annual energy consumption for heating, building services and lighting (Hauser 2005)

Economics

Building costs (Hauser 2005)

Costs	**Construction:**	**Services and equipment:**	**Building cost (total):**
Per net floor area:	1269 EUR/m^2	497 EUR/m^2	1766 EUR/m^2

Indoor environment and thermal comfort
The integrated building concept of the building provides comfortable thermal environment for its occupants during the whole year. Indoor climate measurements were conducted in 2002 and 2003. In the heating mode, indoor temperatures below 21°C appear only in the case when the heat supply is switched off. In the cooling mode, during a very hot summer in 2003, the operative temperature exceeded 26°C during 125 hours, which means 4% of the work time.

Summary of barriers/lessons learned
The cooling power of the ground heat exchanger depends strongly on the temperature and water flows (moisture) of the ground. For very dry ground, the cooling potential could be worn out after a few weeks as the ground temperature rises and only a very limited cooling power can be used. In case of flowing ground water, it is possible to use greater cooling power and rooms can be cooled more intensively.

Simulations showed that a constant cooling power of about 8 W/m^2 is reasonable for the ZUB. Maximum measured cooling power was 40 W/m^2 and the maximum heating power 80 W/m^2. The overheating hours, hours with room temperature above 26°C, could be diminished by using this system up to only 125 h or 4 % of the occupancy time in a representative office room during the very hot summer in 2003.

Since almost all room surfaces are built in a heavy construction, the effect of the clay wall has been found to be of minor importance.

The lighting level observed by the occupants is also dependent on the color and surface of the internal room surfaces. Dark surfaces absorb more light than bright ones. The light floor covering and the white stone walls in the ZUB reflect the light, whereas the darker concrete ceilings are not as good as a reflector.

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Related website: www.bpy.uni-kassel.de/solaropt

Ttechnical barriers and opportunities for integration

This chapter summarizes the barriers and opportunities for implementation of integrated building concepts that have been reported in relation to the building examples described above. The issues reported may be categorized into the following main groups:

1) Process related issues:
- Lack of integrated design
- Lack of holistic design (sub-optimizing)
- Difficult liability issues
- No well established contracts
- Lack of appropriate performance prediction tools
- Lack of knowledge/guidelines
- Difficulties in communication between architects and engineers
- Difficulties in planning for future occupancy changes

2) Technology related issues:
- Lack of standard components
- Lack of performance measurements
- Lack of experience, lack of demonstrated technologies and concepts for different climates
- Concerns about risks and failures
- Lack of integration between different technologies and building components
- Lack of appropriate/optimised controls

3) Costs related issues
- The case studies demonstrates that the investment costs of Integrated Building Concepts may be both lower and higher than standard buildings.
- Running costs are usually lower than for standard buildings
- Extra time and resources needed in early design phase

4) User related issues
- Lack of user satisfaction surveys

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