Promotion of Eco-building Technologies, small Polygeneration and Renewable Heating & Cooling Technologies for Buildings

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Technology Profile
Glazed Double Skin Façade

Long version

This profile is based on the knowledge on Glazed Double Skin Façades (GDSF) at Graz University of Technology/IWT as well as on the provisional results of the still ongoing EIE-project BESTFAÇADE with the following authors:

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Technical description

The Glazed Double Skin Façade (GDSF) is a system consisting of two single or double glazed skins placed in such a way that air flows in the intermediate cavity. The cavity's width may range from 10 to about 200 cm and be ventilated natural, fan supported or mechanical. Apart from the type of the ventilation inside the cavity, the origin and destination of the air can differ depending mostly on climatic conditions, the type of building, the location, the occupational hours of the building and the HVAC strategy. For protection against wind, rain etc. solar shading devices are placed inside the cavity. The air space between the layers of glass acts as insulation against temperature extremes, winds, and sound [Poirazis 2004].

Already described in 1849 by Jean-Baptiste Jobard the first appearance of a Glazed Double Skin Façade in Europe seems to be the Steiff Factory in Giengen / Brenz near Ulm, Germany in 1903 - a three storey structure with two additional buildings built in 1904 and 1908. All of them are still in use. In 1929 Le Corbusier postulated: "la respiration exacte - an exactly regulated mechanical ventilation system…" - and "le mur neutralisant - neutralising walls are made of glass or stone or both of them. They consist of two membranes which form a gap of a few centimetres. Through this gap which is enveloping the whole building in Moscow hot and in Dakar cold air is conducted…." [Le Corbusier, 1964].

Little or no progress was made in double skin glass construction until the late 70's and early 80's of the past century when this type of façades started gaining momentum. In the 90's the increasing environmental concerns started influencing architectural design regarding "green buildings" a good image for corporate architecture. Additionally arguments like "depth" and kind of "crystal image" of the façade have been – and are still – important [Poirazis 2004].

GDSF can provide a thermal buffer zone, solar preheating of ventilation air, energy saving, sound, wind and pollutant protection with open windows, night cooling, protection of shading devices, space for energy gaining devices, such as photovoltaic (PV) cells or solar thermal collectors.

Potential problems caused by GDSF may be overheating or high cooling loads, condensation inside the cavity, sound and fire / smoke transmission from room to room especially in multi storey types, higher investment and maintenance costs compared to single glazed façades and the fact that the intermediate space of the GDSF in most countries is calculated into the total floor area of the building thus reducing the rentable space.

More recently the improved properties and its possibilities to be incorporated in a complex construction increased the use of this type of façade which becomes a part of the buildings technology. A growing field of application is retrofitting or protection of existing façades by means of GDSF.

Qualitative estimation of costs, advantages / disadvantages compared to Single Glazed Façades

Investment Costs

Due to the wide range of technical possibilities and economic boundary conditions also a wide range of costs is reported. A common mistake made today is to base the cost estimate for new GDSF on the prizes of projects already built. Because of the rather fast development in the façade sector, the costs of those buildings may not be relevant for new ones any more. For a first estimate of costs, some results reported from the BESTFAÇADE project are given in the following.

For the most common used GDSF in Belgium (mechanical ventilated façade with juxtaposed modules), total costs range from 500 to 700 €/m² including solar shading. The double skin façade applied at the VERU test facility, Germany amounted to 1255 €/m² (total façade area only 40 m²). Estimated investment costs compared to SGF for a new WSP office building in Malmö, Sweden (2007) are:

► Single skin façade without exterior solar shading = 370 €/m²

► Single skin façade with fixed exterior solar shading (gangway not included, simple control of solar shading included) = 580 €/m²

► Single skin façade including daylight redirection (catwalk not included, simple control of solar shading included) = 680 – 790 €/m²

► Double skin façade incl. Venetian blinds like Kista Science Tower = 920 – 1000 €/m²

► DSF box window type (cavity 0.2 m), Venetian blinds = 560 €/m²

► DSF box window type (cavity 0.2 m), Venetian blinds, daylight redirection = 610 €/m²

The assessments shown above indicate that in some cases shading devices can play a decisive role: in GDSF they are installed in the cavity between the two skins protected from weather influences and therefore can be constructed less costly and additionally allowing utilisation in all weather conditions.

Other sources of investment costs of GDSF compared to (SGF) give the following figures, not value-added in €/m²: Blum, 1998: 750 – 1000 (650), Kornadt, 1999: 850 - 950 (520), Schuler, 2003: 900 (620), Daniels, 1997: 750 – 1500 (--), Wolke: 800 (--), Oesterle, 2001: 750 – 1000 €/m².

Following additional costs of the second skin are reported: Blum: 120 – 380, Kornadt: 300 – 460, Oesterle: 175 – 750, Schuler: 300 €/m².

Additional costs for the exterior skin of the Centre of Justice, Leoben, Austria (2004, louver type, incl. automated wooden blinds) = EUR 610 €/m².

Cost-effective Design Principles

Double skin façades can be constructed economically if the following basic principles are observed [Oesterle et. al. 2001]:

► Use of mass-produced or largely mass-produced prefabricated elements

► Avoidance of opening elements operated by electric motors

► The outer skin should contain non-closable openings

► The façade intermediate space should not be too deep (appr. 30-50 cm)

► The floor of the intermediate space should not be accessible, or only for cleaning purposes

► A minimum number of constructional types should be used

► In larger buildings prefabricated construction should be specified (> significantly shorter assembly times, higher quality and reduction of costs)

With these factors in mind and employing a competent planning, it should be possible to achieve specific costs of 600 – 750 €/m².

Life Cycle Assessment

Though the mere investment costs of GDSF may be significantly higher than those of SGF overall costs, emissions and material flows should be assessed as a basis of a life cycle analysis (LCA) [EPA 1993; Christian 1997, VDI 6025 1996]. The LCA is linked to the building's energy in- and outputs evaluated from cradle to grave. Typically, four stages are considered during the assessment: extraction / production of all materials, building construction, building use and building demolition / disposal.

Because of the requirement of additional space, materials, energy, building time, know how and money, multiple-skin façades always require higher inputs than classical solutions. These extra inputs should be set off to a possible decrease in input during the building use and maintenance. Some studies calculated additional costs of GDSF per occupant of as few as seven working hours per year [Oesterle et al., 2001]. As for the reduction of the operational costs, a decrease can be achieved by reduced heating, cooling and/or lighting energy demand, less frequent replacement and maintenance of shading devices or by improvement of other performances. The latter, however, is sometimes hard to quantify and makes an assessment difficult. All in all the energy demand analysis forms an important step to quantify the buildings over all performance.

Qualitative benefits of solar control, moderated surface temperatures in winter, noise reduction, reduced glare, access to fresh air via openable windows at least in spring and autumn even in very high buildings, aesthetics and increased daylighting are important but generally seen only as intangible 'bonus' benefits. Several studies have analyzed the relationship between room temperatures and humidity, lightning, air quality etc. and work efficiency and thus converted qualitative into quantitative costs [e g. Fisk 2000].

All in all there is very few reliable data available for energy demand and the consumption as well as for investment and maintenance costs of buildings equipped with GDSF, and they are not easy to obtain. Oesterle et al. calculated that the façade cleaning cost increases with 30 % for a naturally ventilated single storey double-skin façade. Though it has to be done at four levels (instead of two) depending from the façade system it might be done from the interior instead of lifting platforms or façade cradles. They further expect an increase of the façade inspection, servicing and maintenance cost with almost 50 % but calculate a decrease of the heating and cooling demand compared to single skin fully glazed façades. As a result, the HVAC-plant capacity can be lowered. Therefore and because of the decreased need for fans because of the natural ventilation, the cost for construction, inspection, servicing and maintenance of the HVAC-plant and fans reduces with 60 %. Summing all figures, it is stated that the maintenance costs of both variants level out [Oesterle et al., 2001].

Description of the different construction options

There are many different principles of how to construct ventilated double skin façades. These can be classified according to three different criteria: Type of Ventilation, Partitioning of the Façade, and Ventilation Mode of the Cavity.

Type of ventilation

The type of ventilation refers to the driving forces of the ventilation of the cavity. Each ventilated double skin façade concept is characterised by only one single type of ventilation which can be: natural, mechanical or hybrid ventilation (mix between natural and mechanical ventilation). In general, naturally ventilated double skin façades are not very appropriate in warm climates, in which mechanical ventilation should be implemented. Even mechanical ventilation may not always solve problems with condensation which may occur when warm and wet exhaust air is ventilated into the gap and meets the cold inner surface of the outer glass pane. To overcome this in some cases window airing bypassing the gap is realized e.g. BiSoP building in Baden / Vienna [Kautsch et. al.].

Partitioning of the façade

The partitioning of the cavity gives the information on how the cavity is physically divided. Though there are numerous mixtures implemented solutions can be principally classified as follows:

Ventilated double window

A façade equipped with ventilated double windows is characterised by a series of windows doubled inside or outside by a single glazing or by a second window. From the partitioning perspective, it is thus a window that functions as a filling element in a wall. Some concepts of naturally ventilated double windows are also called ´Box-window´ in the literature. Advantage: Good noise protection from the outside as well as from room to room and no fire spread from room to room.

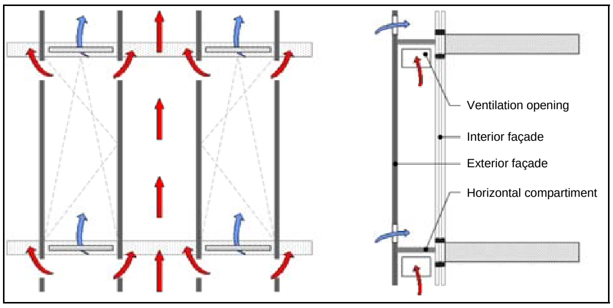
Façade partitioned per storey - Juxtaposed Modules

In this type of façade, which is especially used in Belgium, the cavity is physically delimited horizontally and vertically by the module of the façade which imposes its dimensions on the cavity. The façade module has a height limited to one storey and a width of mostly two windows. Thereby the inner skin is single and the outer skin double glazed. The room air, which is extracted via the double façade, is returning via ventilation ducts to the HVAC system. Advantage: very good noise protection from the outside, no sound transmission and no fire spread from room to room via the cavity.

Façade partitioned per storey - Corridor Type

This type is characterised by a large cavity in which it is generally possible to walk. While the cavity is physically partitioned at the level of each storey it is not limited horizontally, and generally extends across several offices or even an entire floor. Relatively good regarding fire spread but telephony effect possible. Exterior skin has to be open for supply as well as exhaust air – therefore not very good for noise protection from the exterior.

Shaft-Box Façade

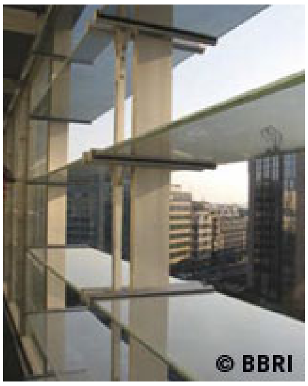


This type of façade is composed of an alternation of juxtaposed façade modules partitioned by storey and vertical ventilation ducts set up in the cavity that extend over several floors. Each façade module is connected to one of these vertical ducts, which encourages the stack effect. The air is naturally drawn into the ventilation duct via the façade modules and evacuated via outlets located several floors above. Advantage: outside skin only open for supply air – therefore good sound protection and at the same time good ventilation.

Multi-Storey Façade

The cavity is partitioned neither horizontally nor vertically and forms one large volume. Generally in this type of façade the cavity is wide enough to permit access to individuals via lattice works which are installed at the level of each storey in order to enable cleaning and maintenance. In some cases, the cavity can run all around the building without any partitioning. Mostly this type of façades is naturally ventilated. Excellent acoustical performances with regard to outdoor noise but special attention has to be paid to the telephony effect. Fire protection is a serious item with this type since the flashover from one storey to the next can be facilitated. Therefore it must not be applied to high buildings.

Louver Type



Though the partitioning of the cavity might be like a multi-storey or a corridor or even a box window type the special feature of the louver type is that the outer façade is composed exclusively of pivoting louvers which are not airtight, even when all louvers put in closed position. This results in lower sound protection but lower risk of overheating and condensation since ventilation with open louvers is unbeatable.

Ventilation mode of the cavity

The ventilation mode refers to the origin and the destination of the air circulating in the ventilated cavity. The ventilation mode is independent of the type of ventilation applied (see type of ventilation). Not all of the façades are capable of adopting all of the ventilation modes described here. At a given moment, a façade is characterised by only a single ventilation mode. However, a façade can adopt several ventilation modes at different moments, depending on whether or not certain components integrated into the façade permit it (for example operable openings). One must distinguish between the following five main ventilation modes:

1. Outdoor air curtain

In this ventilation mode, the air introduced into the cavity comes from the outside and is immediately rejected towards the outside. The ventilation of the cavity therefore forms an air curtain enveloping the outside façade. The dual-pane glazing is usually placed at the interior side and a single pane at the exterior side.

2. Indoor air curtain

The air comes from the inside of the room and is returned to the inside of the room or via the ventilation system. The ventilation of the cavity therefore forms an air curtain enveloping the indoor façade. The dual-pane glazing is usually placed at the exterior side, the single pane at the interior side.

3. Air supply

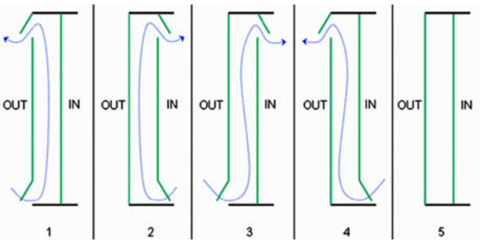
The ventilation of the façade is created with outdoor air. This air is then brought to the inside of the room or into the ventilation system. The ventilation of the façade thus makes it possible to supply the building with air.

4. Air exhaust

The air comes from the inside of the room and is evacuated towards the outside via the gap. The ventilation of the façade thus makes it possible to evacuate the air from the building.

5. Buffer zone

The cavity thus forms a buffer zone between the inside and the outside, with no ventilation of the cavity being possible.



The geometry of the cavity and the properties of the blinds (absorbance, reflection and transmission) may also affect the type of air flow in the cavity. The design of the interior and exterior openings is also crucial for the flow indoors and thus the ventilation rate and the thermal comfort of the occupants.

Advantages and Disadvantages

There are a number of potential advantages mentioned with GDSF which on the other hand don't apply for all types of façades. E.g. individual window airing almost independent of wind and climate conditions might be possible but can cause problems with condensation and sound transmission from room to room especially in multi storey types. Solutions can be the proper partitioning of the cavity and the implementation of sound absorbers. On the other hand wind loads within the cavity can cause problems with open windows. Reduced heating demand thanks to preheating of outdoor air may be an advantage in winter but causes higher cooling loads in summer. Night cooling together with improved burglary protection might be possible but as to closing the ventilation openings in time depends on an intelligent Building Energy Management System (BEMS) or involvement of the cleaning personnel. Significantly better sound protection up to 10 dB towards outside is merely achievable with a closed exterior skin – which can cause problems with condensation. Advantages which apply to almost all types of GDSF are: protected shading devices and lower U-values compared to SGF (depending amongst others on the tightness of the exterior skin).

On the other hand there are a number of potential technological problems with GDSF such a less efficient cross ventilation and insufficient heat removal from office rooms at calm weather if mainly stack ventilation, on warm summer/spring/fall days risk of high temperatures in office rooms with pure window airing, difficult to efficiently filter outdoor air, when mainly stack ventilation. Additionally the GDSF itself may become a source for annoying noise e.g. with obstacles in or bad design of the air inlet and outlet or inappropriate fixing of the shading devices. Since in most countries the space between the two skins is calculated to the floor area the rentable office area is reduced.

As mentioned above the control of flame spread along the envelope depends on the adopted double skin façade typology but always poses a challenge to GDSF. In the case of mechanically ventilated and multi-story-façades appropriate precautions like exhaust of smoke at the top of the cavity, sprinkler systems, injection of fire extinguishing gasses against smoke and flame spread should be considered in consultation with local authorities, insurers, etc.

Energy use, daylight and indoor climate

A traditional glazed façade increases the risk for an unsatisfying thermal comfort close to the façade and glare inside the rooms. A double skin façade will lower this risk. Through efficient utilization of daylight redirection and intelligent control of artificial lighting a reduction of electricity consumption and at the same time improvement of the visual comfort together with good thermal comfort and reasonable energy use is achievable.

Due to the additional pane, the light transmission of multiple-skin façades diminishes by 10 up to 20% compared to traditional façades. The additional effective room depth, the framing of the exterior surface and shading equipment result in an additional decrease of the daylight factors. As compensation for the lower overall transmittance, typically a higher glass to wall ratio is used. The advantage of the higher light gain should be offset against an increase in solar gains. For this purpose the window percentage of the façade may be reduced from about 70 % (i.e. fully glazed looking from the inside) to about 50 % and GDSF including solar shading applied only on south, west and east façades.

As a further solution, day-lighting systems may be integrated in multiple-skin façades. The main advantage is the protection against weathering and soiling. In order to optimise the function of the solar protection an automated control system should be implemented. The characteristics and position of the blinds greatly influence the physical behaviour of the cavity because the blinds absorb and reflect radiation energy. Thus, the selection of the shading devices should consider the proper combination between the pane type, the cavity geometry and the ventilation strategy.

To a certain extent GDSF allow the integration of technical systems for the room conditioning. Local air-conditioning systems may disburden the installation ducts in the building core. With newer projects GDSF developments have been realised that include, apart from the room conditioning, façade-lighting systems and PV elements within the façade.

Technology Implementation Plan

How can this technology be implemented by the planner?

Out of the total energy consumption by a building, from erection to the demolition 15 % derives from the actual construction, while 80 % is used for the operation. Therefore - besides the aesthetical appearance - the most important question is the performance specifications. They have to be set as early as possible during the design process by all participants in cooperation with the owner and if possible with the occupants. The planning process should be realized by a highly specialized team of experts. Especially in the case of prefabrication / elementary building systems a higher amount of planning is to be considered.

The site determines the orientation and shape of a building, as well as the choice of façade and technology. Close to a highway or a loud industry the double skin façade can act as an effective noise suppressor and create a comfortable indoor climate.

Seen from the perspective of energy consumption there are no reasons to have identical façades facing different directions. Contrary the south façade is suited for making use of solar heat and double skin glazed façades where the cavity is used for ventilation, collection of heat and as protection for solar shading functions. The façade facing north can have a more traditional expression with smaller windows and have higher level of insulation. In this way the architecture becomes more environmentally adjusted depending on the location of the building.

Last but not least careful fine-tuning after the completion is required as well as continuous performance monitoring.

What has to be taken into account when installing a glazed double skin façade?

The planning of GDSF in Middle Europe has to be based on the summer conditions. First the overheating problem has to be solved which means decrease of (interior) glazed areas and minimization of internal gains. Secondly the façade should be adapted to possible gains during the winter. Corner rooms with two glazed façades should be avoided since in most cases they need additional heating / cooling.

For buildings equipped with GDSF the setting of performance specifications as early as possible during the design process is highly recommended. Applying performance specifications to double skin façade systems and buildings with these façades provide a more flexible approach to the façade system and building design as well as operation whereby targets for the performance are set which must be met in order that the façade system and the building perform as required. This approach also facilitates the implementation of innovative systems.

Performance specifications have to be measurable, predictable, and technically “sound” and should be applied at three different levels:

A. Building performance specifications

Energy use, HVAC strategy, investment and maintenance costs, noise levels, aesthetics (specified by the client and/or the user).

B. System performance specifications

Energy use, maintenance PMV (Predicted Mean Vote) / PPD (Predicted Percentage of Dissatisfied), air quality, noise levels, daylight quality, operative air temperature, thermal and visual comfort, humidity, degree of user / occupant control, (specified by the client and/or the user and the designer).

C. Component performance specifications

Commissioning, operation, maintenance and deconstruction for e.g. glazing: U-value / g-value in combination with automated shading devices, surface temperature, daylight transmittance (specified by the designer).

Simulation methods

In spite of difficulties with setting the appropriate boundary conditions simulation represents the only method to estimate the yearly energy consumption of a building equipped with a ventilated double skin façade and to assess for example the impact of different control systems and control strategies on the building performances. Simulation tools ought to be used during the all phases of a building project: pre-design, design, construction, operation.

What information and basic conditions are required?

According to [Brunner et. al. 2001] besides the available budget and aesthetical appearance eight determining areas of influence for highly glazed buildings are specified:

1. Boundary conditions: Size (of building and rooms) / orientation, use (assumed level of activity, number of people, operating hours, presence frequency) / outdoor climate (wind load, noise, radiation,..), Materials of outer and inner skin e.g. durability and need of maintenance, legislation e.g. on fire protection

2. Comfort / daylight: Window area, PMV (Predicted Mean Vote) / PPD (Predicted Percentage of Dissatisfied) / daylight quality, max. temperature and humidity, asymmetry / cold air, automatic control with or without manual overruling

3. Internal gains: Equipment / artificial lighting, persons

4. Ventilation / cooling: Air quality, removal of loads

5. Energy use: HVAC strategy (heating, efficiency of heat recovery on air, cooling)

6. Thermal mass: Floor / ceiling, walls / furniture

7. Solar shading: Type / location / material, operation / control

8. Glazing: Area, U-value / g-value incl. and excl. solar shading, surface temperature, daylight transmittance

Legislation

Though there is no special legislation dealing with GDSF some standards may provide an approach.

What interaction is required with other planners and at what stage in the project?

With GDSF the demand on a holistic approach and collaboration between participants in the design process becomes more significant than in a traditional building system where the façade usually acts as a passive part of the building. Team work between architects, engineers, clients and users is required from a very early stage of the project. Since there are in most cases antipodal requirements on the properties of a GDSF an iterative design process with defined planning interfaces is required. In order to arrive at a glazed double skin façade building with a reasonable energy use, good thermal and visual comfort the following actions are required during the building process:

► Energy use and environmental requirements as performance specifications are drafted in the contract

► There is an energy and environmental coordinator from the contract phase until the first year of operation

► Energy and indoor climate simulations are carried out starting already during the contract phase and are refined during the building process

► A governing quality and environmental program with performance requirements is worked out starting already during the contract phase, and is refined during the building process

► Good cooperation between designers to ensure a well performing system: architecture, HVAC, structural engineering, electrical engineering and building physics

► A "network" with energy and climate specialists and designers is established

► Good cooperation between client, designers and contractors

► A life cycle cost analysis is carried out to avoid prioritising investment costs and neglecting operating, maintenance and energy costs. A separate performance specification is worked out for the Double Skin Façade based on analysis of the entire building, to avoid sub optimisation

A user manual should be provided and a period of familiarisation with the building services of at least one year should be calculated.

Market situation of Glazed Double Skin Façades

Whereas glazed double skin façades were characterised by a large percentage of prototypes and the fact that they were incorporated in planning more from an architectural than an engineering point of view in the past, a trend towards well developed system solutions can be observed due to implementation of the EPBD and the associated necessity of proving energy consumption, but also as a result of numerous complaints with regard to comfort. In addition to the rapid ongoing development of components, increasing computing power and sophistication of calculation models play an important role in this context. Among other things, the upcoming implementation of international standards will be instrumental in steering the market towards quality assurance and thus also an increased market presence.

Reliability of Glazed Double Skin Façades

The question of reliability and service life cannot be answered by generalising. The various types of façades, systems and applications are too different. Probably the most outstanding example of a durable GDSF is the Steiff production building in Gingen / Brenz, Germany, that – built in 1903 – was in use almost unchanged for around one hundred years and that, following a phase of restructuring, is now to be used as a museum.

Due to the fact that most GDSF have been kind of prototypes so far, sometimes difficulties have been reported with unproven durability - especially with pane fixtures (those problems may refer to SGF too), mechanically driven shutters or lamellae, problems with certain sealants due to high temperatures in the cavity. Due to the depth of the system larger glass areas may be shaded. This may increase the risk of glass fracture due to stresses induced by differential heating of the pane surfaces. More complex systems need a higher level of maintenance, sophisticated devices are more fault-prone and need qualified personnel together with a higher level of monitoring but since GDSF are a rather new development there has been no scientific in-situ long-term analysis of a bigger group of façades. On the other hand e.g. shading devices or PV elements are protected from weather conditions and therefore longer life-time is assumed.

The use of largely prefabricated components reduces the risk of insufficient performance significantly. Nowadays some big suppliers offer a great number of well tested profiles and façade systems so that except very big building projects where special system development and testing might be suitable it is highly recommended to make use of that offers. Assumed that the GDSF is properly designed there shouldn't be weightily reliability arguments against it.

Obstacles to introduction on the market

Whereas architects mostly like GDSF the reputation of it is not always good among engineers, building owners and construction industry. The main uncertainty is related to the thermal performance, comfort aspects and higher investment and maintenance costs, which mostly result out of the fact that many GDSF have been designed mainly from aesthetic viewpoints instead for technical demands.

Another reason is the non-awareness of legislation related to double skin façades e.g. European Standards EN 13830:2003, prEN 13119:2006 which specifies characteristics of curtain walling and provides technical information on the varying performance requirements. Legislation dealing especially with GDSF is still missing.

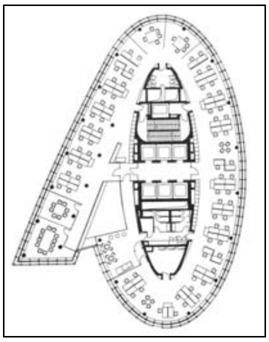
Furthermore the choice of appropriate calculation tools to predict energy consumption at the building level compared to a traditional glazed façade is rather difficult. Besides no reliable documentation of best practice examples exist until now.

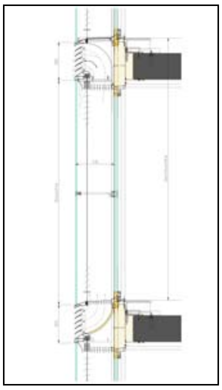
The fact that the intermediate space of the gap of the GDSF in most countries is calculated into the total floor area of the building reduces the rentable space and thus may pose a remarkable commercial obstacle.

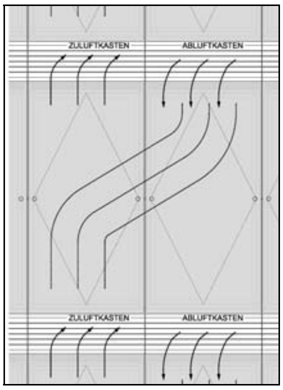
Examples

► Uniqa Tower, Vienna

Height 75 m, gross floor area 38.500 m², gross volume 140.000 m³,prefabricated construction, completion June 2004, 44 Km soil heat absorbers, open space office / fitness centre / bank branch / café / restaurant / entertainment centre, openable window-doors, corridor type, cool and dry air above 22° additional cooling system in the ceiling, 50 cm gap, daylight redirection (more information: http://tower.uniqa.at/index_tow.php).

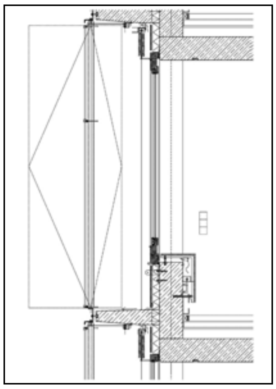


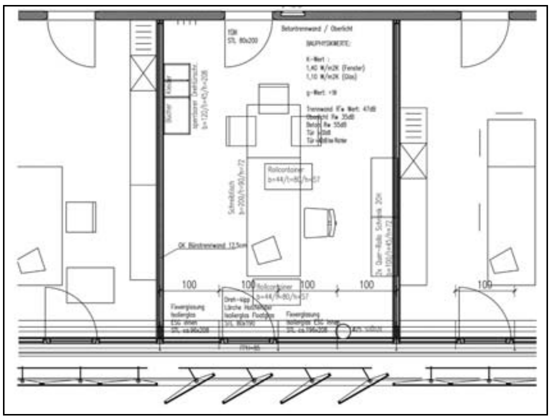




► Center of justice, Leoben

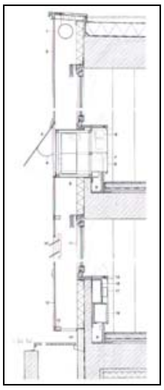
Height 21 m, 3- 5 stories, completion Nov. 2004, total gross storey area 13.139 m², 70 cm gap, corridor-louver type with vertically pivoted glass panes and wooden blinds with automated control strategy, all orientations equipped with GDSF - conventional construction (no prefabrication), wooden interior façade with openable windows into the gap, concrete gangway for fire protection, radiators in front of the parapet, no cooling system.

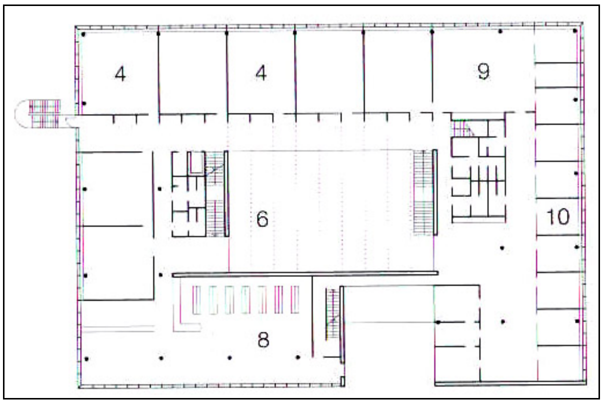




► University of applied sciences, Kufstein

Height 3 stories (11 m), shaft – type, 30 cm gap, total gross storey area 7800 m², completion 2001, radiators air heating / cooling, opening windows into the gap, mechanical ventilation system, (de-)humidification, all orientations equipped with GDSF, lecture rooms fully glazed with openable window-doors and ventilation appliances bypassing the gap with heat recovery, bureaus with window parapets and window airing via the gap and opposite louvers in the exterior skin, additional ventilation ducts on top of the gap





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SIXTH FRAMEWORK PROGRAMME

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