1 | Introduction

With *Façades – Principles of Construction* being the title of this book – now in its second edition –, one might begin to wonder why there is the need for yet another book about façades. As it is, there are sufficient volumes focusing on topics such as transparent façades, double façades or material-specific façade constructions (1, 2). The subtitle – *Principles of Construction* – should shed some light on the purpose of this particular book: it is designed for architects and students who wish to concentrate on the design principles of façades in a more fundamental manner. This book does not focus on specific façade variants; rather it explores basic façade systems, their origin as well as the principles of construction, building structural aspects and the integration with the building itself. The goal is neither a collection of design examples nor a compilation of current and regulation-conforming details, but to create a basic understanding of the façade and its technical realisation. Not based on specific European code norms and technical regulations nor dependant on specific material-related parameters, this understanding will enable the reader to analyse specific project examples with the aim to realise their own developments in a technically sound manner.

1

Jewish Museum, Berlin, Daniel Libeskind, 1999
Façade detail. The architectural concept envisioned a homogenous sheet-metal façade, which, during technical realisation, underwent a metamorphosis to a multi-layered rear-ventilated façade with embedded rain drainage and spillway.

2

Guggenheim Museum, Bilbao, Frank O. Gehry, 1997
Geometrically complex building junction: solving the geometry and implementation of a façade system is part of the architect's responsibility but without modifying the structural system of the post-and-beam façade.

This approach is part of an integral design concept: an architectural design not only includes the concept, the composition of space and the organisation of the building's functions but should encompass its structural realisation. The definition of surface and structural materials and their detailed application is an expression of the building as a whole. Thus, the detail is part of the architectural concept, to be understood as an element on a special scale. The architect needs to exercise creative control of this element; otherwise, the detail will develop randomly and might influence the architectural expression contrary to its original conception.

Today the architect can no longer control every detail in its technical entirety – the range of technological developments and product diversity has become too broad. This book will provide an overview of typical solutions, the underlying systems as well as their functionalities. This information will allow the architect to be a competent partner in façade design. It will enable him or her to understand the suitability of each system in a specific part of the design and to determine its technical and geometrical limits.

We don't see the façade as an isolated building component but as an integral element with considerable importance in terms of the building's appearance. It should include additional functions such as loadbearing, active or passive environmental control (3) and individual creative expression (4).

3

Debitel Headquarters, Stuttgart, RKW Architektur + Städtebau, 2002
Example of integrative planning of architecture and environmental concept: this alternating façade was a new development, featuring an air intake system and a solar chimney for routing of the exhaust air.

4

Winter gardens at the National Museum of Science and Industry, Parc de la Villette, Paris, RFR, 1986
With this hanging glazing, point-supported glass fixtures transfer the weight of the glass panes into the respective pane lying above; wire bracing absorbs the lateral forces.

Façade planning and construction

Façades are not limited to the actual space they occupy as part of the entire structure, but also influence the space in and around the building. A façade is the key element when observing a building from the exterior and has impact on the interior. View, lighting, ventilation, user comfort, some building services and possibly loadbearing are all tasks the façade may need to address. Façades are an integral element of the entire building with direct relation to design, use, structure and building services. This has decisive impact on the entire design and construction process.

Designing a façade is a process of communication and decision-making that focuses on the formulation of the building and its façade. The following steps can be defined as specific phases: initial conception, definition of functionalities, design, implementation coordination and assembly. Certain processes should occur during all of these phases: feedback on overall design and definition of functionalities as well as the element's importance within the overall structure of the building (structure, building services engineering, usage, safety).

We will describe an example of a functionality relating overall building design and façade construction. Water needs to be kept out of the building. The design might include, for instance, an overhanging roof with recessed windows. In terms of the construction process, a layered construction method with targeted drainage via eaves gutters or drainage edges would be preferred (5). Assembly would need to be executed from bottom to top in order to construct overhangs and ensure proper sealing.

5

Eave as weather guard, Ouro Prêto, Brazil
Use of a large eave as weather guard for the wall and window planes below. In the protected upper storey, casement windows were used, whereas in the lower storey, sliding windows were preferred since sealing this type of window is easier.

Similar relative effects can be seen in the example of a full glass façade: the design idea of a transparent envelope usually would entail the choice of a non-loadbearing façade to expose as much glass surface as possible (6). For the construction process, this would mean using a full glass façade set independently of the building structure. It would need to have a movable joint to avoid stress imposed on the glass façade by the main structure.

Why do we now emphasise on façades being highly technological components when they have always been part of the architect's scope of design? In particular, early Modern Architecture captivates us with its technically simple detail solutions. Single glazing could be made simply, without complex aluminium profiles, just flat steel welded for an extremely slim section.

Today's buildings stand in stark contrast to these historic examples of Mies van der Rohe (7) und Niemeyer (9) – they consist of numerous complex and interlinked technical solutions for the loadbearing structure, technical equipment and the façade. Individual design specialisations have evolved for each of these building components. The modern façade is a complex structure with numerous functions and complex technical realisation. When we look at the architectural façade solutions of early Modern Architecture, it becomes apparent that they were relevant in their time, but no longer fulfil today's requirements. Increased demands concerning comfort, e.g. heat-insulation as well as air- and rain-tightness, in the context of most industrial countries no longer allow the use of single glazing. This results in the need for thermal separation of the construction profiles followed by the consequent need to maintain this separation throughout window casements, drainage plains and jointing technology. The complexity of the technical aspects alone increases exponentially. If we further consider today's increased knowledge in material science and its rapid development, the possibilities seem endless, but so do the problems.

6

Farnsworth House, Plano, Illinois, Ludwig Mies van der Rohe, 1950

This summer house lies embedded in the landscape; it sits on stilts to resist the annual floods and to evoke a sense of detachment from the surrounding area.

Development trend complexity

The prevailing trend in façade technology is its increasing complexity. The range of possibilities is expanding constantly and technical solutions become indicators for the state-of-the-art: more and more 'intelligent' façades (10) are being developed with the aim to increase the user's comfort level. But since users need to undergo a process of familiarisation with the new technologies, the question of their actual practicality remains partially unanswered. Thus, some developments are being revised and a few, however sensible with regards to substance, even disappear. Today we know of the issues of double façades and can better judge their advantages and disadvantages. They were built in quantities, but flawed conceptual designs or incorrect use and operation damaged their reputation. When looking at proprietary technologies and systems, we can see that these double façades do have historical predecessors; the Mediterranean box-window (8) for example, or decentralised air-conditioning units, so called 'fan coil units', which we have seen in older American high-rise façades.

7

Façade detail Farnsworth House, Plano, Illinois

The detail consists of an inner flat steel angle-bracket, a clamped single glazing without thermal insulation, and an outer finishing strip. As was customary in those days, no thermal bridges or drainage within the profiles were provided. Because the house was used during the summer months only, this was deemed unnecessary.

8

Historic façades in Bilbao

In Mediterranean climates, glazed balconies serve as part of the living space during transitional periods and as part climatic buffer during summer.

Current topics in façade technology development include energy, user comfort, individual façade expression (11) as well as adaption of existing façades. These topics are all driven by the search for new solutions to create façades for varying functions, climatic circumstances and geographic locations (12). The authors expect two major trends to develop: further emphasis on technical developments with improved design tools, manufacturing methods and system variants, as well as simplifying the façade by integrating components and functions into façades that might be complex to design but easy to manage.

However, exclusiveness does not exist in façade technology: there are no definite right or wrong solutions. Façades always result from individual creative conceptions, designed for a specific place, context and architectural concept. This book should be viewed as a guide to analyse, consider and develop. It challenges the reader to stay informed about new as well as conventional topics, to learn by observing, inquiring and visiting construction sites.

Façade planning is an integral part of the design process that employs constant feedback. It is a process based on progressive steps. This book is structured according to this schematic: the chapter 'From Wall to Façade' discusses the development of today's façades and their typological classification; the chapter 'Principles of Construction' explains the interrelationship between the building structure and the façade system; the chapter 'Detailing and Tolerances' broaches the issue of generating technical details for the general solutions defined previously; topics such as integrated design and building structure aspects of the façade are discussed in the chapter 'Climate and Energy'; the chapter 'Adaptive Façades' analyses how façades can adapt to changing parameters; the section 'Case Studies' describes typical and special façade solutions on the basis of selected projects.

9

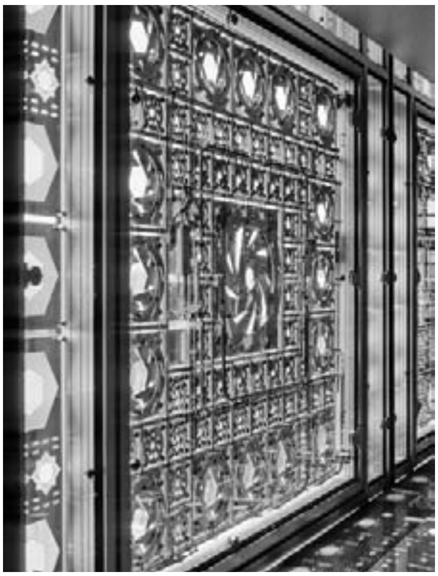
Banco Mineiro de Produção, Belo Horizonte, Oscar Niemeyer, 1953
The slim sections and single glazing have remained unchanged in Oscar Niemeyer's administrative building because the local climate does not necessitate thermal insulation. Air-conditioning units for cooling the interior space in summer are positioned according to the requirement of the individual user.

10

ARAG Tower, Düsseldorf, RKW Architektur + Städtebau with Foster and Partners, 2000
This well designed double façade is a shaft-box system with individual box windows and cross-storey exhaust shafts within the glass façade.

Four new, exemplary case studies were selected for this second and revised edition. They explain four different construction methods that are in common use; particularities are noted in the text. The case studies are meant to be transfered to a particular project or problem. Thus, the rear-ventilated façade of the Concept House in Rotterdam, the Netherlands, is an interesting example of façade cladding that could be similarly realised with many different materials in sheet or panel form. The second case study, the State Archive Nordrhein-Westfalen in Duisburg, Germany, deals with a more traditional single-skin solid masonry construction, which is particularly helpful as an example for extensions to older buildings or restoration of historic buildings. Both examples are wall constructions with windows, and therefore so-called punctuated façades.

The desire for transparency and façades with large glazed areas is addressed with the other two case studies. The new building for the Department for Architecture and Interior Design at the University of Applied Sciences in Detmold, Germany, was executed with a post-and-beam façade; a suitable solution for buildings only a few storeys high. The element façade of the Headquarters Süddeutscher Verlag in Munich is a good example of a very modern high-rise façade, delivered as prefabricated elements and assembled storey by storey. Following the punctuated façades of the examples in Rotterdam and Duisburg with their loadbearing walls, these two curtain wall variants offer an informative introduction into the design of façades which are placed in front of the loadbearing structure of the building. In closing, the authors offer an outlook on the future of façade technology and the possible lines of development.



11

Arab World Institute, Paris, Jean Nouvel, 1989

South façade of the Arab World Institute with a technical interpretation of the Arabic sun screen as an integrated-pane system. The blinds open and close depending on the angle of the sun.

12

Juscelino Kubitschek Complex, Belo Horizonte, Oscar Niemeyer, 1951

North façade of a residential high-rise building from the fifties with sun protection lamellas which can be adjusted for each flat individually. Lamellas of varying incline create a textured surface that changes the building's appearance – from a design point of view, a very modern façade.

2 | From Wall to Façade

The form and function of present-day wall and façade constructions are the result of a long process of development, which is closely related to the history of humanity. Starting from the two original basic forms of human existence – the settled and the nomadic – and the functional, technical and design-related requirements resulting from these conditions, we can outline the resulting forms walls and façades take and their further development. Depending on climatic conditions and the various life styles and dwelling styles that grew out of them, two essentially different basic principles for the construction of the outer envelope of a dwelling place came into use: solid walls fixed to one particular spot and designed for permanence on the one hand, and more flexible, less permanent façades – typically represented by tents for mobile use – on the other.

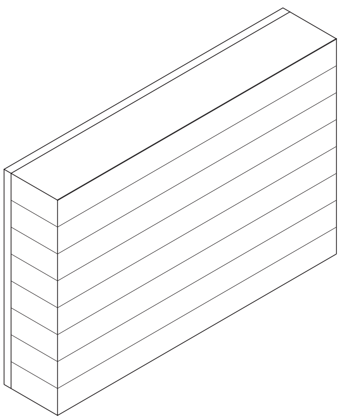
The survey of the development trajectory given here follows not so much cultural or historical as construction trends against a background of structural and functional relationships. Thus, the development is not chronological but one in which the successive steps of the construction developments involved to bring out the interdependencies and relationships inherent in them, as well as the underlying logic. The resulting overview of the phenomenon of the façade should be seen as a snapshot from current perspectives that understandably focuses on present-day developments but not limiting itself entirely to them.

Solid wall construction

People who lived in cold climates and populations who had adopted a settled mode of life preferred wall constructions that were as solid as possible (1, 4). Such walls are built up either of readily available building materials or of elements made suitable for the purpose by simple processes, such as naturally occurring stones, squared stone or fired bricks. The objective was to build a wall that would stand up to climatic influences while still keeping the building method as uncomplicated as possible. Though the construction and finishing of such solid structures has naturally developed in line with advances in technology – present-day solid walls are either built up of structural units with both loadbearing and thermal insulation properties or are provided with elements for this purpose – the basic principle remains unchanged.

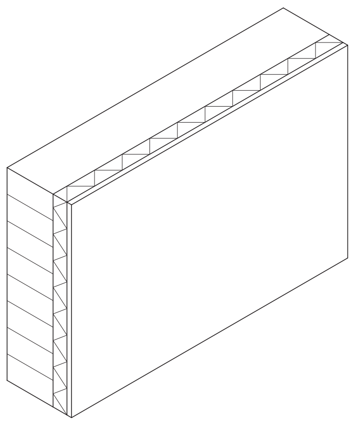
Warm façade, cold façade

Two different types of solid wall construction may currently be distinguished: warm façades (2), where the insulating layer is mounted directly on the outside or the inside of the façade construction, and cold façades (3, 5) where the insulating layer is separated from the climatic protection layer by a layer of air. The latter principle allows the insulating layer to dry out if water penetrates into the façade as a result of damage to the protective layer.



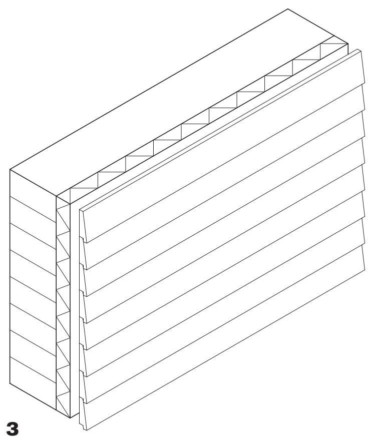
1

Solid wall
Solid wall constructed from monolithic or composite elements. Often, the masonry is plastered, shown here with an internal plaster.



2

Warm façade
Warm façades have a thermal insulation layer applied directly to the surface of the building. If the insulating layer is applied on the outside, it also has to be water-resistant to ensure that the insulating properties are not lost due to weathering. If the insulating layer is on the inside, the ability of the solid wall to store heat will no longer actively influence the interior environment.

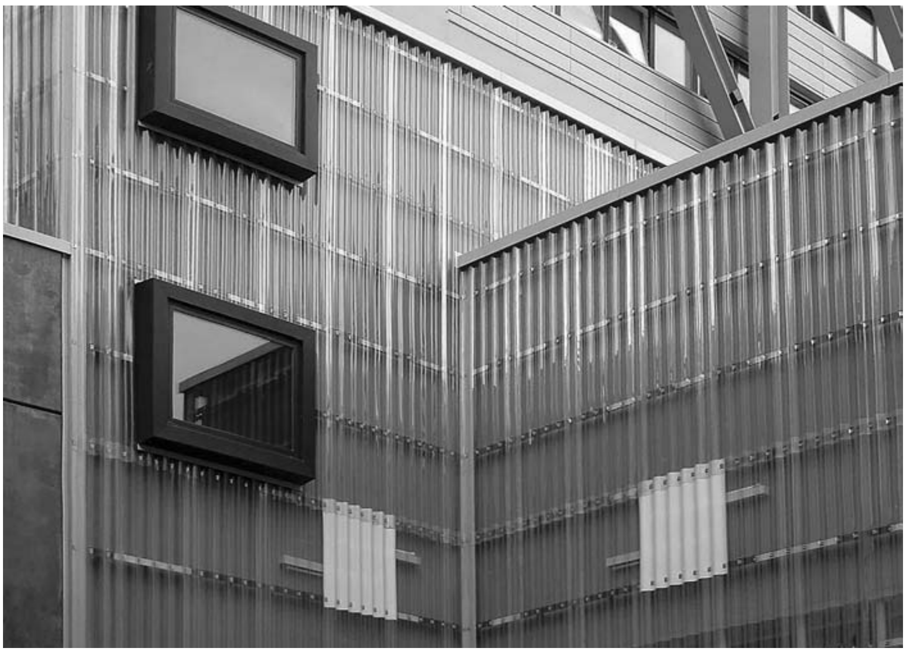


3

Cold façade
Cold façades are characterised by the presence of a cavity, ventilated internally, between the outer layer that offers protection against the weather and the thermal insulation layer. Potential condensate can escape via the cavity.

4

Marketplace in Siena, 13th century
Solid masonry wall as a loadbearing and space-enclosing structure.



5

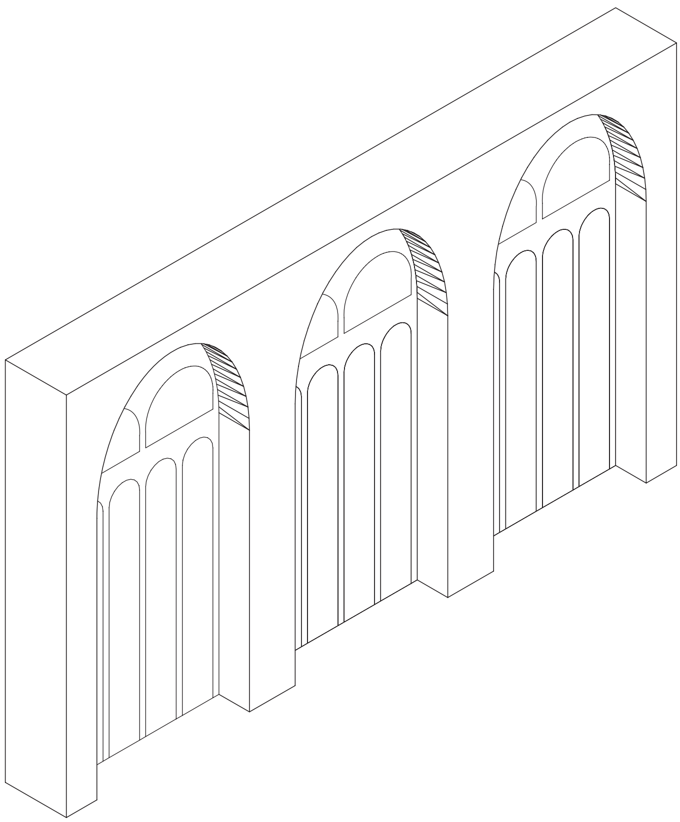
Port Event Center, Düsseldorf, Norbert Wansleben, 2002
The cold façade of the ground floor of an office building in the port of Düsseldorf. The transparent outer layer that offers protection against climatic influences allows the skeleton of the building, the ventilated cavity and the thermal insulation layer to be seen.

Openings in solid wall construction

Openings were originally made in the walls to allow smoke to escape (6). At a later stage in the development, the openings were enlarged to let light in. The method used initially to solve the problem of the weakening of the fabric of the solid wall by the creation of openings in it was to use horizontal beams as lintels.

In Gothic architecture, the amount of solid masonry used in the wall was gradually reduced to allow large areas of glass to be incorporated into the walls, with the aid of constructive techniques of which the ingenuity is still impressive today.

Driven by the wish to admit even more light into the interior of the building, the amount of masonry used in the wall was gradually reduced (8). As the Romanesque style of architecture was succeeded by the Gothic, the previously almost monolithic walls were progressively replaced by filigree structures that may be regarded as precursors of the skeletons used in present-day building techniques. The roofs were shell constructions with cross-wise support, resting on pillars and loadbearing walls (7). This allowed the vertical forces to be concentrated at a number of predetermined positions, from where these forces were transferred to the ground. This made it possible to create large openings in the relatively unstressed parts of the walls. Since the transfer of loads also leads to lateral forces in this system, these lateral forces also have to be transferred to the ground by means of suitable ties or external buttresses.



6

Dissolution of masonry in a church window
The introduction of large windows in churches and cathedrals went hand in hand with a reduction in the area of masonry. The glass area was divided into small window frames.

7

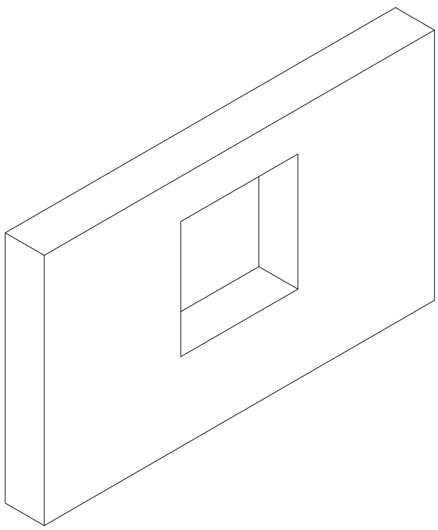
Cathedral of Amiens, 1220-1269
The space was opened up by dividing the structure into loadbearing and covering elements. Large areas no longer had any loadbearing function, thus allowing windows to be created in them.

8

Merchants' houses in Antwerp, 16th century
As the merchant classes increased in stature, building methods permitting large areas of glazing in façades also came to be used for profane purposes, as in these historic merchants' houses surrounding the marketplace in Antwerp.

Bridging the gap

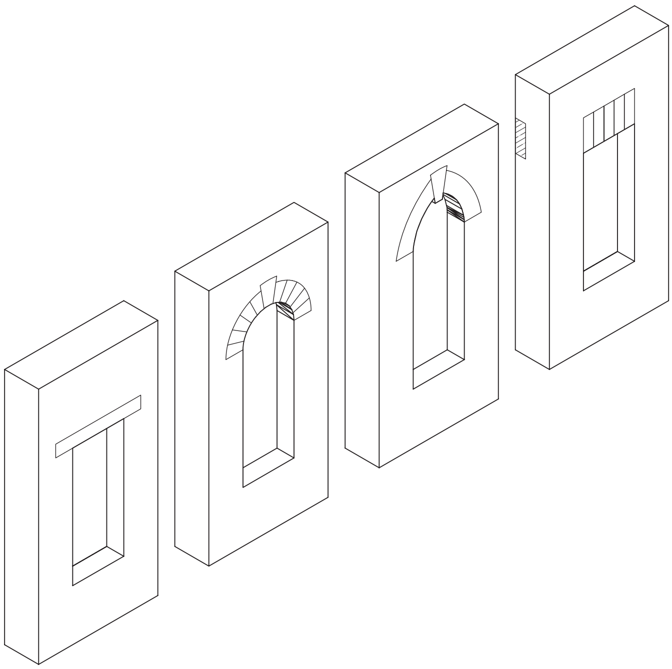
Since the use of window lintels to span large openings in walls (9) very soon reached its structural limits, the next stage in the development was the use of arches for this purpose. In Gothic architecture, these arches became pointed since this form is more capable of bearing the weight of the wall lying above. Present-day building styles continue to use lintels – made of steel or reinforced concrete – to span openings in solid walls (10).



9

Openings in walls

Openings in a solid wall allow fresh air and light access to a building.



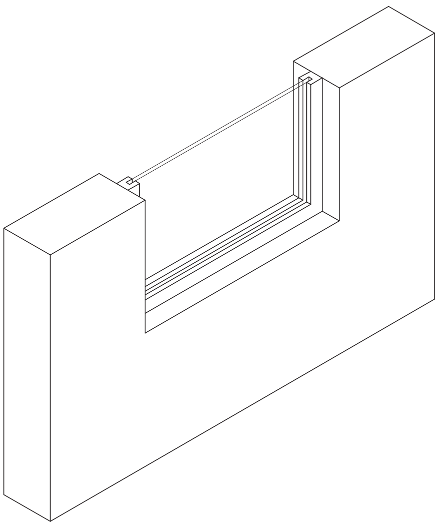
10

Bridging the gap

Openings in solid walls were initially spanned with wooden lintels. Arches were later introduced, since they made it possible to bridge wider gaps. In the Gothic style, these arches were pointed to allow them to bear greater weights of masonry above them. Modern architecture would conventionally make use of concealed loadbearing elements made of steel or concrete to span large openings.

Closing apertures – single glazing

In addition to creating apertures in the wall to introduce light and air into the room there is the requirement to close off the space against cooling and unauthorised access. Thus, the apertures were filled in with translucent materials – in the case of Roman thermal baths, for example, with thinly cut sheets of marble. The development of glass as a building material made it possible to fill the openings in the walls with single panes of glass that not only provided natural lighting in the houses, but also allowed the people inside to view out (11, 12). The production technology initially only allowed small panes of glass to be made, and the resulting windows were correspondingly small. Development of the glass-in-lead technique made it possible to construct much larger windows. This, combined with the use of stained glass, allowed magnificent results to be achieved especially in sacred architecture. At present, large single glazing is often used mounted in steel frames (10).



11

Single glazing

Single glazing was used in apertures to provide natural lighting, to allow views out from inside the building and vice versa, and to prevent heat loss from the building. Various techniques were developed to join initially available small panes of glass so that larger openings could be filled.

12

Weißenhof Siedlung, Stuttgart, 1927, Ludwig Mies van der Rohe, Le Corbusier, Walter Gropius

Single glazing in steel window frames in a building complex at the Weißenhof Siedlung in Stuttgart. The windows are positioned on the outside of the wall apertures to produce a flat façade.

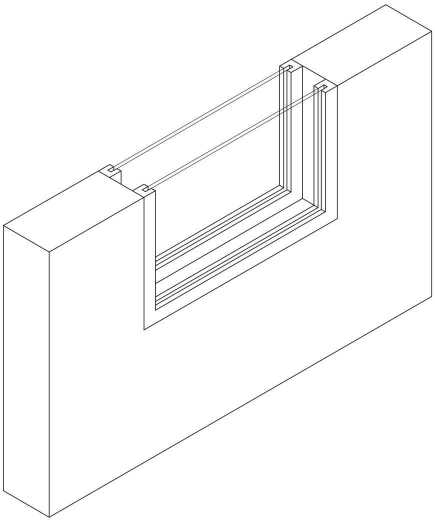
Box window

The box window may be seen as a further stage in this development. Here a second pane of glass is added, slightly set back from the first, to create an additional climatic buffer if this is required by the climate or the season (13, 14). The space between the panes is not hermetically sealed, to avoid condensation (15).

This may be called the first intelligent wall: depending on the state of the weather or the occupant's needs, the second window pane can be slid up or opened otherwise to let in the outside air or slid down to improve thermal insulation. Depending on the climatic conditions, the user decides how many panes should be opened or closed.

14

Box window
Depending on the season, the outer window sashes can be opened or closed. Shown here are summer conditions; the configuration allowing free window ventilation without overheating of the cavity between the inner and outer window panes.



13

Box window
A box window is produced when a second pane of glass is installed to meet seasonal conditions. Depending on the temperature, the user can decide how many panes should be opened.

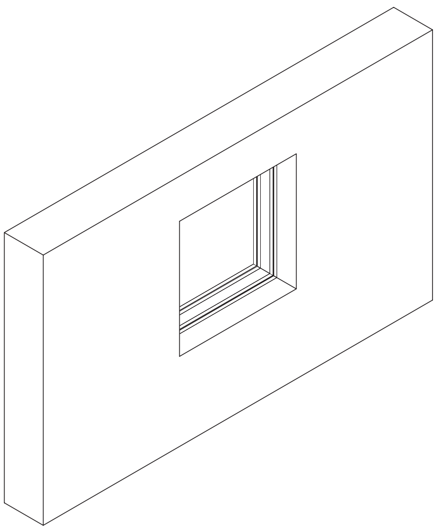
15

Loggias in façade, Bilbao
These loggias built in front of the actual windows may be regarded as a variant of the box window: in spring and autumn, these spaces can be used as an additional room while in winter they are closed off to act as an extra climatic buffer.

Insulated glazing

The next step arguably in the development of the box window is insulated glazing or double glazing. This consists of two panes of glass permanently joined together with an insulating layer of air or inert gas in between (16, 17), providing a more effective barrier between the internal and external environments.

After some experimentation with different methods of glass mountings, the panes of glass are nowadays usually mounted in aluminium or plastic profiles with the aid of a silicone sealant.



16

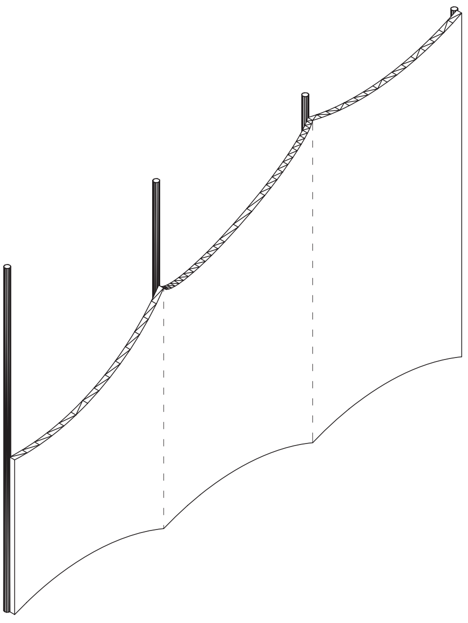
Insulated glazing
Two panes of glass permanently joined together to give insulated or double glazing a more effective barrier between the internal and external environments.

17

Fondation Cartier, Paris, Jean Nouvel, 1994
The façade consists of single glazing on the left and double glazing on the right.

Walls with skeletal structure

In a parallel line of development found in nomadic societies, tents consisting of a supporting skeleton and an outer covering to keep out the elements were the main form of building (18). It would be clear that in order to facilitate the transport of the tent, both the skeleton and the outer cover had to be as lightweight as possible. There was no place for massive structural elements here. Under these conditions, it was necessary to separate the functions of support and enclosure.



18

Tent

Tent-like structures arose through the need to move one's home frequently from one place to another as is inherent in the nomadic way of life. These structures were designed for ease of assembly and dismantling, which made it necessary to separate the functions of support and enclosure from each other.

Half-timbered construction

The two parallel developments outlined above, of the gradual dissolution of the solid wall to give more window space, and of the tent with its separation of support and enclosure, combined to bring about the gradual transformation of the solid wall into the relatively lightweight modern façade. This is achieved by building a supporting frame or skeleton (originally of timber) and infilling in the intermediate spaces with an appropriate cladding (20). The European predecessor of this building technique is half-timbered construction (19), in which a timber skeleton is built and the spaces in between the timber elements are infilled in with different materials according to the region: interlaced branches, mud or clay (the combination of these two being the well-known 'wattle-and-daub'), or bricks. Apart from the choice of material for infilling the gaps in the timber skeleton, these structures may vary in the method used to mount successive stories: the ceiling of one storey, and the floor of the one above, may either be mounted in the wall (as in the French or Normanic tradition) or rest on the wall (as in the Germanic tradition). In the latter case, we get the overhanging of successive storeys that was characteristic of medieval European buildings.

19

Half-timber houses, Detmold, 16th century

In a half-timbered construction, the loadbearing capacity is provided by the skeletal structure while the infill in the intermediate spaces merely has an enclosing function. The overhanging of successive storeys is clearly visible.

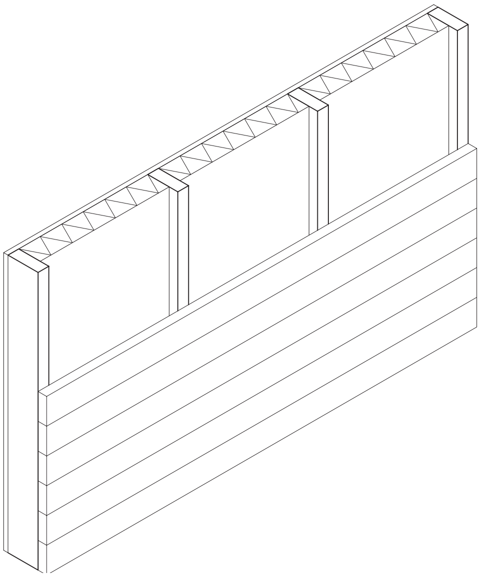
Platform and balloon framing

The American variant of this principle is the timber-frame construction. This consists of bearing timber members, the spaces between which are infilled with sheets of wood products. Since this type of construction does away with a solid outer wall, it has poor thermal buffering properties.

A distinction is made here between platform frames and balloon frames: in balloon frames (22), the ceiling of one storey, and the floor of the one above, are mounted in the wall while in platform frames (21) they rest on the wall. In multi-storey buildings, the walls are erected on the completed platform provided by the flooring.

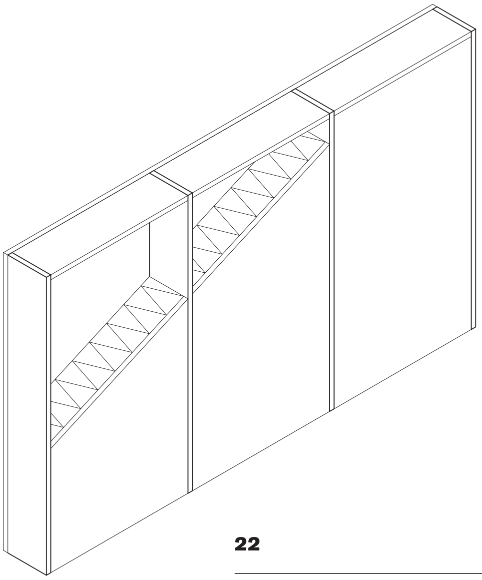
21

Platform frame
In the platform frame variant of the timber-frame construction, widely used in America, the walls are made of vertical timber members of which the spaces in between are infilled with wooden boards and thermal insulation material. The ceiling of one storey, i.e. the floor of the one above, rests on the wall.



20

Timber-frame construction
A timber-frame structure is built up of relatively slender timber members, the space between which is infilled up with cladding on the inside and the outside. The space between these two layers of cladding acts as thermal insulation.



22

Balloon frame
A balloon frame consists of posts one storey high provided with cladding on the inside and the outside. In contrast to platform frames, balloon frames have the ceiling/floor unit built into the wall.

Resolution of the wall into loadbearing structure and façade

The development described above took thousands of years. The subsequent steps in the development process occupied no more than about a century. Once again, there is no need to trace the development in chronological order – it makes more sense to outline the structural development trajectory.

In the run-up to the Neoclassical era, architects did their best to separate the various functions of the wall even further. Bearing, sealing and the transmission of light were becoming more and more clearly distinguished from one another, though it may be noted that technical limitations did not yet allow the loadbearing function to be completely separated from the others. Nevertheless, it had become possible, for example, to incorporate large window openings in the wall without the need for structural connections of the kind that were required in the churches and cathedrals of previous centuries.

On the basis of these developments, Neoclassical architects finally succeeded in separating the outer envelope of a building completely from its loadbearing structure, thus allowing the wall to dissolve into a façade. The bearing function is provided by columns, which are as far as possible enveloped into the interior of the building, while the façade leads an almost independent existence on the exterior (23).

23

Farnsworth House, Plano, Illinois, Ludwig Mies van der Rohe, 1950

An example of the total separation of loadbearing structure and façade is provided by the Farnsworth House designed by Mies van der Rohe. The plane of the loadbearing structure is situated in front of the façade, emphasising the dual-plane design theme. The glass façade situated behind the loadbearing members is very unobtrusive, almost eliminating the visual difference between inside and outside in this highly innovative creation.

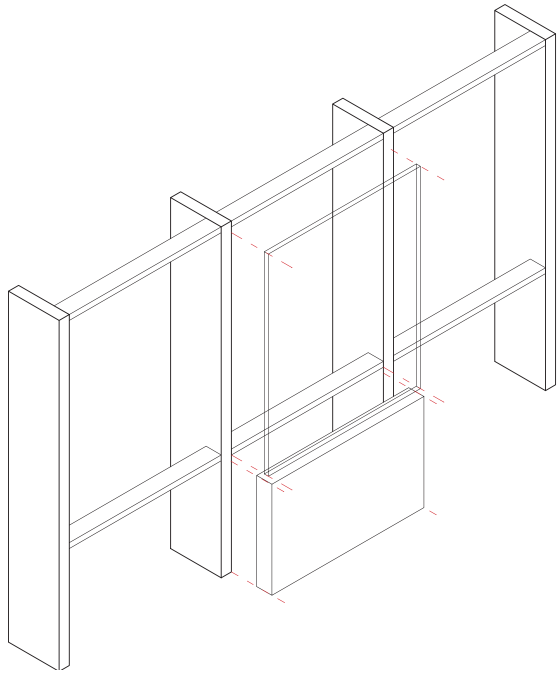
Post-and-beam façade

The further resolution of the wall into façade and loadbearing structure is based on theoretical ideas that were developed at the time, and led in the last analysis to the glass boxes that are such a common feature of present-day cityscapes.

The next evolutionary stage – not so much in chronological as in structural order – was the development of the post-and-beam façade as the logical next step in the dissolution of the solid outer wall. This system consists of storey-high posts linked by horizontal beams. The gaps between successive posts and beams can be made to perform various functions, such as for cladding, lighting and ventilation (24, 25). In these standing post-and-beam façades, the posts serve not only to transfer the wind forces and self-weight of the structure to the ground but also to provide support for the cladding and other functions.

24

Post-and-beam façade
Post-and-beam façades consist of storey-high vertical posts linked by horizontal beams. The spaces between these members house the appropriate functions.



25

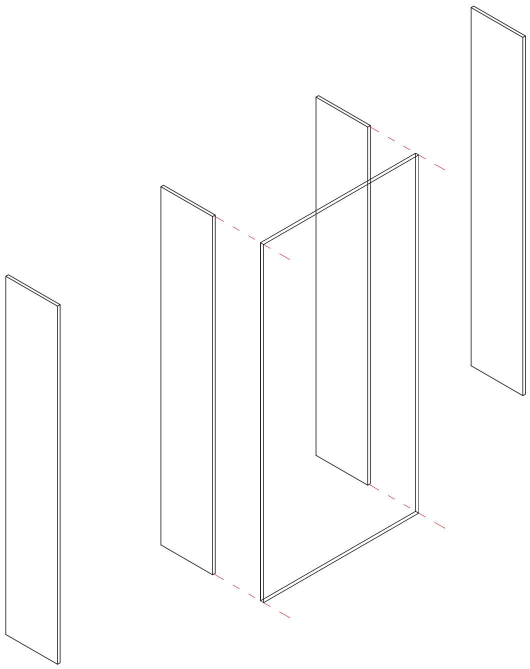
Library, Delft University of Technology, Mecanoo, 1998
Post-and-beam system used in the new library at Delft University of Technology, consisting of vertical post and horizontal beam elements. The panes of glass are mounted in external frames.

Post façade

Apart from pure post-and-beam systems, post systems and beam systems (where tie rods are used to bear loads) have also been developed. The objective of these variants is always to increase the degree of openness, thus improving the transparency of the structure. In post systems, the structural limit is determined by the maximum permissible distance between posts (26).

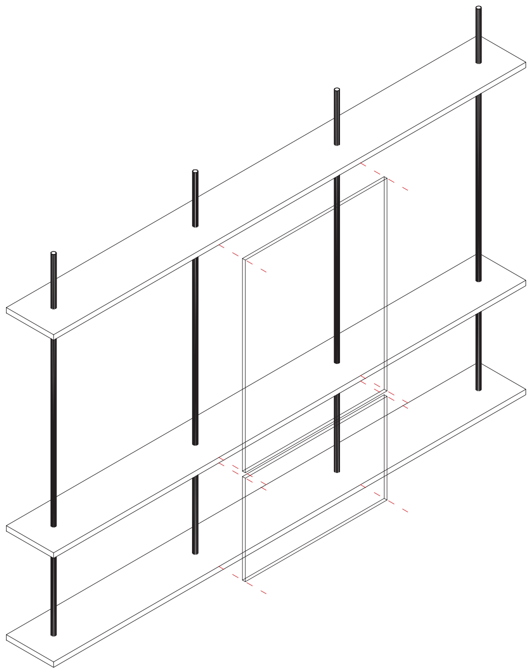
Beam façade

When the construction is reduced to using only beams instead of a standing post-and-beam system (29), the result is a suspended system (27) where loadbearing capacity comes from above to reduce structural mass and to avoid exposing structural elements to buckling. Such systems generally require heavy-duty tie-rod structures mounted near the roof to bear the entire weight of the façade. The beams only have to resist lateral forces.



26

Post construction
The storey-high posts lead wind loads and the self-weight of the structure to the ground.

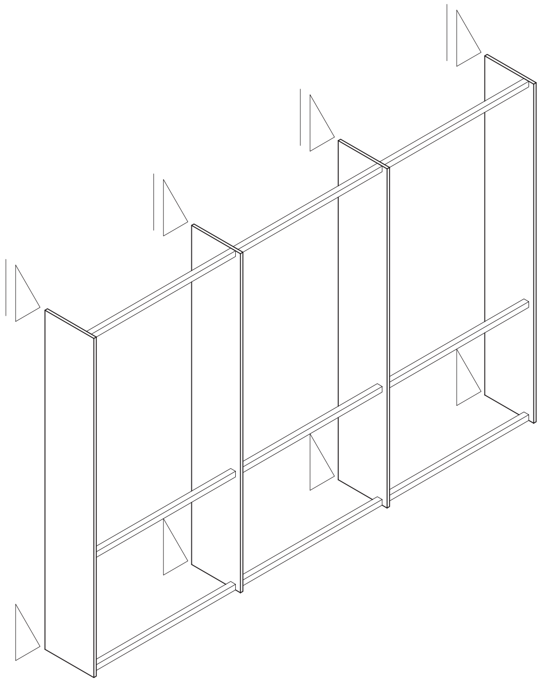


27

Beam façade
Façade constructions in which only beams are used require a vertical suspension system to bear the weight of the façade. Wind loads are here transferred to the ground via the beams.

Curtain wall

From a structural point of view, systems in which the façade hangs from the front of the roof may be regarded as precursors of the development of curtain walls (28, 30). Since the construction is practically independent of the building's main loadbearing structure, the façade can be partitioned almost at will and cladding or glazing used to meet the various aesthetic or functional requirements. The vertical and lateral loads are generally led to ground floor by floor, but special loadbearing elements may be added to bridge longer spans.



29

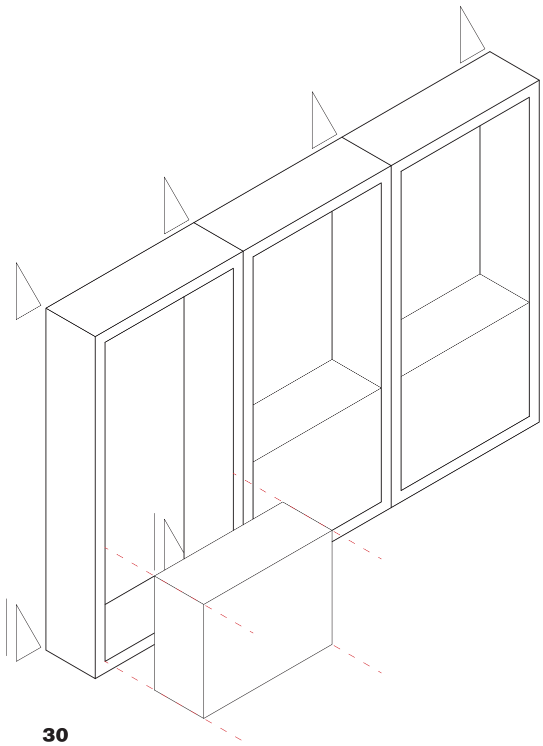
Standing post-and-beam façades

Standing post-and-beam façades usually consist of storey-high modules. However, the problem of the post being subjected to buckling has to be considered.

28

Federal Center, Chicago, Ludwig Mies van der Rohe, 1964

Mies van der Rohe's Federal Center in Chicago is an example of a curtain wall. It reflects the demand for industrially produced façades that at the same time satisfy architectural preferences: the façade is made up of prefabricated elements, assembled by craftsmen on site.



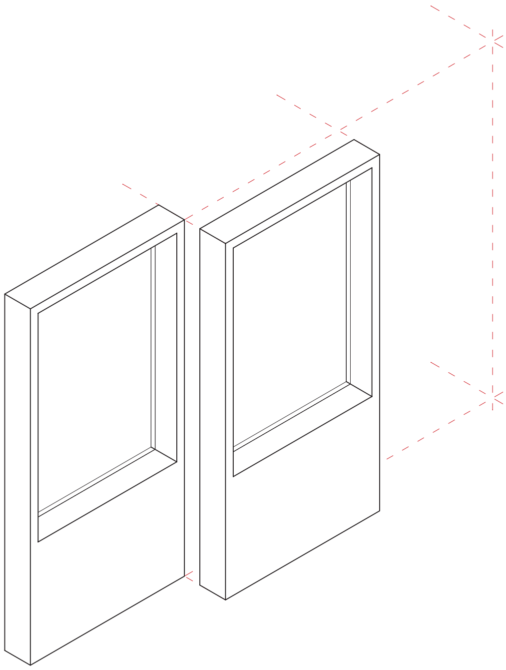
30

Curtain wall

Unlike pure post-and-beam systems, curtain walls are suspended from above with the aid of tie rods. This approach has the advantages of avoiding buckling in the posts and of a large degree of independence from the main structure of the building.

System façade

The curtain walls used at the moment may be divided into stick and unit systems (31). Depending on the type of construction, it may be possible to prefabricate various elements of the wall and assemble them on site, or to prefabricate the entire system wall off-site and install it as a whole. Its advantages are a guaranteed production quality, rapid assemby and low labour requirements on site. Unitised systems have become particularly established in the area of high-rise façades (32), since here units are used in a highly repetitive manner and can be mounted from the storey above with the aid of a crane. For lower buildings with easy access around all sides of the building the consideration should be whether a unit system façade offers advantages in terms of the building process and progress.



31

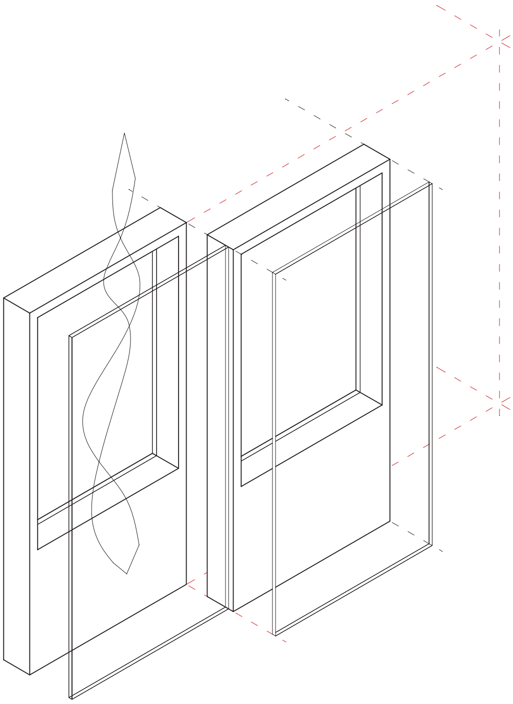
System façade
System façades, unlike post-and-beam systems, can be fully prefabricated and mounted on site by a small labour force.

32

Westhafen Haus, Frankfurt, Schneider + Schumacher, 2005
This system façade consists of storey-high façade elements mounted on an external frame, together with glazing and ventilation ducts built into the vertical posts. The separation of the façade from the building's loadbearing structure by means of the supporting elements behind the façade is distinct.

Double façades

One of the interesting developments that may be observed at this time is the rise of the double façade (33) resulting from the shift of various functions related to the interior functions of the building immediately behind the façade. For example, instead of installing ventilation systems in the building, the ventilation can be provided by thermal insulation between the two layers of the façade. On the basis of experience, the initial variants of this concept have developed into ventilation systems encompassing one or several stories. The initial euphoria concerning the technical and design possibilities of this approach has been replaced by a more pragmatic approach on the basis of greater understanding of the mechanisms underlying the effects produced. As a result, double façades now tend to be used only when called for. There is no need for double façades on all sides of every new building. Under certain circumstances, however – e.g. high levels of street noise, high wind loads or increase in building height – such façades may be the appropriate and economical solution (34).



33

Double façade
A double façade is obtained by adding an extra layer of glazing outside the façade to provide the building with ventilation or additional soundproofing. This system may be realised in various ways, depending on the functions desired and the requirements made on the façade.

34

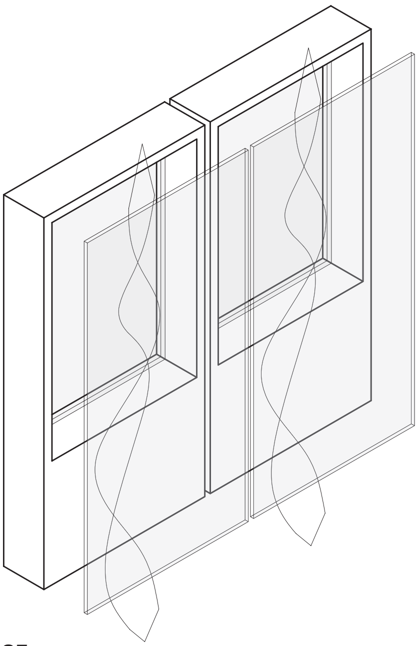
Single and double façade: Triangle Building, Cologne, Gatermann + Schossig, 2006
An example of the façade for a high-rise building offering different functions depending on the requirements. The single façade may be seen on the right of the picture, while on the left an additional layer of glazing has been added to create a double façade with a ventilated space between the two layers.

Second-skin façade

On the basis of present knowledge of the underlying principles, four main types of double façades may be distinguished. The first variant, known as the second-skin façade, is obtained by adding a second layer of glass over the entire outer surface of the building (35, 36). This has the advantage of technical and structural simplicity and the fact that it does not involve a large number of moving parts since the outer single layer of glass is simply mounted on the inner insulated glass façade structure. The disadvantage is that it offers few possibilities of controlling the interior environment of the building; there is thus an attendant risk of overheating.

Box-window façade

The second variant embodies the above-mentioned principle of the box window, by including storey-high façade elements in the system, which individual users can open at the top and the bottom (37). The advantage of this model is the freedom the system gives individual occupants in controlling their own internal environment. The disadvantage is that the freedom given to one occupant may have an adverse effect on the conditions experienced by another, since e.g. the exhaust air from one floor can influence the quality of the incoming air on the floor below. This problem can be avoided by staggering the ventilation inlets and outlets.



35

Second-skin façade

A second-skin façade is produced by adding an external layer of glass to the inner façade. This has the advantage of being easy to construct but the disadvantages of limited control possibilities on the interior and, in the case of high buildings, the attendant risk of overheating.

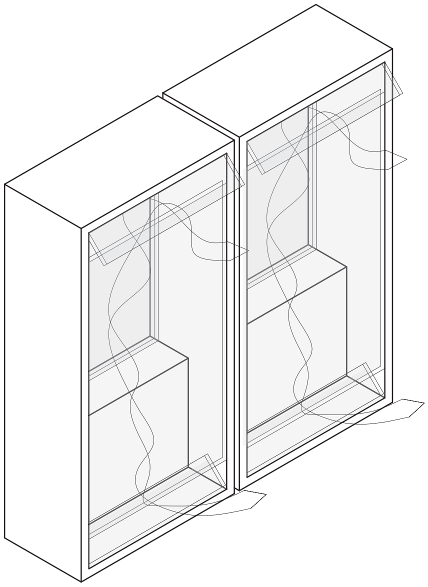
36

Box-window and second-skin façade

On the left we see a window element added on the inside to form a box-window façade, while on the right an early example of a second-skin façade may be seen. This has been created by adding an additional layer of glass outside the basic façade.

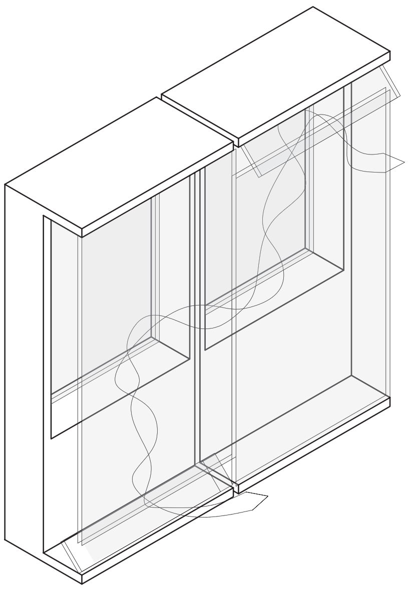
Corridor façade

To deal with the problem of interference between the ventilation systems at different levels, the third variant – the corridor façade, with staggered air inlets and outlets – was developed. This used horizontal baffles at ceiling height in the space between the two skins. However, the uninterrupted horizontal flow of air could give rise to noise interference between neighbouring rooms. It is not always possible to install these baffles later, since this type of façade depends on the presence of horizontal connections (38, 39). Particularly due to the uninterrupted space between the two skins, the building can be naturally ventilated from all directions.



37

Box-window façade
Storey-high box windows with ventilation flaps at top and bottom offer the possibility of individual control.



38

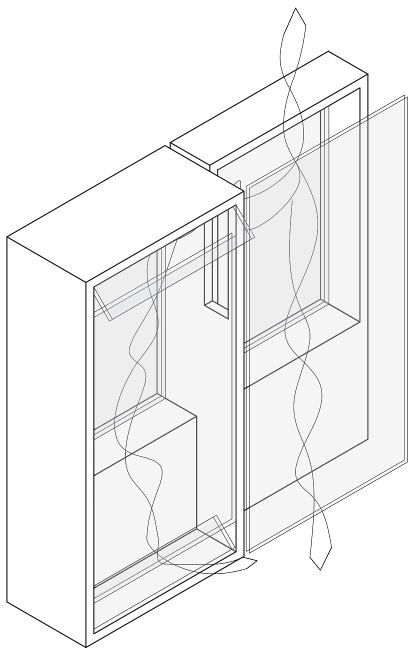
Corridor façade
Corridor façades connect neighbouring double-façade elements in order to permit staggered ventilation of the space between the two skins.

39

Stadttor Building, Düsseldorf, Petzinka Pink und Partner, 1998
An early example of a corridor façade: the storey-high façade elements have rotary timber baffles with insulated glass on the inside and a continuous single-pane glass skin on the outside.

Shaft-box façade

The most effective version of the double façade, but that involving the greatest constructional and control-engineering effort, is undoubtedly variant number four, the shaft-box façade (40, 41). Discrete box windows or other façade elements release their exhaust air into a vertical shaft mounted on the façade and extending over several floors for greater thermal efficiency. The height of the shaft means that a stack effect ensures vertical motion of the air in the shaft, hence enhancing the efficiency of the system. However, in order to allow for controlled ventilation, an adjustable ventilation flap leading to the shaft is required in every box window element.



40

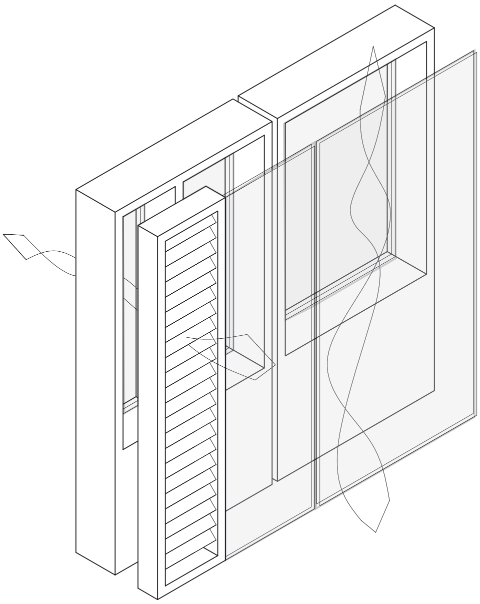
Shaft-box façade
Shaft-box façades, featuring box windows that release their exhaust air into a shaft that extends over several floors, offer a double façade system that requires complex installation but is highly effective.

41

Photonics Centre, Berlin, Sauerbruch Hutton Architects, 1998
Early variant of the shaft-box façade, consisting of vertically separated ventilation shafts in the plane of the façade which merge at the top for effective ventilation of the space enclosed by the double façade.

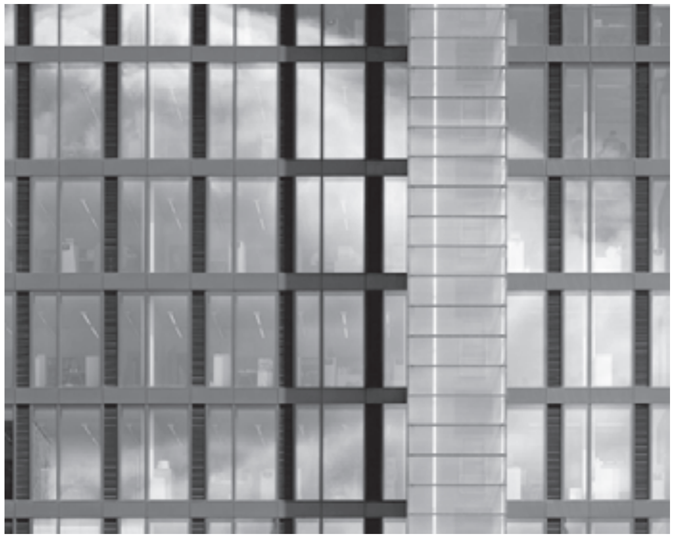
Alternating façade

The double façades described above do not offer complete solutions to the problem of variable ventilation requirements. One approach to this problem was the development of alternating façades, also known as hybrid façades (42, 43). These are basically single-skin façade constructions that can be converted locally to double façades by the addition of a second skin. The objective here is to combine the benefits of the simplicity of the single-skin façade with the buffering effect of the double façade. In summer, ventilation can take place via the single skin area of the façade; an additional exterior grating can provide efficient ventilation during rain or at nighttime. In winter, the double-skin area of the façade can be used for ventilation by using the warmed up air from the cavity between the two skins to ventilate the interior. During summer, this area can be opened to prevent overheating of the cavity.



42

Alternating façade
In alternating façades, a second skin is added locally to a single-skin façade construction to provide the benefits of the buffering effect of the double façade in the areas affected. A grating can be mounted in front of the single-skin areas to allow for ventilation during rain and at nighttime regardless of weather conditions.



43

Debitel Headquarters, Stuttgart,
RKW Architektur + Städtebau, 2002
RKW worked together with Transsolar Climate Engineering to develop an alternating façade for the Debitel head offices in Stuttgart. Different parts of the façade in this building were built as single-skin façade with a permanent louvre layer, single-skin façade with a louvre layer behind it and double façade.

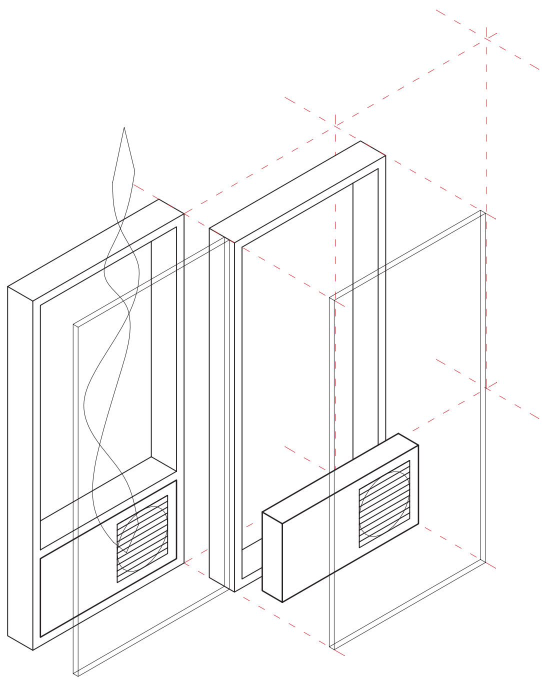
Integrated façade

The idea of the double façade underwent consistent further development by integrating functions other than ventilation, such as air-conditioning or control of lighting levels, in the façade. The resulting system was then generally called a 'modular façade' or 'hybrid façade' (44, 45). When taken to the extreme, it offers the possibility of divesting the building itself of all functions apart from that of bearing its self-weight and incorporating the enclosure function as well as all environmental-engineering functions within the façade. This constructional approach could thus engender a hitherto unknown synergy between façade construction and internal environmental control engineering, leading to a fundamental change in building design. Instead of the old core-oriented approach, a number of essential functions are now transferred from the core to the façade. Several such concepts have been developed by system suppliers to date; however, due to the necessity to make according decisions very early in the design process, the market is hesitant to employ these systems, even though the high degree of prefabrication of integrated façades makes them advantageous.

44

Post Tower, Bonn, Helmut Jahn, 2003

Helmut Jahn worked together with Transsolar Climate Engineering to develop one of the first hybrid façades for the Post Office Tower project in Bonn. Environmental-control modules built into the top part of the façade could be controlled locally as individual units.



45

Integrated façade

The integrated façade incorporates not only ventilation functions as described above but also active environmental-control or lighting components.

During the design of the Lloyd's building in London in 1978 Mike Davies, a colleague of Richard Rogers, developed the concept of the 'polyvalent wall' – a façade that apart from the classic functions of sealing and insulation can also assume other functions such as environmental control, ventilation and individual control of lighting. Consideration of current developments in the hybrid façade shows that we still have a long way to go to reach the ideal polyvalent wall envisaged by Mike Davies. Apart from the above-mentioned limitations associated e.g. with the double façade (46) and the technical problems associated with the construction, operation and logistics of the modular façade, it may be argued that concentrating exclusively on improving the glazing is a dead-end approach: if one tries to incorporate all functions in the glass, problems still remain in the design of a particular building component or the choice of the best building material. At present, a more sensible philosophy would seem to be the separation of functions into various levels and their incorporation within various building components, which are then ultimately combined in the modular façade (47).

46

Stadttor Building,
Petzinka Pink + Partner, 1998
An early example of a double façade: the exterior glass envelope protects the interior timber façade.

47

debis Headquarters, Renzo Piano, 1997 and Daimler-Chrysler Building, Hans Kollhoff, 1999, Potsdamer Platz, Berlin
The appearance of these façades – glass or solid – is quite different while function and use are similar.