English Summary

The façade of a building and its adaptability to different climatic situations outside the building has a huge influence on the energy costs of the building and the climatic conditions within the building. Guaranteeing agreeable interior conditions while using as little energy as possible places high demands on the openings which control and regulate the exchange between the external and the internal atmosphere.

Ventilation in particular provides potential for cutting costs and at the same time raising the comfort level within a building. The opening mechanisms in use today lead to energy losses and a lack comfort due to their methods of operation. Optimised ventilation together with improved insulation provide the starting point for this new and already tested solution: A vertical sliding mechanism with opaque, highly insulating elements allows for natural ventilation.

The vertical sliding mechanism offers many advantages when used in building shells. Large format sliding mechanisms in combination with the increased weight per unit area of modern multi-pane insulation glass results in high loads on the framework construction and window hardware. Thus, their use is only conditionally suitable in applications with moving opening elements. The traditional combination of ventilation, lighting and a view afforded by the window located on closed wall panels is thus placed in question.

In contrast, the use of highly heat-insulating panel elements facilitates the construction of lighter opening ventilation frames in the façade. When combined with large-format fixed glass comprising multi-pane insulation glass with a high heat penetration resistance in the place of opaque wall panels, the functions are entirely restructured. This restructuring enables the targeted and thus more economical use of materials and can make an important contribution to the improvement of energy and material flows through the building shell.

The aim of this assignment is to develop an opening element which provides new possibilities for natural ventilation in conjunction with the vertical sliding mechanism and the use of opaque opening ventilation frames. During the assignment research, it has become clear that extensive scope for development exists in contrast with the common, vertically sliding systems - in particular with respect to the mode of operation.

The project is divided up into three areas of activity:

Initially, a requirements analysis is researched and analysed on the basis of historic and current examples of vertical sliding windows, in particular with respect to operation and effectiveness. With the aid of a step-by-step selection process, the performance of theoretical possible configurations of vertical sliding systems is assessed and the potentials estimated accordingly. Capability characteristics for an improved opening element are defined as a result of the theoretical assessments and with respect to the weaknesses detected in the available systems on the basis of the analysis.

Computer simulations were conducted in parallel with technical developments, in order to enable the evaluation of the ventilation characteristics of the solution method. In order to assess the findings, a test rig was set up with a 1:1 scale and comparative measurements were obtained under real conditions. The simulations and the measurements both confirm the advantages of the ventilation element over conventional opening formats.

In order to harmonise findings for the development of a prototype, variants are developed for the technical implementation of the solution method and assessed using working models.

This process takes place in close exchange with cooperative partners from the fields of façade and mechanical engineering.

The development work leads ultimately to the invention of a new type of opening mechanism and to the construction of a prototype with the predefined performance characteristics. This is successfully put through the first trials and durability tests which are a prerequisite for an introduction to the market.

Requirements analysis and definition of the performance characteristics

In a theoretical preliminary test process, a range of sliding pattern variants were compared and an estimate of potentials conducted.

If one combines these results with the market research findings, one discovers that the market does not offer a simple configuration with a two-part sliding mechanism above the breast height which conforms with the following performance characteristics:

Double-split opening for infinitely variable constant ventilation.

- Full opening at mid-height for shock aeration and view.
- Manual drive with intuitive operation.
- The vertical slide element comprises a double leaf with counter-directional coupling of

the elements. It is possible to suspend this coupling if the user prefers. It is therefore possible to slide the elements synchronously or to move one element independently of the other.

During the next stages of the project, computer simulations and measurements are carried out in order to estimate the ventilation characteristics of the solution method. The vertical sliding element is compared with a conventional tilt-in sash. Whilst it is possible to fully open the vertical sliding element to provide ventilation throughout summer days, a conventional window can only be placed in its tilted position due its the geometrical space-consuming characteristics.

Simulations

For the summer ventilation case, zonal thermal calculations shall first be used to obtain characteristic values across one entire day for the room temperature gradient, the

perceived temperature and the air exchange.

The results show that the vertical sliding element fares better than the tilt-in sash in the temperature values comparison: Working hours with a perceived temperature of over 30°C occur half as often with the vertical sl iding element.

In order to achieve a reduction in the room temperature to below the external temperature, additional scenarios are simulated with the activation of a thermal mass as an additional active system. In combination with this measure, the vertical sliding element is

able to attain superb atmospheric room conditions, because it is easy to motorise and can thus be utilised in conjunction with a superior building control system.

With the aid of high resolution CFD simulation, the first scenario examined is that of constant ventilation in conjunction with the summer case, during working hours and at night.

At the selected observation time points, the temperature layers in the room and the internal and external temperature differences with the tilt-in sash and the vertical sliding element balance themselves to such an extent with constant ventilation, that the

natural drive for the air exchange is largely neutralised. The effectiveness of the natural
drive forces at the start of a ventilation sequence are particularly clear with the simulation results for the winter ventilation case.

When examining the ventilation in winter, a decisive advantage of the vertical sliding element is highly apparent: The user is able to intuitive set infinitely variable opening dimensions as respectively appropriate. This facilitates natural ventilation without resulting in restrictions to comfort, even with the coldest of external temperatures.

Diagram 6 shows the massive propagation of cold air after opening the tilt-in sash window, whilst the sliding element enables sufficient air exchange without affecting comfort

The results of the simulation show that the vertical sliding element permits a broad spectrum of ventilation possibilities, due to its demand-orientated air dosage. Thus, the maximum double-split opening is superior to the tilt and turn window for night-time cooling, whilst a minimal opening crack is also very effective for targeted natural ventilation with cold external temperatures.

Measurements

In order to test the results under real conditions, measurements were carried out on a test rig with a 1:1 scale at the Biberach Technical University.

During a short observation period, wintertime ventilation with the vertical sliding element is compared once again with the tilt and turn window, with the same ventilation profile selected in both cases.

The air speed and room temperature are measured on the test rig and the air exchange
is calculated on the basis of the discharge of a measuring gas introduced beforehand.

It is apparent here that a higher level of air exchange takes place via the double-split opening of the vertical sliding element despite a lower mean air speed, and that greater ventilation effectiveness is thus achieved.

The measurements confirm the conjecture, that the observation of the ventilation behaviour over a shorter period of time shows much clearer differentiation between the opening formats than is apparent over longer-term observations.

Technical workings and construction of the prototype.

The technical workings are based on an empirical process.

The solution methods are checked on a step-by-step basis using the working models.

The findings are incorporated throughout a constant development process and serve to harmonise the technical solution upon which to construct the prototype.

Firstly, the operating states are defined for the opening element. These specify decisive key positions for the ventilation and are derived from the performance characteristics formulated during definition of the objective.

The following three operating states are specified as the main operating states:

Closed state (A).

- No ventilation is taking place.

Symmetrical double-split opening (B).

- An infinitely variable opening height from the minimum to maximum double-split opening can be set. In this position, the
individual regulation of the ventilation intensity as defined by the user is focal.

Full opening (C).

- A large, continuous opening cross-section at medium height should be produced in order to cater for the needs of the user
for shock aeration and external supply.

In order to provide a detailed analysis of the movement stages and the basic technical
sequences, the complete motion is divided up into individual steps. It is possible to differentiate between four movement stage variants for the changes between the three main operating states.

It is possible to draw conclusions on the operating and technical requirements with the aid of this systemisation and on the basis of the complete motion performance characteristics.

The technical foundations for the constructural implementation are developed in paral-
lel with the analysis of the movement stages.

Seal plane

- Weight compensation
- Coupling
- Operation
- The window panes are in a closed state on a single plane because a straight, continuo-
us seal is favoured due to the beneficial physical structural characteristics. The weight
compensation and the coupling of the two panes, in conjunction with the operation, provide the focuses of the next stages of technical development.

The following table conveys a simplified picture of the suitability of an independent or dependent weight compensation system for the coupling types.

On this basis, an estimation of the design variants is carried out with respect to opera-
tion and serviceability and a selection of solution methods results.

Initially, assessments concentrate on those solution methods in which the weight compensation of the two panes takes place independently. In the case of the associa-
ted working models, weight compensation is planned in the form of springs, whilst the coupling configuration comprises a switchable rack and pinion system. An arm moves
the lower panes to the sliding level.

The basic principle is transferred to the model, although it is apparent that the venting action is elaborate and likely to incur high costs.

With conventional vertical sliding windows, the process of opening the lower pane takes place via a cranked guide slot.

As this principle cannot be combined with spring-based weight compensation, the conversion of force for weight compensation is examined on a subsequent working model. The two panes are suspended on steel cables which act as tension members. They are moved as the cables are reeled onto shafts by operating cords.

This fundamental technique is similar to that applied with a roller blind.

This build type facilitates the direct transition between all of the desired operating states. The technical and economic outlay appears to be calculable because the drive
and weight compensation systems are already in common use. An advantage of the cord operation is that it is detached from the window as a moveable part. However, user comfort is not entirely satisfactory because the user must operate too many ele-
ments, in the form of the handle and the two cords.

In order to be able to utilise the advantages of the cord, whilst achieving a simplified operation, the process is reduced to one cord. This is made possible by driving the two panes with one cord, with the types of coupling and weight compensation chan-

ging automatically during the movement process.
Full opening is the result of the continuation of the opening process beyond the maximum double-split opening. Thus it is not necessary to set the operating state required when starting from the closed state. The panes are initially counter-directionally coupled. In the maximum double-split opening position, the counter-directional coupling changes to a parallel coupling. With the weight of the panes in this phase no longer reciprocally balanced, additional weight compensation becomes effective.
The basis for the technical implementation of this design is an automatic switching of the type of coupling. With conventional vertical sliding windows, the dependent weight compensation is produced with a direct directional change of the cable connection, meaning that no change in the type of coupling is possible. Only when the two panes are suspended from the same shaft, i.e. an indirect coupling with the shaft, is it possible to achieve an automatic transfer from counter-directional to parallel coupling upon correct selection of the winding.
Prototype
This principle, comprising the weight compensation and coupling of the two panes of a vertical sliding element, presents an entirely new innovation and provides the decisive foundations for the build type and functionality of the first prototype.
By activating the handle on the lower pane, this is released and subsequently tilted. From this position, it is vertically shifted to a cranked guide slot. The pane is suspended on a steel cable and is raised by winding the cable onto a shaft. The rotational movement required for this is produced by the user activating a drive chain. The top pane is also connected with the shaft via a steel cable. As the lower pane is raised, the top pane‘s cable is also unwound and it is lowered in a counter-directional synchronous movement. The panes are now reciprocally counter-balanced. In the twinned position, the upper pane‘s steel cable is fully unwound and the maximum double-split opening produced. If the rotational movement is continued, the upper pane is hoisted once again as its suspension cable is wound up in the opposite direction. The opening procedure for the lower pane continues and the pane moves synchronously upward. The weight compensation for both panes is provided by transmission gearing.
Design drawings have been generated with the cooperative partner on this basis and the first functioning prototype of the opening element produced.
The prototype is to be presented to the public on the „Holzbau der Zukunft“ [Wooden Construction for the Future] exhibition stand at the BAU 2007. Its production demonstrates that it is possible to further develop the vertical sliding mechanism for improved, natural ventilation. In contrast to available systems, the newly developed movement mechanism enables the user to operate an intuitive system to enjoy ventilation in accordance with their needs, with the double-split opening and automated changeover to full opening,
Even during the investigative phase, contacts with interested parties resulted in actual build applications being considered, due to the specific advantages of the newly developed element. In the event of a real implementation, the opening element would be adapted to the object-specific requirements and subjected to outstanding tests for ap-

provals required prior to market introduction. According to current estimations and as one would expect, the costs for the opening element lie above those for a tilt and turn window of the same size. It would thus appear important to present the advantages in an economically assessable manner, and to publish these for the target groups. After initial series production experiences and an increasing product spread, one would anticipate that a reduction in the manufacturing costs would follow.