NEW OPTIONS FOR THE ENVELOPE

Applications for modular pre-tensioned textile frames

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ABSTRACT

The goal of designing the right building envelope in terms of thermal, structural and weather performance commensurate with the building's geographical position is a formidable goal. Adding individuality, value and design finesse, whilst remaining within budget, can be more challenging.

The separation of performance and appearance in terms of inner and outer layers is an established concept in performance clothing design. Using technical textiles on the outer skin offers exciting opportunities to create outstanding sustainable façades, with flowing or transformative properties and optimal climatic performance.

The established use of system technology in curtain wall design is well accepted and industry system platforms form the basis of most standard as well as many bespoke façade concepts. The ability to utilize pre-tested system components and combine them with modified profiles or gaskets provides the opportunity to realize maximum physical performance, optimize costs, reduce lead times, as well as to reduce development risks.

Through the process of "systemization", the components needed for the effective and broader application of textile solutions in façades can move into the mainstream of façade construction and so create new opportunities to improve the technical performance and physical appearance of buildings. The concept of frugal product design provides rationalization effects, which further enhance the cost effectiveness of systemized textile applications in both developing and developed markets, for new and refurbishment projects.

Finally, frame systems create fresh opportunities for new functionalities within the façade. The addition of dynamic elements such as operable louvers and shutters in combination with intelligent controls and or the use of innovative lighting and printing techniques completes the outlook on how the textile outer skin is evolving.

ZUSAMMENFASSUNG

Eine Fassade zu entwickeln, die allen Anforderungen in Bezug auf Wärmeschutz, Statik und Witterungsschutz gerecht wird, ist eine anspruchsvolle Aufgabe. Werden darüber hinaus Aspekte wie Individualität, Wertigkeit, Design und Budget mit einbezogen, kann es eine wahre Herausforderung werden.

Die Trennung von Funktion und Gestaltung in Form einer inneren und äußeren Schale ist bei Funktionstextilien bereits etabliert. Die Verwendung technischer Textilien in der äußeren Schale erweist sich als eine sehr gute Möglichkeit zur Schaffung nachhaltiger Fassaden mit fließenden oder transformativen Eigenschaften und bestmöglicher klimatischer Leistungsfähigkeit.

Die Nutzung von Systemtechnologien ist im Fassadenbau weit verbreitet. System-Baukästen bilden dabei in der Regel die Basis für Standard-Fassadenkonzepte; häufig werden sie ebenfalls als Grundlage für kundenspezifischer Sonderfassaden verwendet. Durch die Kombination vorgeprüfter Systemkomponenten mit modifizierten Profilen und Dichtungen können optimale bauphysikalische Eigenschaften erzielt, Kosten optimiert, Lieferzeiten verkürzt sowie das Entwicklungsrisiko verringert werden.

Der Prozess der „Systematisierung“ kann dazu beitragen, dass jene Komponenten, die eine effektive und breitere Anwendung textiler Fassaden-Lösungen unterstützen, sich im Markt etablieren und dass sich dadurch neue Möglichkeiten zur Verbesserung der technischen Leistungsfähigkeit sowie des äußeren Erscheinungsbildes eröffnen.

Das Konzept der „FRUGAL-Products“ führt zu Rationalisierungs-Effekten, die die Wirtschaftlichkeit textiler System-Anwendungen in Schwellenmärkten und in entwickelten Märkten, sowohl im Neubau als auch bei Modernisierungsprojekten, erhöhen.

Schließlich eröffnen Rahmen-Systeme Chancen für erfrischend neue Funktionsweisen innerhalb von Fassaden. Das Hinzufügen dynamischer Elemente wie beweglicher Lamellen und Fensterläden kombiniert mit einer intelligenten Steuerung und/oder Nutzung innovativer Beleuchtungs- und Drucktechnik vervollständigen den Ausblick auf die Weiterentwicklung äußerer textiler Hüllen.

KEYWORDS

Textile facade; frugal design; climatic design; sustainability; solar shading

INTRODUCTION

There are basic requirements a façade must fulfill: thermal performance, weather tightness and affordability are just a few examples. The façade has to be structurally sound, allow adequate daylight to pass into the inner space whilst appropriately reducing the effects of solar irradiance i.e. allowing provision for sun protection. Glare protection, at best a serious nuisance, or reflections from the façade itself, which have implications for surrounding areas are also factors, which need consideration during the design and planning process.

The question of appearance is not strictly essential to the buildings performance; however, throughout history increasing affluence and the availability of capital has allowed humankind to go beyond basic functional requirements, allowing the creation of trend-setting iconic buildings. The design restrictions which angular materials such as steel, glass and concrete pose together with the strict doctrine of form following function lessened the options for the façade leading to a global harmonization of appearance in the last century. In the new millennium, the onset of new design technologies, advances in material science and the shift of economic power is presenting new architectural opportunities. Whether form actually has to follow function is a question which today more difficult to answer.

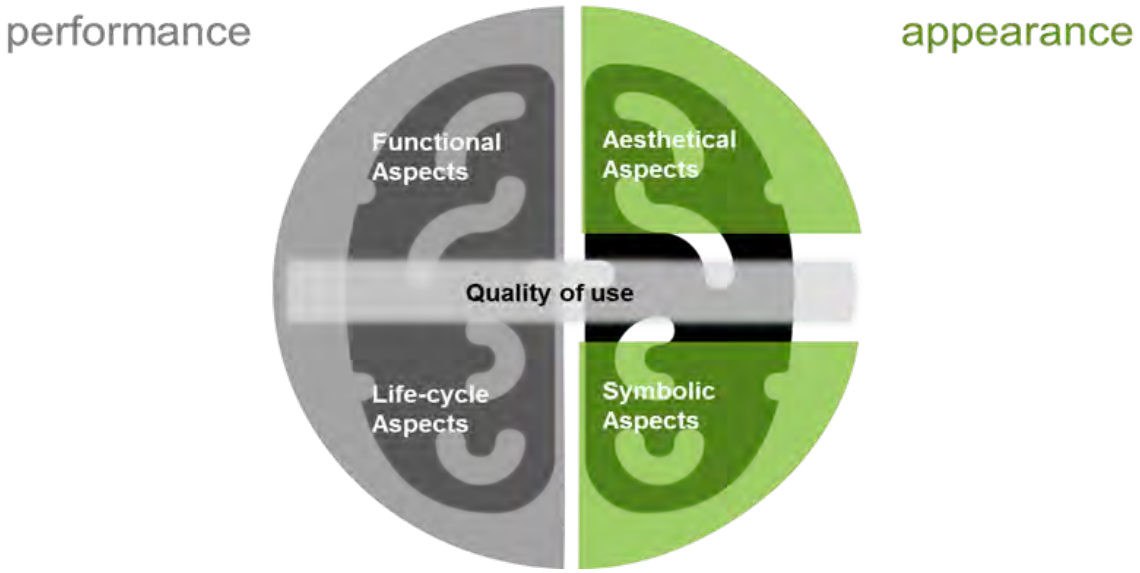

Figure 1: Façade perception, like or dislike, a cognitive representation, based on Gros 1976 [1]

The appreciation and evaluation of everything seen and experienced occurs on both an emotional and a rational level and is a vital part of decision-making. Performance aspects tend to be fact-based and are generally quantifiable, whilst form, color

and texture stimulates emotional responses. It follows therefore, that the perception of, and the personal experience associated with a particular façade might occur in this way. Emotional responses are generally stronger drivers than logical ones; hence, a subconscious like/dislike decision with respect to a particular façade is likely to come from its appearance rather than its performance! This process is of particular relevance in the retail, hospitality and recreational real estate markets where discretionary consumer choices are prevalent.

CHALLENGES

SUSTAINABILITY, COST AND INNOVATION

The issue of "climate change" has added additional challenges as well as performance requirements to façade design. The energy certification bodies have been successful in raising awareness and rating systems are regarded as a trusted guide to building and façade performance. Legislation also requires energy efficiency and climatic sustainability to achieve minimum levels, although this differs substantially between markets and regions.

These performance factors have led to pressure on building costs whereas the dictate of "build to budget" limits the ability to invest in the "non-essential" emotional facets of the façade, its appearance. As this trend continues, the creation of avant-garde façade concepts may become more difficult to justify unless more cost effective material and fabrication options become available.

Extending the building life cycle as represented in Figure 2, is one of the keys to improving sustainability. Since the speed at which obsolescence occurs is increasing, there is a need to build flexibility into the building's design, allowing for change of use, ownership or corporate branding. This is particularly relevant for the façade, which should remain as adaptable as possible but conversely is traditionally one of the most costly to change.

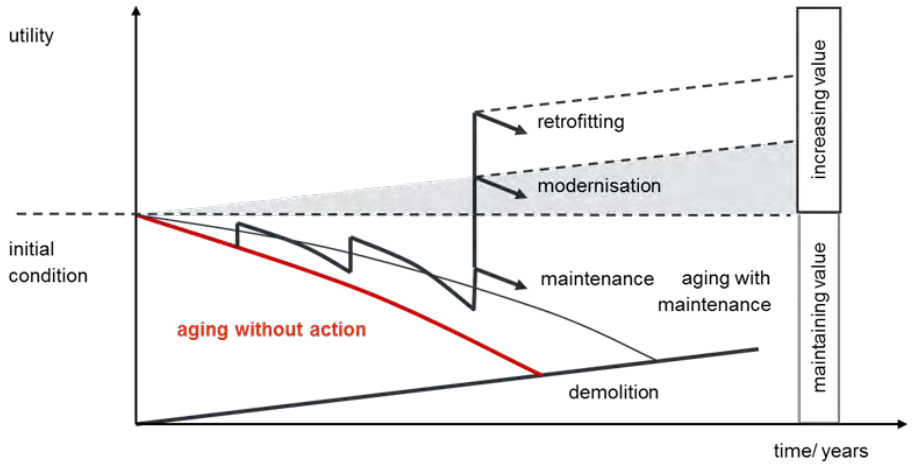

Figure.2: Options for extending the building life cycle, adding value and improving sustainability (Based upon Harlfinger 2006) [2]

Flexible solutions for the outer skin provide an opportunity later in the building life cycle to change use, modify corporate identity or meet new technical or commercial requirements. The ease with which the façade cladding can be transformed is an important factor in ensuring the façade retains a contemporary appearance and the building its value.

The need for higher building differentiation, to identify with and to participate in a particular trend seems to become more relevant with increasing affluence (compared to basic physical requirements). Maslow's hierarchy of needs [3] provides the basis for this assumption; however, the boarders between developed and developing markets are becoming harder to define. It appears that the need for status symbols, whether as real estate or as consumer goods is, anecdotally just as important in new markets as in the developed world. This natural progression reflects itself in the spectacular high-end façade concepts seen in industry publications.

CUSTOMER SATISFACTION

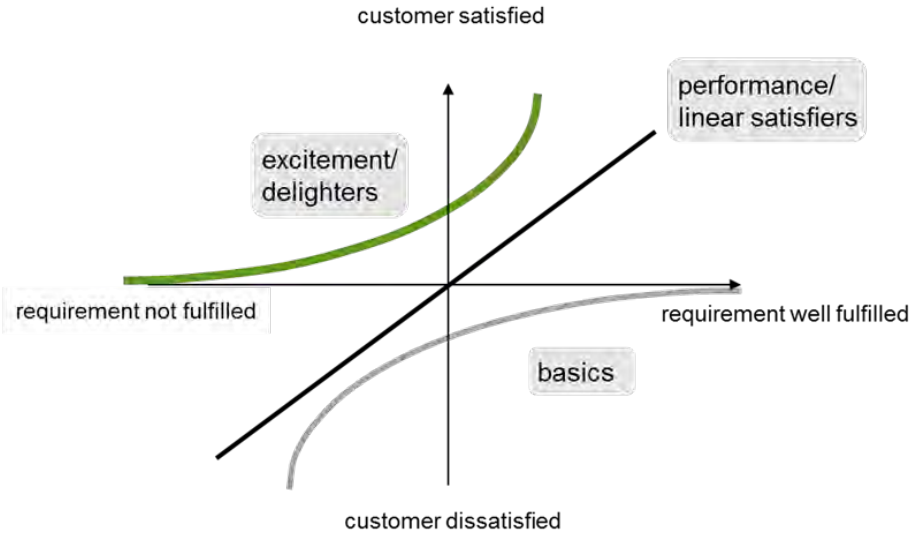

Figure.3: Categorization of product characteristics are relevant for customer satisfaction, Kano [4]

The relationship in the context of “basic” and “delighter” factors and customer satisfaction/dissatisfaction is represented in Figure 3. The fulfilment of basic factors is taken for granted, if however, these expectations are disappointed, the customer will be dissatisfied. Reliability for example, has become a basic expectation and no longer produces a positive emotional reaction, rather the lack of it, can prove very detrimental. Performance factors (energy efficiency and increased technical performance such as solar shading) however are explicitly required and specified in detail. If they are attractive and function as expected, the client will react with specific satisfaction.

The unspoken excitement factors are the real distinguishing features (often design aspects). Customers become inspired by product characteristics that are unexpected, but meet their requirements and taste. It is essential to aim at specific target groups, since these factors work on a subjective level, have symbolic functions such as status and prestige and depend strongly on the sociocultural background of those involved. Individual quality is the key, but this is emotion-driven and following a temporary trend is, by its very nature of short/medium term duration and unpredictable.

FUNCTIONAL CONCEPTS AND PRINCIPLES

An in-depth discussion of performance factors and functional optimization falls outside the scope of this paper. Importantly however, the relative importance of performance factors in the building design will not be the same in all instances. The building’s global geographical location, its local position in relation to other buildings and landscape features as well as its purpose and size have a natural influence on the façade. Cost or budget is then the final and decisive factor in determining to what extent the façade can fulfill or indeed go beyond these fundamental criteria.

VERNACULAR ARCHITECTURE

The Igloo, Figure 4, is perhaps the best example of climate dictated façade design. It is well insulated, robust and made from local materials. By its very nature, it is carbon neutral and can be easily recycled. In the tropics, long roof overhangs protect long houses, Figure 4 from rain and provide shading from the high equatorial sun. These are just two examples of natural building evolution based on climatic and resource availability. The industrial age has enabled architecture to progress beyond these constraints, a process that although offering freedom of expression, imposes demands and responsibilities on the building professions.

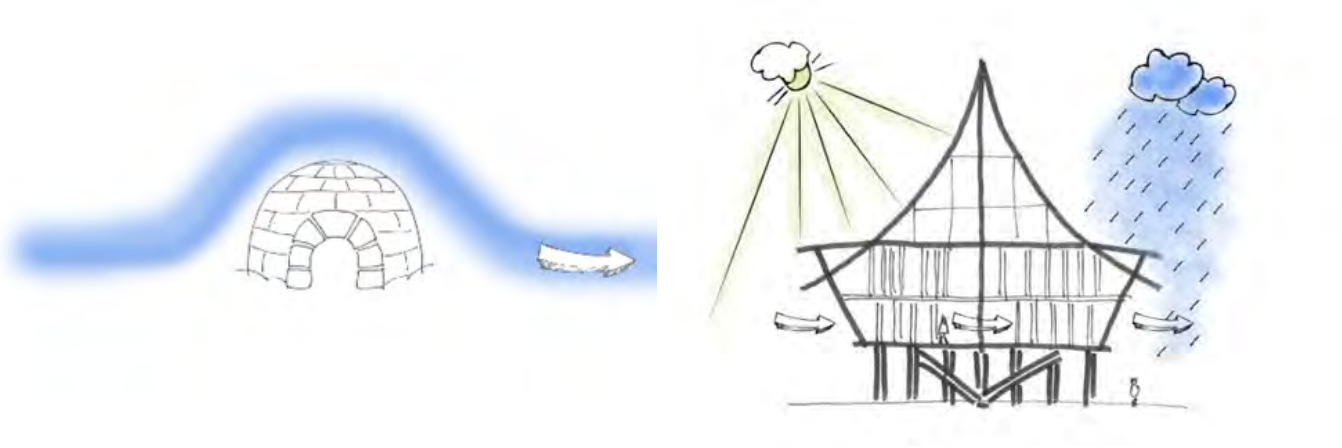

Figure.4: Examples of climatically inspired design; the arctic igloo (left) and (right) the tropical long house

SEPARATION OF PERFORMANCE AND APPEARANCE

The evolution of the curtain wall, i.e. the separation of the façade from the building's structural support, has enabled the creation of buildings, as we know them today. Large glazed areas, a high degree of transparency and with it the opportunity to build the higher and more complex structures now common features in the urban landscape. The negative attributes of these facades are often excessive energy loss and/or solar gain, both of which result in increased energy use whether it be for heating or cooling.

As the industry has evolved, the performance of modern curtain wall and window systems has greatly improved. Thermally broken profiles and insulated glazing units mitigate problems of energy loss via conduction. Solar shading glass, interior and exterior shading systems mitigate solar gain. Ventilation systems and mechanical cooling systems ensure that the building remains habitable throughout the year.

The next level of façade evolution has now taken place. It involves the separation of the façade into zones encompassing performance and appearance. Each has its own set of performance criteria and objectives dependent on the design brief. The first or inner skin is responsible for providing a reliable weather tight envelope, ventilation as well as transparent areas providing daylighting and contact with the environment. Profiles incorporate appropriate measures to achieve thermal performance and can easily fulfill a catalogue of pre-defined project specific criteria.

The outer skin is responsible for the form, structure and color of the façade. It also regulates solar heat gain via its shading function. The use of dynamic shading concepts in combination with sun tracking controls ensures that an optimal balance between shade and natural lighting in the inner space is maintained. Since this is no longer a weather tight barrier, the new outer skin offers a freedom of expression which would otherwise not be possible and enables the outer skin to fulfill its primary function and that of providing formal, aesthetic and symbolic functionality.

EXAMPLES OF EXISTING OUTER SKIN SOLUTIONS

Aluminum louver blades have long formed the backbone of second skin façade design as used on the curtain walling in Figure 5. The problems associated with "the glass box" quickly became apparent and shading solutions using extruded aluminum profiles remain the mainstay of "brise Soleil" architecture to this day.

The glass louvers shown in Figure 5, vertically installed in front of the curtain wall are also able to create interesting visual effects and at the same time act as a self-ventilating temporary double skin providing solar protection. In both cases, a fully automatic sun path tracking and weather responsive control system controls the louvers.

Figure.5: (Left): Highlands University, NM, active aluminum louvers and sun tracking controls. [B] (Right): Municipality of Lund, Sweden, active glass louver blades and automatic sun path tracking. [C] Photos: author

OPTIMIZATION: EFFICIENCY, EFFICACY AND PROFICIENCY

Leaving aside the 2° global warming debate, regulatory factors and the effects of sustainability labels such as LEED or BREEAM, consider the proposition that building costs and the availability of capital determine the propensity of an investor to utilize state of the art technologies. Investors wanting to maximize their return may therefore be reluctant to invest in high cost, state of the art structures since this would reduce their return on investment or minimize their profit on re-sale. This is particularly the case in the developing world, which by coincidence has some of the most difficult climatic conditions and at the same time the biggest demand for new build in the near future.

In construction, the market penetration of innovative solutions is unevenly spread. This may be due to a lack of communication, perhaps budgetary or time and risk constraints acting as inhibitors. One innovative option is the use of textile coverings. These generally have a lower environmental impact (being less energy intensive per square foot to manufacture and re-cycle) than materials such as aluminum or glass. Re-usable textile frame solutions are effective and efficient and they rate well in comparison to other shading options.

	Criteria and material characteristics						
Shading system	Weight + structural	Installation compexity	Colour + Design	Shading efficiency	Transparency	Longevity vs follow on cost	Investment + capital cost
Alu. louvres fixed	■■■□	■■□□	■■■■	■■□□	■■□□	■■■■	■■□□
Alu. louvres active	■■■□	■■■□	■■■■	■■■■	■■□□	■■■□	■■■□
Glass fixed	■■■■	■■■■	■■□□	■■□□	■■■■	■■□□	■■■■
Glass active	■■■■	■■■■	■■□□	■■■■	■■■■	■■□□	■■■■
Perforated sheet fixed	■■□□	■■□□	■■■■	■■□□	■■□□	■■□□	■■□□
Perforated sheet active	■■□□	■■□□	■■■■	■■■■	■■□□	■■□□	■■□□
Woven metal fixed	■■■■	■■■■	■■□□	■■□□	■■□□	■■■■	■■■■
Woven metal active	■■■■	■■■■	■■□□	■■■□	■■■□	■■□□	■■■■
Textile fixed	■□□□	■□□□	■■■■	■■■■	■■■□	■■■■	■□□□
Textile active	■□□□	■■□□	■■■■	■■■■	■■■■	■■■□	■■□□

Figure.6: A comparison between typical outer skin materials and design criteria and characteristics. Ranking 1-low, 4-high. Source: author

The table in Figure 6 shows materials and applications, which commonly provide the basis for unique and expressive outer skins. Their performance in terms of shading and daylighting efficiency can be designed to meet the buildings requirements through the correct application of sun path analysis Figure 7 and the calculation of the shading cut off angle between the

components. The addition of actuators and control systems turn passive facades into dynamic climatic interactive installations. These technical issues have been largely resolved in recent years but the issue of ease of fabrication and cost remains a limiting factor preventing them from gaining wider appeal.

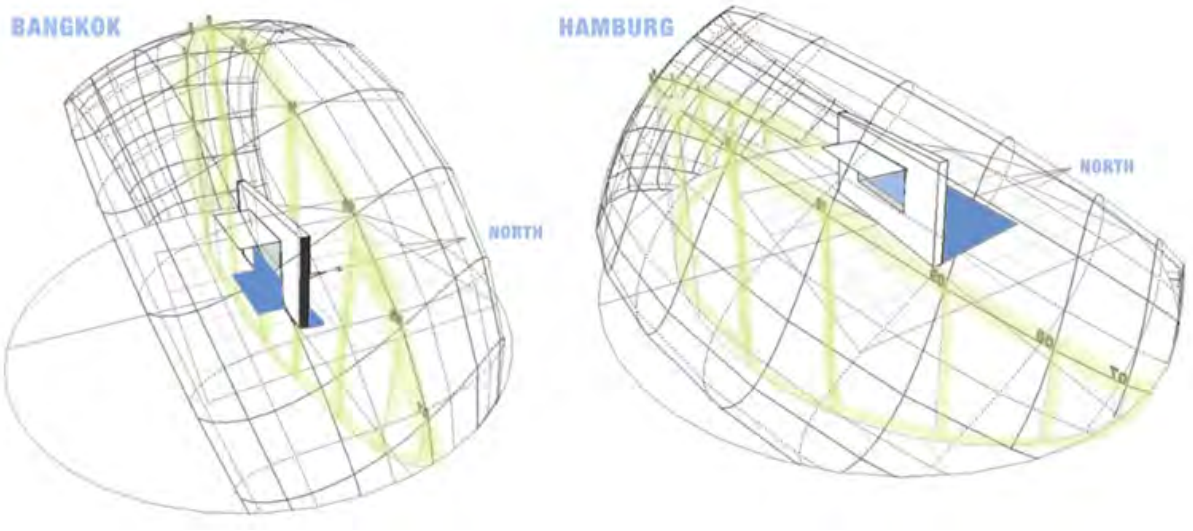

Figure 7: A Sun Path comparison between Bangkok, Thailand and Hamburg, Germany [7]

The fact that metal louvers are difficult to post form, that glass is limited structurally in terms of unsupported span and is physically a high density building material, provides natural limitations to the extent to which prices per square meter can be reduced. The relative cost of the raw material and the relative inability to achieve economies during fabrication and installation means that the market share these outer skin solutions remain ultimately limited.

THE "FRUGAL" CONCEPT, A STRATEGY FOR LOW AND MIDDLE MARKETS [5]

The attributes of "FRUGAL" products are:

F = Functional, R = Robust, U = User friendly, G = Growing, A = Affordable, L = Local

"Frugal" products are often associated with entry-level products whether it be consumer or investment goods targeted at the emerging markets. They target customers' needs in that they offer exactly the mix of USP's required. As budgets are limited, value for money is paramount. They are not just "stripped down" versions of existing products but are tailored specifically to the market need. Affordability is essential to their success. Local availability, ease of use and reliability further enhance their appeal.

In emerging markets, a lack of capital is a major hindrance to improving façade performance and acts as a restriction on the use of new techniques and materials. By comparison, the established construction markets in the developed world also find it difficult to adopt new technology. The relative return on investment and risk aversion act as a break on innovation. Applying "Frugal" concepts to façade construction provides an interesting insight in to how the future might develop.

Any new construction material must establish itself if the goal of mainstream usage is to be realized. Such materials have to be manufactured efficiently and cheaply, offer a good balance of physical performance, low density, high tensile strength, UV-stability, be fire retarding and rate positively in terms of environmental impact. Fabrication and installation needs to be simple, delivering direct cost benefits thus making it an automatic choice for façade applications.

High performance technical textile installations based on system frame solutions appear to provide a way forward. Textiles come in a wide range of colors; weave designs, transparency and texture. They have the required durability, physical and chemical stability to endure decades of use. In short, they provide efficiency in terms of raw material utilization, efficacy in terms of their performance and proficiency in terms of a tried and tested technology.

SYSTEM TECHNOLOGY – CONFORMITY VS. INDIVIDUALITY

Mass production has always been associated with conformity. Whilst being efficient, standard systems are sometimes viewed with skepticism by the architectural profession unless they can provide the opportunity for adaptation.

Figure 8: Conformity vs individuality, building systems provide the basis for rational and economic construction; the architect chooses what he creates. Photo: Schüco

The prerequisite for a systems' success is its ability to replicate a defined standard e.g. water tightness in gaskets. The goal of system technology being, to reduce the complexity of fabrication, provide compatibility between system components and connections and maintain a high level of variability.

System Profiles simplify the planning process. The system manufacturer is able to draw on a wide variety of product applications and this experience, combined with a detailed knowledge of the structural performance characteristics of the system, enable accurate and targeted products and performance specifications to be provided. This reduces the risk of planning errors and accelerates the design and decision making process. This is particularly important where the use of new materials and product innovations is concerned and where a costly or time-consuming learning curve is not an option.

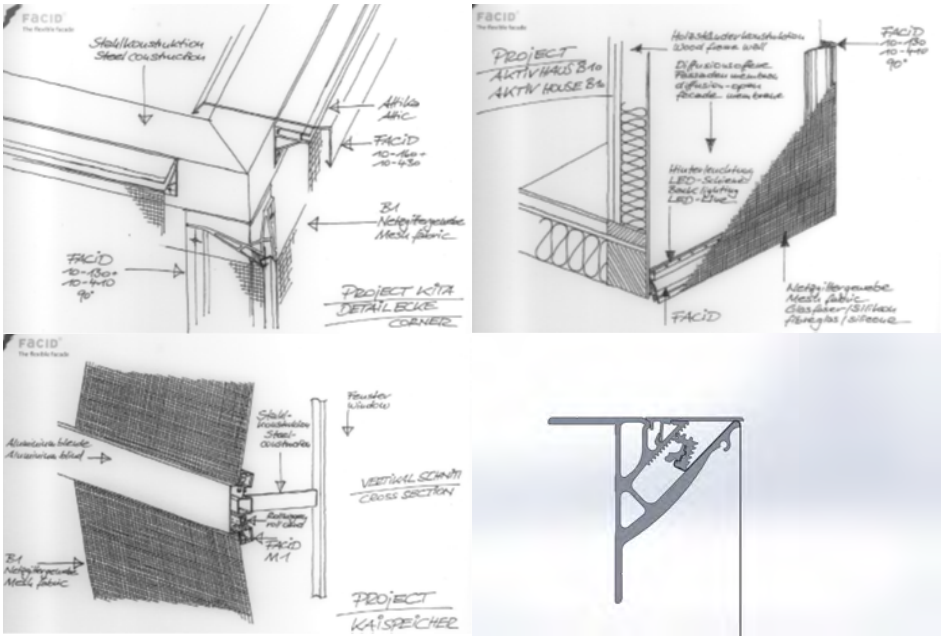

Figure 9: System profiles provide pre-designed solutions for most applications and form the basis for new façade ideas [6]

Globalization adds another level of complexity to system construction; the need create not only solutions for differing climate zones, regulatory frameworks, taste and budgets, but which also allow for differences in working practices. A comparison between a developed and a developing nation for example make this conundrum clearer. A fabricator in Europe has access to automated production facilities i.e. CNC machine tools, together with a skilled (but costly) workforce. Fabrication takes place under optimal conditions and productivity, transport and infrastructure is good. In this environment, a system consisting of a multitude of complex components, each requiring elaborate fabrication and assembly methods can remain cost effective and efficient.

A system, which is fabricated in developing markets, needs to take account of other factors in order to be successful. A general reliance on a low cost, readily available but less skilled workforce and a lower level of production automation i.e. the use of hand tools and semi-automated processes means that the system has to function reliably within these constraints. Interestingly these same system attributes are also beneficial in developed markets as they increase flexibility of response and ease installation, especially important in the refurbishment market.

Figure 10: Example of system frames, which allow simple tooling and fabrication procedures to be used [6]

Irrespective of the market, the application system technology makes it possible to reduce planning time, increase the efficiency of fabrication and simplify installation. The combined effect is to eliminate the learning curve per project, reduce risk, increase quality and so reduce cost.

COMPUTATIONAL DESIGN: PROOF OF CONCEPT AND OPTIMIZATION WITHIN SYSTEM BOUNDARIES

The use of planar frames with pre-defined deformation characteristics can be used as the basis for a parametric outer skin construction. Computational design enhances the process by identifying areas where performance boundaries are exceeded. The process is also used to optimize the frame size and shape, so reducing the number of individual bespoke units. By improving the ability to plan complex structures, automatically accounting for system constraints, optimizing parts and cutting lists, process efficiency is increased and risk and costs reduced.

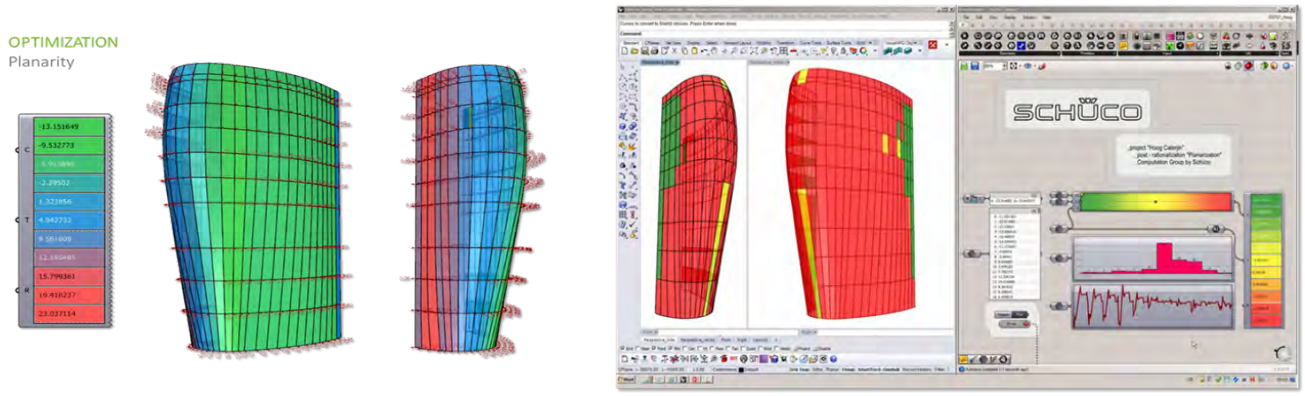

Figure 11: (Left): Example: Computational design tools used to plan and evaluate complex interactions between façade elements. (Right): Example: Grasshopper model. [7]

Textiles have very different structural properties compared with traditional sheet materials. This is reflected in the design of the frame profiles and in the sub-structure required to withstand not only the façade design loads but also the tensioning load itself.

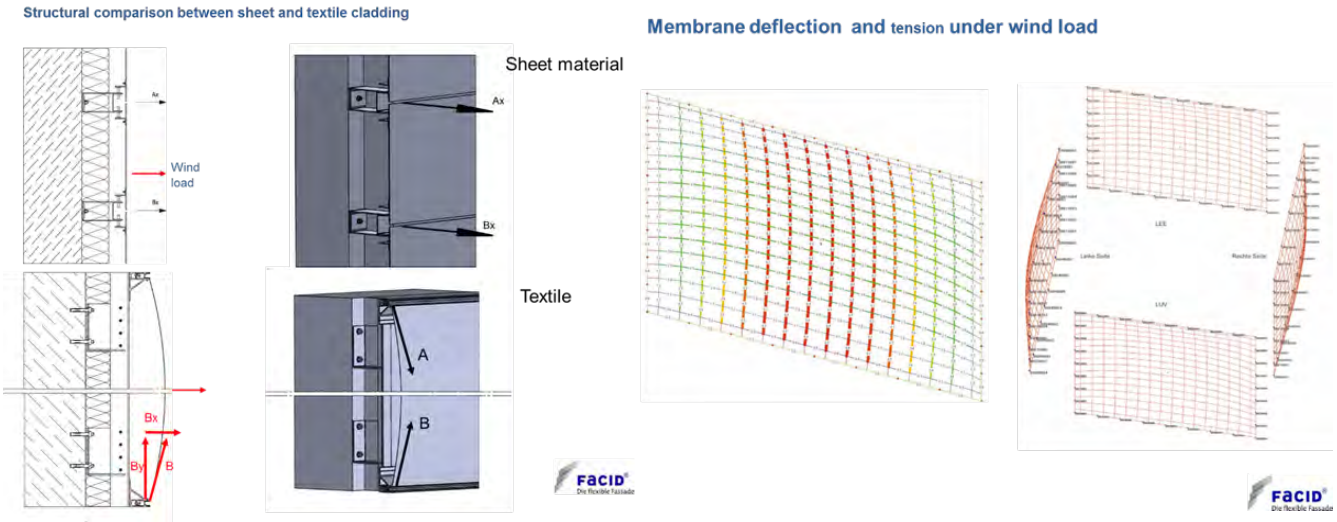

Figure 12: (Left) Structural requirements for frames tensioning textile coverings are more challenging than for solid sheet materials. (Right): Structural analysis of the textile skin enables the correct frame profiles for the tensioning load to be chosen. [6]

SOLUTIONS AND PROJECTS

The goal of bringing spectacular and energy efficient façade design into the middle market is best achieved by a combination of rationalization and the intelligent application of new materials and systems.

EXAMPLE: TEXTILE APPLICATION IN THE RETAIL SECTOR

A visit to the supermarket is not a prospect one usually welcomes! The market is saturated and the fight for the weekly spend is intense. Price and quality belong to the basic performance factors consumers expect. Therefore, the ability to differentiate oneself from ones competitors through the creation of an emotional bond with the customer has long been a goal in retailing. Here, the Austrian arm of a Germany supermarket group has embarked on the refurbishment of its sites.

The solution shown in Figure 13 uses a tensioned textile surface instead of panels. The textile frame solution provides a joint free covering over 30 meters (100 feet) in length along the underside of roof overhang and the fascia. The void is backlit using energy efficient LED-Lighting and creates a smooth surface, free from shadows and hot spots. It gives the building a unique contemporary look, which enhances the customer experience. In darkness, the drive by effect also strengthens brand recognition. The ease with which the textile covering can be replaced is a key factor in ensuring the façade will retain its contemporary appearance.

Figure.13: (Left) Reference project, Hofer Supermarket Austria, by day, (Left), by night. [A]

In the retrofit market, textile frame solutions can modernize existing facades at low cost thus reducing the need for re-development and improving returns on investment. Building life extension provides major environmental and cost benefit. These façade solutions fulfil the goals of performance and appearance as previously discussed. They are visually stimulating, exhibit excellent technical and environmental performance.

Figure 14: Reference project: FBI, park garage, Sorrento Valley, San Diego, USA, a textile façade curtain provided structure and privacy [D]

Figure 15: Reference project: A hospital (OPZ), Munich, Germany, the textile outer skin façade provides solar shading performance, privacy and adds structure [E]

SUMMARY AND OUTLOOK

There are a multitude of demands placed on a façade; those pertaining to performance i.e. function and those of appearance i.e. form. The way, a façade performs on a technical level is particularly important to those who directly interact with it, its users, but also for the observers evaluating it from afar, certain factors such as reflection and glare having detrimental effects on surrounding areas are also important. Technical performance is expected and fulfillment creates little emotional reaction. Equally, dissatisfaction levels quickly rise when performance expectations are unfulfilled. Appearance factors such as color, shape and structure, produce strong emotional reactions and are known as “delighters”.

It is therefore the appearance (form) factors, which function as the means of projecting style, image and technical standing to a wide audience, and the façade plays a leading role. The ability of the façade to react to trends, to be flexible in its response to changes of ownership, corporate identity, color and design, in sectors where branding and image are important cannot be over stated.

An increased use of glass, metal woven products or aluminum as the basis of the outer skin is limited by the inherent material constraints i.e. density, difficulty of fabrication, installation and their full cost in the widest environmental sense. Technical

textiles in combination with system frame solutions provide pre-tested, reliable and risk-free platforms for the creation of second skin facades. Specifically designed tools and services from the system provider simplify and accelerate the planning process. The “Frugal” approach embodied in the system design creates opportunities for mass-market application in both the developed and emerging markets.

Existing reference projects have proved the façade concept based on system frame technology to be multifunctional, providing solutions for opaque as well as transparent surfaces. The addition of printing techniques and backlighting adds further to the application spectrum.

The issue of climate change has sharpened design focus and the issue of “grey energy” will become a criterion for choosing materials in the future. Regulatory pressure to improve thermal performance in summer has increased as has social and peer group pressure to acknowledge climate change and to reflect this in environmentally sound corporate design.

Standalone outer facades using fabric-textile solutions provide flexible, creative and affordable options delivering exceptional building performance. Intelligent system technology provides a basis for cost effective construction offering a high level of design flexibility. The application of high performance textiles in system frames provides a not only technically efficient way forward but also promises to simplify the design process on a significant scale.

The resulting façade solutions will be more attractive to institutions and investors and will enable growing numbers to enjoy the combined benefits of performance and appearance derived from such an outer skin facade.

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