New Look at Building Facades: Creative Low Energy Efficieny Facades

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Abstract: ***These days, as we all are moving towards modern trends, the shape of architecture is also changing, the façade treatment and character is also shaping much like plants, people, or other living things, and the skin of a building is that surface which interacts with the world at large. The skin has a responsibility to protect the contents; much like our skin protects us. It also makes a statement to the greater world about the building, a statement that connects the form and function of the building: it might conceal and camouflage, it might flaunt, strut, pose and parade. Given these complex duties, skin is no simple matter for the architect or designer of a building, skin might fulfill the important function of insulating against cold to conserve body heat. It might equally insulate against heat and keep a creature from overheating. Differing colors and patterns might provide camouflage or generate recognition and attraction between members of a particular species. This is a study on the skin of building and the surface which interacts with the world at large.***

Keywords: energy efficient, facades, technology, built structure

1. Introduction

The fundamental physiology of animals, including humans, operates with only one goal in mind—to sustain itself. The main purpose of the body's luminal surface is to moderate the outside environment in order to ensure the efficient operation of what is inside. This altruistic relationship can inform ways in which the built environment maybe developed in a more public-spirited manner. With so many hard surfaces being built in urban areas, more consideration should be put into the potential of these surfaces to actively contribute to the urban climate. Although some designers are already engineering facades to collect energy, respond to the changing environment, and protect the occupants from intolerable situations, the purpose of most urban building facades is to be a "pretty face" to the public eye. However, that same luminal surface can be designed and engineered to do much more, thereby contributing to the common good. Surfaces on the outside of buildings can filter air, clean water, regulate temperature, generate breeze, and contribute to public health. When considered in such a way, the outside of a building may be better categorized as part of a hybridized area of public works, private development, etc.

2. History

As our industry continues to evolve, harnessing and embracing new technologies and materials, our buildings adapt, and our role as façade designers also changes. In the beginning it was simple; a wall that supported the roof or floor with a hole to let in the air and light. There might be a door or a shutter to keep the rain out but very simple. Glass is a naturally occurring substance. It is disputed whether the Egyptians or the Mesopotamians developed techniques for making glass, but it was not until the Romans started to develop new ways of making glass that glass started to be used to create windows. After the fall of the Roman Empire, Venetian artisans kept skills for glass making alive during the dark ages – in parallel with those in India and China. Techniques and chemistry of glass continued to evolve through the middle Ages by the 1100s and 1200 and this lead to the craze for stained glass windows. This trend of stained glass windows influenced the master builders of cathedrals to develop buttresses and flying buttresses and other techniques for creating large areas of glazing.

The technology for the manufacturing of glass continued to evolve over the centuries. Over this time the crown glass technique became more prolific. As the industrial revolution matured into the Victorian age methods for producing window, glass continued to develop with glass sheets cut from large blown cylinders becoming the new mass production technique. This technique supplied the hectares of glass used in the construction of the revolutionary Crystal Palace at the original Expo, the Great Exhibition of the Works of Industry of All Nations in 1851.

Mass production techniques in the 1800s used timber for window frames with some use of wrought iron frames for industrial and transport buildings. In the US, larger buildings were being developed where structural steel frames carried the building's weight in place of masonry walls.

These allowed larger areas of glazing to be created. Brick and stone were still being used to form the spandrels or solid sections of wall but no longer load bearing. This form of construction continued through the US skyscraper boom of the 1930s. With the advent of modernist architecture and the elimination of decoration and the focus on functionality, architects began to explore how glazing and façade designs could create transparency, again splitting the façade from carrying vertical building loads.

This fashion led to large areas of glazing being created with minimal framing. Initially a European style, the modernist aesthetic transferred at scale to New York and Chicago. After the Second World War, architectural styles pulled together several new materials to develop curtain walls. In the 1950s Pilkington in the UK developed the float glass line which is still by far the most commonly used production process to this day.

Aluminum had become increasingly common in the first half of the 20th century. It was not until various alloys were developed that it became the strong and ductile material that has become common in construction. A key advantage was that aluminum could be extruded into fine and precise shapes and then tempered to give it a higher strength, making it ideal for forming window sections.

As a result, this rapidly supplanted bronze that had previously been used for high end glazing. Given the challenge of high rise construction, American manufacturers developed stick curtain wall systems. These used the third new component – widely available gaskets and seals to form complete curtain wall systems.

The next step in the evolution of curtain walling was the move from stick systems assembled on site to pre-assembled units completed in the factory. The advantages quickly became self-evident with the speed of construction using a high-quality product, made on site.

And of course, we now have living façades, with green walls and vertical greenery – very dramatic and ecologically beneficial to our cities when used appropriately.

The Facade Engineer

Alongside the post-war developments in façade systems, engineering consultancies as part of their broader service might have included advice on cladding systems and some early façade engineering – example includes glazing to the Sydney Opera House.

As facade systems continued to evolve in complexity, and the role of it forming a robust future, the sealed envelope became for a while separated and less integrated with the rest of the building fabric, it became the realm solely of specialist sub-contractors. In the late eighties, engineering consultancies began to offer façade consultancy services independently, to design and advise on cladding and curtain wall systems. We are now in 21st century and in the world of multifaceted building envelope design. Projecting the identity for the development whilst creating comfort for those inside means that the walls and windows must work very hard and in a relatively small space.

The façade zone is only a few centimeters thick, but in that space the façade should be to able to stand up, withstand the wind and any earthquakes, accommodate the building behind moving, keep water and pollution out, insulate from the heat or cold, let the warming sun and cooling breezes through, or keep the warm air and heat energy out, give views out and let the right amount of daylight in, cut noise from outside yet let people connect to birdsong and the sound of the street if desired, stop conversations and fire spreading through the building and protect us from intrusion and blasts. A tall order for walls and windows that should provide us with delight inside and out is respected.

Due to the myriad of performance requirements and aesthetic ambitions, a broad palette of materials and systems are being used to form our façades including stone, ceramics, brick, concrete, GRC, insulation and timber which all play their part together with the gaskets, seals, adhesives, fixings and brackets to form walls and windows.

To work successfully in the field of façade design, we need to be masters of how the façade performs and its materials are used. And we also need to know how to bring these components together. Mindful of fabrication, erection, installation, financing and contractors' and suppliers' roles. Façade design is an intriguing and inspiring discipline where all of the skills and hard work are on display for the world to see and are tested daily by the environment.

The façade design needs to start early as it clearly plays a key role in the design of any building. Although having its greatest impact on the perimeter zone of a building, a well-designed façade can have a greater impact on overall ambiance, and help to create a comfortable space.

This of course helps with improving energy consumption and makes a big step towards achieving green targets where energy is the biggest façade design driver now. Façades often have a large ecological impact. Embodied carbon, and impact of extraction and fabrication processes are all issues. Exploring the type of materials to be used in a façade and developing a strategy is best done at the very earliest stages of a project. Perhaps timber framed curtain walls could be adopted as an alternative.

Only at the very start of a project, before any marks have been put down, you can ask the questions to decide what the façade should be:

- Is the building shape and orientation right for views, daylight and sun-path?
- Should the form of the façade or the building be self-shading?
- What is the right portion of windows to solid wall?
- How to make the most of daylight?
- What should the façade be made of to reduce ecological impact?
- How could the façade be reused or recycled at the end of its life?

These are all very fundamental questions that might drive the performance, appearance and fabric of the façade in very different directions. Even if a particular aesthetic is maintained, an early assessment of these aspects may still have a significant impact.

Evolution of Future of Façade Design

We have gone through some exciting years of harnessing the potential of software to imagine, design and define some spectacular building and façade forms. The façade industry is finally harnessing recent digital developments, however, for us at Arup having something quick and easy to use, that can display and record information is our aim.

To this end, we have used gaming software to develop tools that allow users to navigate around a digital twin of their façade. All sorts of design information, construction records or progress photos can be loaded onto that digital twin.

The key with this digital twin is that it needs to be easy to use for those that do not code or draw in the digital space and rather than an alternative to a BIM model, this practical way to access and interact with the information that these models contain.

Our aim is that the digital twin with all the information and records will eventually be passed on to the building owner and those who will operate and maintain the building.

We also see that the design phase will use tools that both simplify and enrich the process. By combining different skills, analysis programs and IT platforms, we are developing interactive apps that allow designers to explore design options on the fly whilst avoiding lengthy iterative loops.

When it comes to glass, we have nearly reached the point where glass selectivity can no longer be improved; the only way to reduce energy coming in will be to reduce the amount of daylight. To avoid this and get better performance from glazing in our façades, they are becoming responsive such as the huge umbrellas that we designed for the Al Bahr towers in Abu Dhabi. Shading the building from outside only when needed.

Our Role in the Future Façades

So how will the façade designer's role and focus change through the 21st century? The focus on environmental impact will become an ever increasing driver. The ecological impact of the materials we choose will soon be influencing and driving our designs.

Apart from counting and measuring embodied carbon and water, assessing pollution and other impacts we will also plan for the future use of materials once these have served their purpose. It is inevitable that the role of the façade designer will continue to evolve and morph as more and more considerations will need to be addressed and balanced.

The key skill though will be the ability to create an enjoyable journey from concept to handover to the operation and re-purposing of the façade for all participants. This will be enabled through embracing and harnessing new tools and applying our intellect underpinned by our collective experience in the industry.

Yet for all this focus on performance and ecological impact, we all aspire for our buildings to have an identity, to take their place in the city scape and to bring delight to their surroundings and to the people who pass by or walk inside to work, live and play. The façade designer will orchestrate the materials, systems and geometry to realize this vision.

Create difference from environment, create internal environment

	Skin function in organisms	by/what	architectural analogy
Primary function, happens in the intermediate space between the inside and the outside			
Construct	Provide structure	shell / internal structure with soft body and skin	> building construction
Protect	Protect and enclose inner organs	soft or tensioned layer	> membrane systems
	Mechanical Protection		> hard outer layer
	Self-healing		> self-healing materials
	Protection from radiation		> UV protection
	Protection from dirt	surface characteristics, chemical action	> self-cleaning
	Protection from micro-organisms	surface characteristics, chemical action	> oxidation surface
	Production of insulation	outer layer (hair, feathers)	> thermal insulation
Exchange	Sensing	diverse information	> sensors
	Harvesting of energy	thermal, solar energy	> solar systems
	Control air exchange	oxygen, carbon dioxide	> diffuse systems
	Thermoregulation		> thermal balance
	Regulation of circulation		> thermal balance
	Exchange of substances, prevent loss	nutrients	> filter systems
	Water and humidity - Sweating	water	> cooling
Integrated function, also use of a mechanism already there			
Signal	Appearance in environment	colour, patterns	> communication
	Signalling	colour change etc.	> communication
Integrated function in the intermediate space, can also happen elsewhere in the organism			
Store	Storage of energy	thermal energy	> heat storage
	Storage of chemical energy	fat, sugar	> energy storage
	Storage of humidity		> water storage

Facades Systems

With the facade embodying up to 35% of the construction costs as well as being hugely accountable for the buildings' response to climate change, it has never been so important to understand which façade solutions deliver not only a cost effective and sustainable facade, but also one that is aesthetically pleasing and technically performing.

The façade forms the external weatherproof envelope of a building. (Vertical building enclosure).

More than any other component; they create the image of the building. The building envelope should be designed to mediate public-private boundaries within the architecture, both inside and out.

In modern buildings, the façade is often attached to the building frame and provides no contribution to structural stability. Sustainable facades are defined as exterior enclosure that uses least possible amount of energy to maintain a comfortable environment, which promotes productivity to certain material which has less negative impact on environment.

Essentially There Are Two Types of Facades:

Opaque Facades; which are primarily constructed of layers of solid materials, such as masonry, stone, precast concrete panels, metal cladding, insulation, and cold formed steel framing. Opaque facades may also include punched openings or windows.

Glazed Facades; such as curtain walls or storefront facades which primarily consist of transparent or translucent glazing materials and metal framing components.

Factors That Effect Thermal, Visual, and Acoustic Comfort of Façades

Environmental Conditions		Visual Comfort	Acoustic Comfort
Opaque facades	Material properties of cladding Amount of insulation Effective heat resistance properties (R – value)	Wall to wall ratio	Material selection and properties
Glazing	Orientation Number of glass layers Layer thickness Heat transfer coefficient (U- value) Visual transmittance Solar heat gain coefficient(SHGC)	Orientation Window properties, size, location and shape Glass thickness and color Visual transmittance reflectance	Number of layers Layer thickness Layer density
Framed and supporting structure for glazed facades	Thermal properties of the frames		Material types

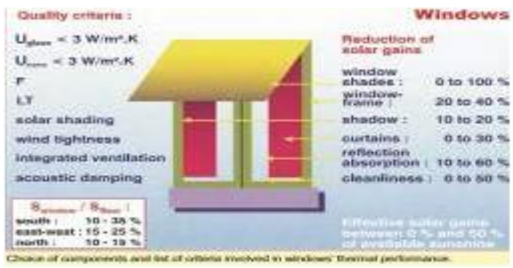
Desired & Smart Properties of Facades

Desirable Properties
- Low CO2emission
- Thermal and Moisture Insulation
- Storage
- Solar Isolation
- Natural Light
- View
- Fresh Air
- Sound Insulation
- High insulation e.g. vacuum insulation
- Self-cleaning
- Security/Safety/Fire Protection
- Aesthetics

Smart Facades;
- Facade is an interactive inside-outside interface
- Sensor system/interact with clothing or skin sensors
- Reactive materials and surfaces
- Embedded technology can control inputs/ outputs (Dynamic envelopes)
- Opportunities for nano materials

Fenestration Components

Fenestration components and materials allow natural light to enter into the building, decide the amount of energy consumption and the heat loss or gain of the building. Thermal Resistance (R-value) - It is an assembly's or a material's resistance to heat transfers, and is expressed in h-ft2 or m2-K/W. Heat Transfer Coefficient (U-value) - It is the inverse of R-value. It measures the heat transmission through a material or a façade assembly, expressed in Btu/hr-ft2- of or W/m2-oK, and is usually used to define thermal performance of glazed parts of facades assemblies.



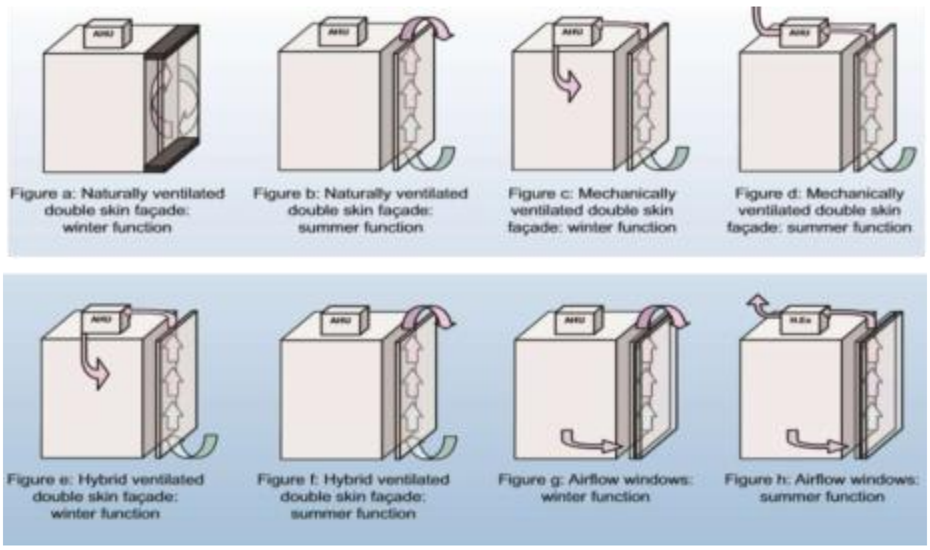
Cladding Systems	Embodied Energy
CMU	
Brick cladding, continuous insulation and polyethylene membrane	247
Steel cladding, continuous insulation and polyethylene membrane	370
Precast concrete cladding, continuous insulation and polyethylene membrane	291
Cast-in-place concrete	
Brick cladding, continuous insulation and paint	113
Steel cladding, continuous insulation and paint	236
Stucco cladding, continuous insulation and paint	99
Steel framed (16 in.)	
Brick cladding, continuous insulation, cold-formed steel framing, cavity insulation and polyethylene membrane, gypsum board and paint	96
Steel cladding, continuous insulation, cold-formed steel framing, cavity insulation and polyethylene membrane, gypsum board and paint	219
Wood cladding, continuous insulation, cold-formed steel framing, cavity insulation and polyethylene membrane, gypsum board and paint	61
Precast concrete cladding, continuous insulation, cold-formed steel framing, cavity insulation and polyethylene membrane, gypsum board and paint	141

Cladding Systems	Embodied Energy
Steel framed (24 in.)	
Brick cladding, continuous insulation, cold-formed steel framing, cavity insulation and polyethylene membrane, gypsum board and paint	91
Steel cladding, continuous insulation, cold-formed steel framing, cavity insulation and polyethylene membrane, gypsum board and paint	213
Wood cladding, continuous insulation, cold-formed steel framing, cavity insulation and polyethylene membrane, gypsum board and paint	55
Precast concrete cladding, continuous insulation, cold-formed steel framing, cavity insulation and polyethylene membrane, gypsum board and paint	135
Curtain wall	
Vision glazing and frames	148
Opaque glazing	135
Metal spandrel panel	138

Hot Climate Double Facades

- Passive solar heat gain in winter.
- Reducing thermal losses in winter.
- Reducing overall solar heat gain.
- Support of natural ventilation (with the stack effect).

The double skin consists of two transparent surfaces separated by a cavity, which is used as an air channel.

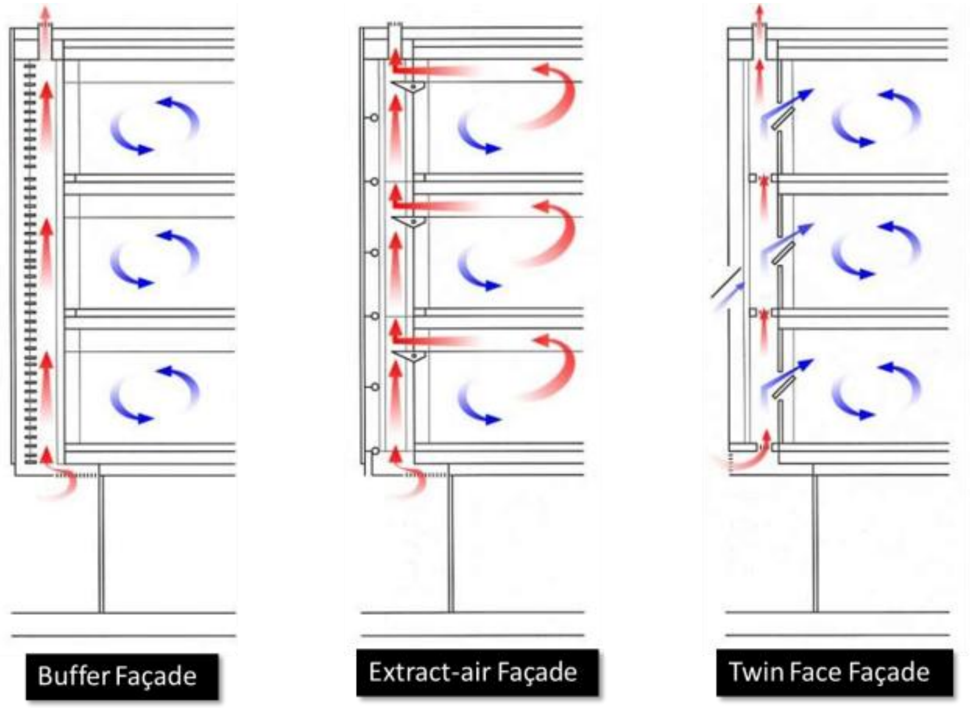


Why Double Skin Facades?

- Reduction of peak wind pressure
- Improvement of energy efficiency of façade by Passive solar heat gain in winter
- Reducing thermal losses in winter
- Reducing overall solar heat gain (in summer)
- Support of natural ventilation (with the stack effect). The air corridor may or may not form part of the cooling system.
- The system can be responsive that opens and closes according to solar path.
- The cavity is seen as a great place to locate the shading system as it could be protected from snow, ice and wind.

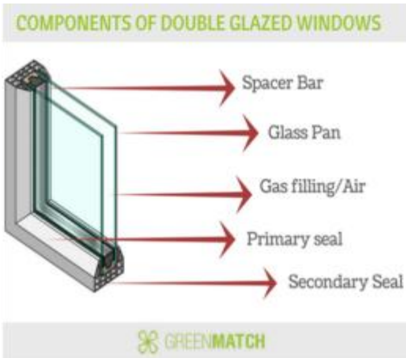
Finally; Architectural infatuation with tectonics and appearance!

Note 1; the shading layer must be very durable to withstand exposure to the elements as well as cleaning.
Note 2; The combination of high humidity and dust while fresh water is mostly desalinated makes Facade cleaning a major issue.



Case study
01 (M.P) 1st green building located in Indore

Plot No 26, Scheme No 94 C, Ring Road, Near Hotel Radisson

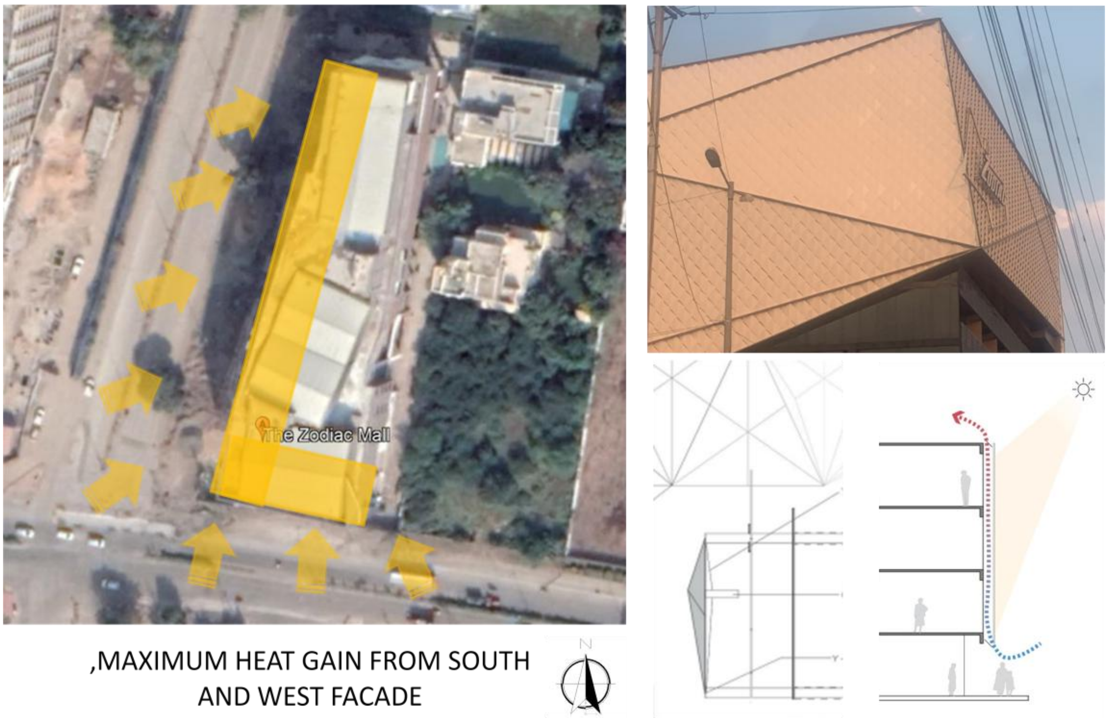


Maloo – 01

,MAXIMUM HEAT GAIN FROM SOUTH AND WEST FACADE

The North-facing and East-facing sides consist of single glazing, while the South and West have double glazing to obstruct unwarranted heat from entering the building. A vacuum is created which act as insulation, which helps in reflecting sunlight and heat back into the atmosphere. The result is two-fold: the building interiors remain cool and comfortable for occupants, while energy consumption decreases, resulting in overall savings.

Zodiac Mall



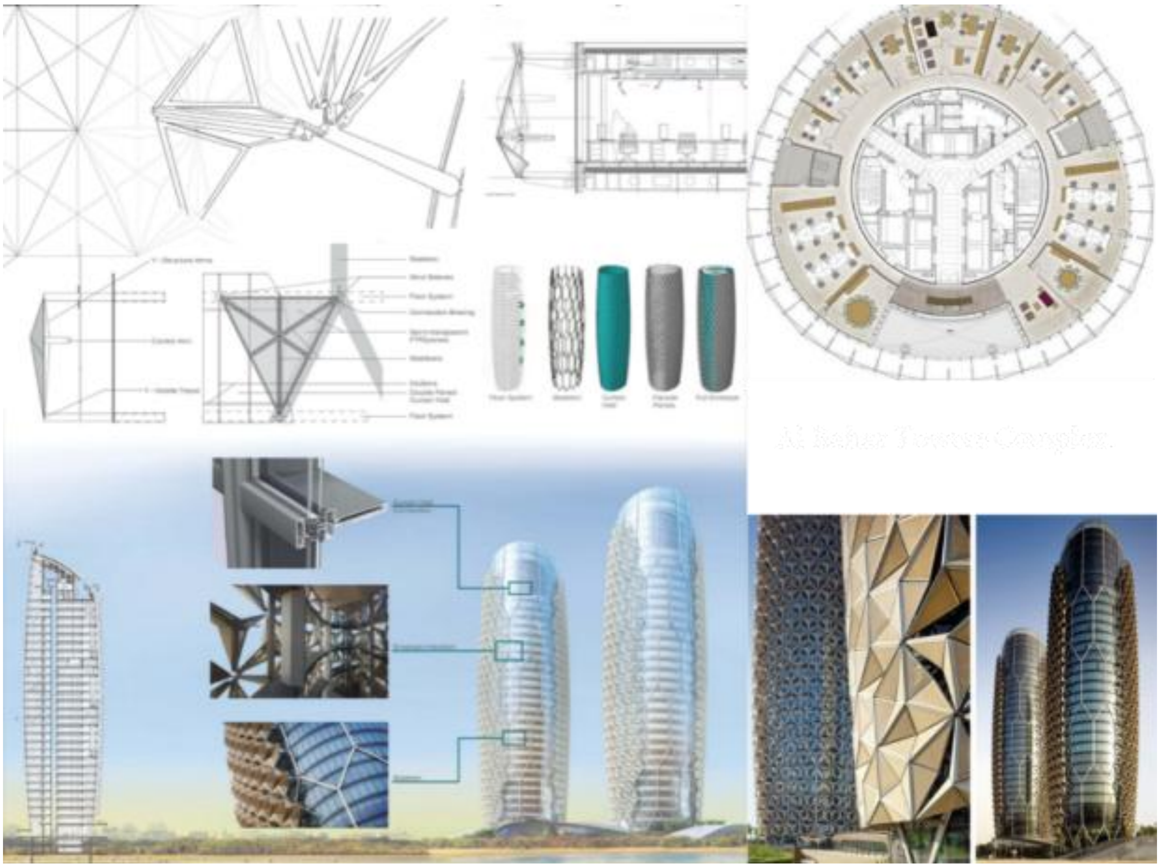
Zodiac Mall Indore
Near Agrawal Public School, Indore

Role of Double Facade

The North-facing and East-facing sides consist of simple openings, while the South and West have double skin façade made with ACP panels to obstruct unwarranted heat from entering the building. A gap is created which act as insulation, reflecting sunlight and stop heat to enter into the building. The result is two-fold: the building interiors remain cool and comfortable for occupants, while energy consumption decreases, resulting in overall savings.

Intelligent Building Facades
The human skin is a good model how we would like the building skin to behave. It adapts to temperature and humidity, can feel a breeze or the slightest touch, and can repair itself. It is waterproof and yet permeable to moisture.

The screen operates as a curtain wall, sitting two meters outside the buildings' exterior on an independent frame. Each triangle is coated with fiberglass and programmed to respond to the movement of the sun as a way to reduce solar gain and glare. In the evening, all the screens will close.



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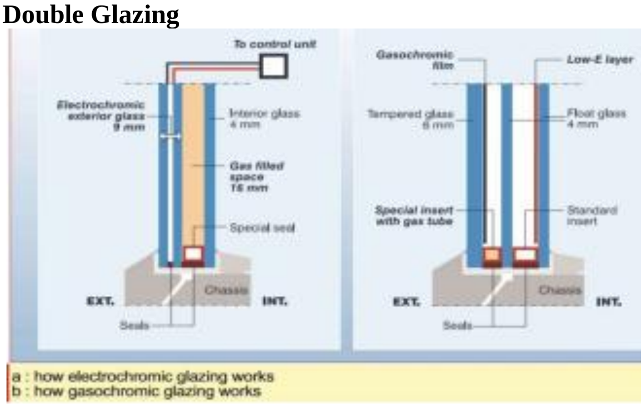
Smart Window / Facade Color-Changing

System Type	Spectral Response	Input Energy	Interior Result Visual	Interior Result Thermal
Photo chromic	Specular to specular transmission at high UV levels	**UV radiation**	Reduction in intensity but still transparent	Reduction in transmitted radiation
Thermo chromic	Specular to specular transmission at high IR levels	**Heat (high surface temperature)**	Reduction in intensity but still transparent	Reduction in transmitted radiation
Thermo thropic	Specular to specular transmission at high and low temperatures	**Heat (high and/or low surface temperature)**	Reduction in intensity and visibility, becomes diffuse	Reduction in transmitted radiation, emitted radiation, and conductivity
Electro thropic	Specular to specular transmission toward short wavelength region (blue)	**Voltage or current (control system and electrical supply required)**	Reduction in intensity	Proportional reduction in transmitted radiation
Liquid Crystals	Specular to diffuse transmission	**Voltage (control system and electrical supply required)**	Minimal reduction in intensity, reduction in visibility, becomes diffuse	Minimal impact on transmitted radiation
Suspended particle	Specular to diffuse transmission	**Current**	Reduction in intensity and visibility, becomes diffuse	Minimal impact on transmitted radiation

Double Glazing



Other Color-Changing Smart Materials

Macha on chromic-materials react to imposed stresses and/or deformations.

Chemo chromic-materials exposed to specific chemical environments.

More Renewable!

SMIT (Sustainably Minded Interactive Technology) Solar and wind power micro cells fixed onto facades.

- Wind Loads and Facades
- Building Envelopes Design
- Considerations;
- Wind Pressures
- Weather Performance
- Integration with Building Services
- Structural Integrity
- Blast proof/earthquake
- criteria
- Energy Performance
- Maintenance/ Cleaning/Recycling

Development of structural systems

First Generation1780-1850

The exterior walls consisted of stone or brick, although sometimes cast iron was added for decorative purposes.

The columns were constructed of cast iron, often unprotected; steel and wrought iron was used for the beams; and the floors were made of wood.

Second Generation 1850-1940

Framed structures, a skeleton of welded- or riveted-steel columns and beams, often encased in concrete, runs through the entire building. This makes for an extremely strong structure, but not such attractive floor space. The interiors are full of heavy, load-bearing columns and walls.

Third Generation 1940-

Present with in this generation there are those of steel-framed Construction (core construction and tube construction), reinforced concrete construction (shear wall), and steel-framed reinforced concrete construction. Hybrid systems also evolved during this time. These systems make use more than one type of structural system in a building.

Strategies to Mitigate Wind Effect

Wind produces three different types of effects on tall buildings: static, dynamic, and aerodynamic.

Structurally, static effect is independent of time; but dynamic analysis is an attempt to take into account how the system responds to the change through the period of time;

When the building is flexible, the building interacts with wind load and affects its response; that is called aerodynamic effect. Wind tunnel testing is used to predict motion perception and pedestrian level effects.

To reduce the impact of wind on a tall building and mitigate the response of the structure of tall building, there are two main concepts:

Structural; Increasing the building structural stiffness Architectural; Aerodynamic (Geometric modifications) of the building.
Modifications on cross-sectional shapes, such as slotted, chamfered, rounded corners, and notching on a rectangular building, can have significant effects on both along wind and across wind responses of the building

Tall building structural systems

Interior structures

A system is categorized as an interior structure when the major part of the lateral load resisting system is located within the interior of the building.
By clustering steel columns and beams in the core, a stiff backbone that can resist tremendous wind forces is created. The inner core is used as an elevator shaft, and the design allows lots of open space on each floor.

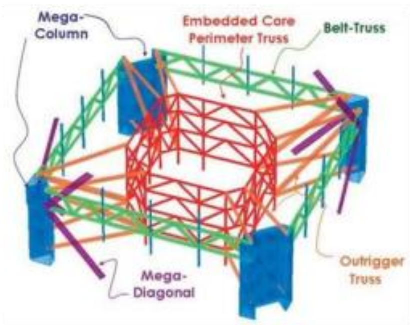
Exterior structures

If the major part of the lateral load-resisting system is located at the building perimeter, a system is categorized as an exterior structure.

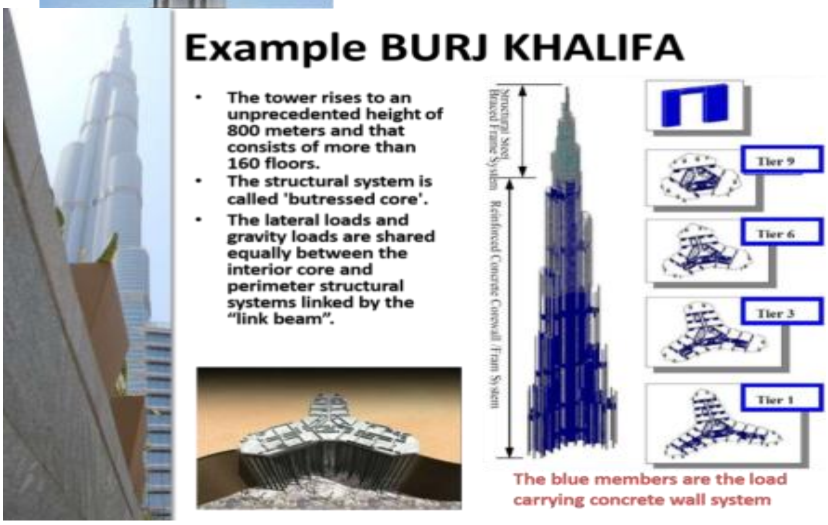
In newer skyscrapers, the columns and beams are moved from the core to the perimeter, creating a hollow, rigid tube as strong as the core design, but weighing much.

NOTE: any interior structure is likely to have some minor components of the lateral load-resisting system at the building perimeter, and any exterior structure may have some minor components within the interior of the building.

Shanghai World Financial Center - Outrigger Structure



The **Outriggers are** effectively act as stiff headers inducing a tension-compression couple in the outer columns.



Future tall buildings

We are entering the era of the "megamall." These buildings are over 600 meters in height, or double the height of a super tall. To build higher the base of the building will have to be made wider. The bundled tube system was a great innovation and was able to span great heights during it's time, to attain the height of bur Khaliah the bundled tube system will need a bigger base when compared with the buttressed core system.

3. Conclusion

- Careful planning and staging is critical with relation to budgets and schemes.
- Technology advancements should be utilized where feasible
- Primary elements related to energy: glazing, gaskets, framing and sealant performance.
- Accent elements such as sunshades can be introduced but detailing the interface requires co-ordination and design.
- Climate (Solar radiation, Outlook temperature, etc.)
- Site and obstructions of the building (latitude, local daylight availability, atmospheric conditions, exterior obstructions, ground reflectance, etc.)
- Use of the building (operating hours, occupant's tasks, etc)
- Building design regulations have to include Facade building Bylaws.

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