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Use of High - Performance Glass as a Sustainable Building Material

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Abstract*- In the present scenario energy consumption has increased substantially in the buildings, due the materials used some of which have low initial cost but high maintenance cost. Glass is extensively used in buildings to harvest maximum light and to reduce energy consumption for internal lighting requirements. When more natural light enters the building, equal amount of heat also enters the building. If clear glass is used, energy consumption for internal lighting will significantly reduce, but at the same time energy consumption for achieving indoor comfort will be escalated. Similarly, if glazing is not installed in the right orientation, i.e., if larger glazed areas are placed on the east and the west of the building this will lead to rise in indoor temperature of the building and hence more energy consumption to achieve ambient indoor temperature. In this report, a study has been attempted to understand the effective use of glazing in different climatic zones of India. As per Energy Conservation Building Code (ECBC) India is divided into five different climatic zones. With the help of case studies from five different climatic zones, suitable locations for placement of glazing have been analyzed. The study also includes effective use of various glazing systems, like double / triple glazing, gas filled glazing, low- emissivity coating, heat absorbing tints, etc. in reducing energy consumption and enhancing the occupants' comfort level and their productivity.

INTRODUCTION

A vast array of glass and glazing solutions exist to satisfy the needs of the most ambitious architects and building engineers. Glass offers both a positive balance of energy through the building envelope and the provision of sufficient daylight to reduce artificial lighting needs. Glass generates minimal environmental impact, which makes it a product of choice for sustainable buildings. Architects increasingly seek to bring natural environmental factors into the interior of buildings by maximizing natural daylight. This is achieved through the use of larger glazed areas in facades and roofs, and entirely glazed facades, where the glass is a structural component of the building.

Green buildings emphasize on the resource usage efficiency and also stress upon the three R's - Reduce, Reuse and Recycle. In the present scenario energy expenditure has increased a lot. The boost in energy consumption is due to the increase in the number of buildings that are being constructed these days. Energy-saving is a key driver. In Europe target to reduce Carbon dioxide emission, tougher legislation for energy-saving glass are formed, making insulating glass units mandatory. In hot climates due to large glazed areas reliance on air conditioning is mitigated by the use of advanced solar control glass, allowing the sun light into buildings while blocking much of the heat. In cold climates, low-emissivity glass reduces heat loss, while allowing high levels of valuable free solar gain to heat the buildings without significant loss in natural light. However, in summer, unless combined with solar control glass, it can become uncomfortably hot. Fire- resistant glass also has an important role to play in promoting the sustainability of communities. The correct choice of glass can help to reduce the capital outlay, running costs and associated carbon emissions of buildings. Glass manufacturing has an age-old tradition which dates back to around 3500 BC when glass is believed to have been first artificially produced in Egypt and Mesopotamia to be used as jewelry and later as vessels. Since then processes have constantly evolved from craftsmanship to today's high-tech industrial processes and the number of glass types and applications have multiplied. Glass has shaped Europe's cultural heritage, regions, industries, living conditions, technological deployments, etc. like no other substance. Simply think of glass masterpieces such as Bohemian crystal, the Murano Island of Italy, the Mirrors Gallery of Versailles palace or stained glass in Cathedrals.

Figure 1- Glass Vessels

Figure 2- Stained Glass in Cathedrals

LITERATURE REVIEW

Two centuries of Glass Research: Historical Trends, Current Status, and Grand Challenges for the future [1]

The field of glass science and technology has a remarkable history spanning about two centuries of research. In this article, John C. Mauro and Edgar D. Zanotto have analyzed the number of research papers and patents related to glass and amorphous materials in the published literature.

Architectural Glass-Type, Performance and Legislation[2]

According to Jelena Savic, Danijela and Veliborka glass has been more extensively applied in architecture, as a result of improvement its production technology. There are great number of glasses in use depending on its purpose and the application potential. Apart from its traditional role, the glass is progressively used as a structural, load bearing material.

A comparative study on high-performance glazing for office buildings[3]

Q. Jin and M. Overend have studied High-performance glazing facades for a commercial buildings. They have conducted a comparative study on 13 glazing scenarios on the facade of a typical cellular office room model. The simulations provide the energy demand/ generation and indoor environmental quality of the scenarios in three geographic locations (London, Helsinki, and Rome), four orientations, and four window-to-wall ratios (WWRs) (30%, 50%, 70%, and 90%).

Comparison analysis of Green building materials and conventional materials in energy efficiency performance [4]

In this paper Srikant Misra, G.R.K.D. Satya Prasad, Navnit Kumar and others have observed the effect of some of the component of green building materials like concrete, recycled steel, insulated concrete forms, engineering wood products, green roofing products and glass. They have also studied the extent, this green glass reduces the overall power consumption of the building as compared to normal glass by using simulation process (Using ECO-nirman whole building performance tool software).

Use of Energy-efficient Materials and Sustainable Design Strategy for Large Sports Architecture in Beijing [5]

Prof. Sun Yimin and Xiao Hui have studied the Beijing Sports University Training Center and Beijing Shooting Range Hall by selecting Energy-efficient building materials. The architectural design follows the "public building energy conservation design standard" (Beijing local standard DBJ01-621-621), which requires an energy saving level of 65%. It applies the approach of green, energy efficient and environmental friendly, in the architectural design and material selection, reasonability designs, the thermal performance of building envelope and reduces building energy consumption.

The main components that use energy-efficient building materials include:

Outer wall - Decorative insulation bearing integrated block at BSU Training centre and Heat preservation and sound insulated precast concrete wall panels at Beijing Shooting Range Hall

Curtain wall – broken bridge aluminium alloy glass at BSU Training center and Ecotype double breathing at Beijing Shooting Range Hall

Roof- Multi-functional composite metal roofing at BSU Training center and at Beijing Shooting Range Hall
The main energy conservation goal of large sports building is to consume as less energy and resources as possible, in the meanwhile minimizing the impact on environment and ecology, and providing the users with a healthy and comfortable building environment. Choosing energy-saving materials in the process of design and construction, and implementing building energy efficiency standards, is an important approach to realize the energy conservation goals and promote the sustainable development concept of the large sports building. Through the reasonable design and selection of energy efficient materials, one can gain great energy efficient performance in the long run with a small increase in building cost.

Evaluation of Artificial Ageing Methods for Glass [6]
Surface damage that accumulates on the surface of glass is known to govern the strength of this material. It would therefore be very useful to use artificial ageing techniques to replicate this level of damage; this would allow a rapid and cost effective assessment of the expected glass strength and the long term performance of novel glass products and treatments. Some artificial ageing methods exist but it is unclear whether the surface damage induced is correlated with the physical damage found in naturally aged glass. Kyriaki Corinna Datsiou, Mauro Overend have done research, to evaluate available artificial ageing methods of glass using as a reference naturally aged annealed glass.

The artificial ageing methods of the as-received specimens involved the induction of:
A single flaw on the given specimen with a custom-made scratching device (SC series) and Uniform damage to the specimen with the use of dropped grit (SA series).

Each ageing method was then evaluated with destructive and non-destructive testing. These results were then compared to those obtained from the naturally aged glass (NA series). A 65% reduction in mean strength with the respect to the as-received annealed glass was noted for the naturally aged series. This reduction was approximated (62-79%) by the artificial aged series.

Solar PV Facade for High-rise Buildings in Mumbai [7]
Professor Dr. D. P. Kothari and Aseem Kumar Sharma aimed to assess the potential for using Solar PV Facades in high-rise buildings in Mumbai, India. They also discuss the present status of different Solar PV technologies and facade types. It intends to examine the relative performance of mono-crystalline and thin film technologies used for Solar PV Facades in high-rise buildings using established software RETScreen 4.
Solar PV Facades into a building reduces the price of solar power generated by the system because the solar panel facade serves both as a facade and as an electricity supply. The payback period is less than 2 years.

Solar Passive Architecture Cooling Techniques [8]
Various types of solar passive architecture principles are reviewed in this paper. A passive cooling technique is one of the energy efficient design principle helping the building to consume less artificial energy. It helps to save energy and reduce the global warming. C. V. Subramanian and M. Divya, have discussed about general passive cooling techniques and advanced passive cooling techniques. With the help of case study they have discussed how effectively various types of passive cooling techniques available can be incorporated in the building design for warm humid climate of Tamil Nadu region. Also the building interior can provide adequate comfort by incorporating such passive techniques and reduces the artificial energy consumption.
Glass is a solid-like and transparent material that is used in numerous applications in our daily lives. The natural and abundant raw materials such as sand, soda ash and limestone are melted in furnace at a very high temperature to form a new material: glass. At high temperature, glass is structurally similar to

liquid, however at ambient temperature it behaves like solid. As a result, glass can be poured, blown, pressed and molded into plenty of shapes.

GLASS MANUFACTURING PROCESS

Glass industries are characterized by a multitude of production processes depending on the final product manufactured and its applications.

Glass requires raw materials which are of two kinds: different types of sand and recycled glass. These raw materials are mixed together, charged into a furnace where they are melted at around 1500°C to form molten glass. The molten glass is then taken out of the furnace to be shaped and cooled. For specific application, the glass obtained may be further processed to have specific properties such as increased mechanical strength and high resistance to breakage.

The exact composition of glass may vary to meet specific application requirements but the most commonly used type of glass, i.e. soda-lime glass, is made of silica sand, soda ash, limestone, dolomite, and glass cullet (recycled glass). Additional materials such as iron oxide or cobalt can be added to the mix to give green or blue colour to the glass.

LIFE CYCLE OF GLASS

Step 1: Raw Materials

Float glass is made up of quarry-extracted raw materials (sand, dolomite, limestone) and synthetic material (soda ash). Material optimization: Use of cullet significantly lowers the consumption of raw materials. Nowadays manufacturers are using 30% of cullet in glass production process. One tonne of cullet replaces 850kg of sand which would have otherwise been extracted from a quarry.

Step 2: Manufacturing of Float Glass

To produce float glass, the raw materials are melted in furnace at 1,500°C and then cooled down. Producing the heat to melt the raw materials requires the combustion of fossil fuels and results in CO_2 emissions. Cullet melts at a lower temperature than primary raw materials. Hence reduces energy consumption and limits CO_2 emissions. 1 ton of cullet allows a reduction of 255 to 300 kg CO_2

An optimized manufacturing process

- Environmental approach: 100% of the Saint-Gobain Glass manufacturing facilities are certified ISO 14001 – Internal Environment Management Systems.
- Energy savings: 10% of energy has been saved by Saint-Gobain Glass in 5 years through optimizing furnace combustion at the design stage, reducing CO_2 emissions by as much.
- Water management: 100% of furnaces are cooled down with closed-loop systems, minimizing water withdrawals and discharges.
- Air emissions: 80% of glassmaking furnaces are equipped with filters to limit dust, SOx, acid gases and metal emissions.

Step 3: Processing

In this stage, the glass is cut and assembled to form double or triple glazing. Cutting and assembling the glazing units requires electric energy and water for washing the glass sheets. The cullet (cutting scraps or trimmings) is produced at this stage. It is important to recover this waste glass so that it can be reused in the manufacturing process.

Process optimization

The main two objectives at this stage are:

Optimization of manufacturing process to reduce energy consumption and water withdrawals.

Sorting of glass scrap to favour good quality cullet for recycling in the float glass production furnaces.

Step 4: Transport: Transport includes the distances covered between the last processing facility and the site where the glass is installed in buildings. All other transports are taken into consideration at step 2, 3 and 4.

Transportation Optimization: Transportation inevitably incurs energy consumption and CO_2 emissions. Minimize travel distances. Optimization of transport loops and truck loading.

Fleet rejuvenation and purchase of low-particle emitting trucks. Eco-driving training programs which have enabled drivers to reduce their fuel consumption- in some cases by 25%.

Step 5: Glazing Life

High performance glass is used extensively as a construction material in most buildings, in both exterior and interior applications, for functionality, for decoration and for interior fittings. High performance glazing saves energy and reduces CO2 emissions and does so throughout its life.

Step 6: End-of-Life:

During demolition, dismantling, window replacement at the end of its life, glass usually becomes waste which is only recycled in low proportions today.

Table 1– Embodied Energy and Embodied Carbon

Description	Embodied Energy (MJ/kg)	Embodied Carbon (kg CO2 e/kg)
Primary glass	15.0	0.86
Toughened glass	26.2	1.27
Glass Wool	28.0	1.35

Application of Glass: Glass is an innovative material that has unlimited applications. Glass is used in the following:

Packaging (jars for food, bottles for drinks, flacon for cosmetics and pharmaceuticals)

Tableware (drinking glasses, plate, cups, bowls)

Housing and buildings (windows, facades, conservatory, insulation, etc.)

Interior design and furniture (mirrors, partitions, balustrades, tables, shelves, lighting)

Appliances and Electronics (oven doors, cook top, TV, computer screens, smart-phones)

Automotive and transport (windscreens, backlights, aircrafts, ships, etc.)

Medical technology, biotechnology, life science engineering, optical glass

Radiation protection from X-Rays (radiology) and gamma-rays (nuclear)

Fiber optic cables (phones, TV, computer: to carry information)

Renewable energy (solar-energy glass, wind turbines)

All of this is made possible by the countless properties of glass.

Types of Glass and their Uses in Construction Works

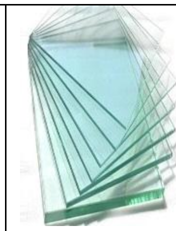
Following are the types of glass used in construction:

Annealed Glass

Annealed glass is the most commonly used architectural glass. It has good surface flatness because it is not heat-treated and therefore not subject to distortion typically produced during glass tempering. On the downside, annealed glass breaks into sharp, dangerous shards. It is clear and flat, so it causes glare.

Heat-Strengthened Glass

Heat-strengthened glass is heat-treated glass products, heated and quenched in such a way to create residual surface compression in the glass. The surface compression gives the glass generally higher resistance to breakage than annealed glass.

		
Figure 7 -Heat Strengthened Glass	Figure 8 - Toughened Glass	Figure 6 - Annealed Glass

Toughened Glass/ Fully Tempered Glass

Toughened glass (figure 8) provides at least four times the strength of annealed glass, which gives it superior resistance to glass breakage.

Table 2- Properties of Glass

Sr. No	Description	Annealed Glass	Toughened Glass
1	Tensile Strength	40 N/mm2	120 to 200 N/mm2
2	Compressive Strength	1000 N/mm2	1000 N/mm2
3	Young's Modulus (E)	70 kN/mm2	70 kN/mm2
4	Density	2.42 – 2.52 g/cm3	2.42 – 2.52 g/cm3
5	Thermal coefficient expansion	9 x 10–6 /oK	9 x 10–6 /oK
6	Poisson's ratio	0.2	0.2

Factors to be considered in selection of glass U-Factor:

U- Factor indicates the rate of heat flow due to conduction, as a result of temperature difference between the two sides of glass. The lower the U-Factor, lower the heat transferred through the glass. U-value is measured in W/m2 oK.

Solar Heat Gain Coefficient (SHGC)Solar heat gain coefficient is the ratio of the solar heat gain that passes through the fenestration to the total incident solar radiation that falls on the fenestration.

Visible Light Transmission of Glazing (VLT)

Light Transmittance factor determines the visual performance of glazing. Visible Light Transmittance indicates the percentage of the visible portion of the solar spectrum that is transmitted through a given glass product. Acoustic performance

Understanding the type of sound coming from a source is an important step in determining the type of glass to be used.

Sound type for example: Low frequency (125Hz to 800 Hz)- Urban traffic, Gun shot, Disco , Appliance like TV and Radio. High frequency (800Hz to 5000Hz) - Airplanes, fast moving train, Factories

Types of Glazing: There are many types of glazing available which includes the following

Insulated (Double glazed, Triple glazed)

Insulated glazing (Figure 9) refers to glazing units consisting of two or more panes of glass. Insulated glazing can be double glazed or triple glazed.

Gas Filled Glazing

To improve the thermal performance of glazing, the space between the glass panes is filled with inert gas. Because these gases have higher resistance to heat flow than air, they are sealed between the window panes to decrease the glazing U-factor (Figure 10).

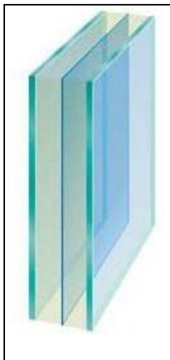


Figure 9 – Insulated Triple glazed

Figure 10 – Gas Filled Glazing

Figure 11 – Heat Absorbing Tints

Heat Absorbing Tints: Tinted glass absorbs a large fraction of the incoming solar radiation and glare thus reducing the solar heat gain coefficient.

Low Emissivity (Low-e) Coating: Low Emissivity coatings are microscopically thin, virtually invisible, metal or metallic oxide layers deposited on a window or skylight glazing surface primarily to reduce the U-factor by suppressing radiative heat flow. Spectrally Selective Glass: Spectrally selective glass blocks long wave radiation. The multiple layers of silver in the coating allow the glass to selectively transmit and reject certain wave lengths of solar radiation.

Reflective Coatings: Reflective coatings usually consist of thin, metallic layers which come in a variety of colours including silver, gold and bronze. Reflective coatings on glazing reduce the transmission of solar radiation, thereby blocking heat.

Building Envelope: The building envelop refers to the exterior facade, and is comprised of opaque components and fenestration system. Vertical Fenestration WWR up to 40% and WWR in the range of more than 40% and up to 60%

Climate	WWR ≤ 40%	40% < WWR ≤ 60%
	Maximum SHGC	Maximum SHGC
Composite	0.25	0.2
Hot and Dry	0.25	0.2
Warm and Humid	0.25	0.2
Moderate	0.4	0.3
Cold	0.51	0.51

Table 3 – Vertical Fenestration SHGC Requirements

Climate	Maximum U- factor(W/m2 oK)
Composite	3.3
Hot and dry	3.3
Warm and Humid	3.3
Moderate	6.9
Cold	3.3

Table 4 – Vertical Fenestration U-factor (W/m2 oK) Requirements

Window Wall Ratio	Minimum VLT
0 - 0.3	0.27
0.31 – 0.4	0.20
0.41 – 0.5	0.16
0.51 - 0.60	0.13

Table 5 – Minimum VLT Requirements

Climate	Maximum U-factor		Maximum SHGC	
	With Curb	Without Curb	0 ~ 2% SRR*	2.1% ~ 5% SRR*
Composite	11.24	7.71	0.40	0.25
Hot and Dry	11.24	7.71	0.40	0.25
Warm and Humid	11.24	7.71	0.40	0.25
Moderate	11.24	7.71	0.61	0.40
Cold	11.24	7.71	0.61	0.40

Table 6 - Skylight U-factor and SHGC requirements

*SRR: Skylight roof ratio is the ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior roof.

Advantages and Disadvantages of Glazing

Advantages: Thermal comfort: Through its solar control and effective insulating properties, high-performance glazing increases thermal comfort in both summer and winter. Solar gains in the summertime are reduced so that houses neither overheat nor require air-conditioning. In winter, the cold stays outside and the heat inside which reduces the need for heating.

Visual comfort: Daylight is an essential part of human well-being. As a transparent medium, glass lets natural light penetrate to the heart of a building and provides an opening to the world outside. Patterned and textured glass diffuses light, safeguards privacy and creates convivial and contemporary living spaces.

Acoustic comfort: Traffic, public works, music played at full blast just some of the daily sources of noise pollution which damage our quality of life. Acoustic insulation glazing plays a decisive role in shutting out these disturbances. It enables a gain of up to 10 decibels compared to traditional glazing.

Recyclable: Glass is 100% recyclable and it does not degrade during the recycling process, hence it can be recycled again and again without loss of quality or purity

Security and safety: When laminated or tempered, glazing offers different levels of safety and security. Potential injuries may be avoided if glass shatters (e.g. roofing glass, bay windows, and shower screens) and safety glass protects people and property in case of aggression.

Indoor air quality: Today, most people spend more than 90% of their time inside vehicles or buildings. Indoor air quality is therefore critical. Unlike other materials which discharge elements into the air, glass is inert. Notably glazing emit very low amount of VOCs (volatile organic compounds).

Easy to clean: Outside pollution and dust continuously alter a window's properties, reducing solar heat gains. As self-cleaning glazing stays clean longer than traditional glass, this saves not only water and detergent but also time.

Disadvantage

Expensive Material

Manufacturing of glass is high energy consuming process due to high temperature required for processing the raw materials, and it is an expensive material and ultimately increases the cost of a building. Figure 6 – Annealed

Objectives

To study the effective use of glass as a sustainable building material for different climatic zones in India. Energy Conservation Building Code (ECBC) – India, has divided the country into five different climatic zones. To find the suitable locations for placement of glazing and effective use of various glazing systems, like double / triple glazing, gas filled glazing, Low- emissivity coating, heat absorbing tints etc. in reducing energy consumption and enhancing the occupants comfort level and their productivity.

Passive Architecture: Passive architecture is the design of buildings and site planning that take advantage of local climates enabling the structure to naturally assist the building in its ability to store thermal energy from the sun and cool the structure by shielding it from the sun rays.

Passive Design Features and their Advantages

Orientation of Building

The orientation of a building in a particular direction, therefore, can heat or cool the building depending on the climatic zone in which it is constructed. Proper orientation can help increase or decrease the heat load by 5%.

The optimum orientation of the building for the tropical region should be considered keeping the longer axis of the building along east- west.

Sunshades:

These are installed at the top of windows/doors to obstruct sunrays that enter the building during summers but allow them to enter during winters. This helps protect the building from overheating during summers and keeps it warm during winters, thereby reducing electricity consumption

Window Design:

Windows in a building allow light, heat, and air to come in. Therefore, decision regarding location of windows should be based on the requirement of heat in the building. The sizes of windows and their shades also depend on the climatic zone. Double glazed windows with air gaps can act as good insulation. The insulating air gap lowers the heat gain of the building. It should be used for air - conditioned spaces.

Building Insulation

Insulation can be added to walls or roofs to reduce heat transfer. It also help s in moderating indoor thermal comfort and is effective in reducing temperature fluctuations in non-air-conditioned spaces. Some commonly used insulation materials for roof are mineral wool, extruded/ expanded polystyrene, PUF (polyurethane foam), and vermiculite.

Cavity walls are an effective method of insulation. Fly ash-based aerated concrete blocks and cellular concrete blocks have good insulating properties and can be used for wall insulation.

Landscaping

Landscaping provides a buffer against heat, sun, noise, traffic, and airflow. It is also effective in diverting airflow or exchanging heat in a solar-passive design. Deciduous trees, such as amaltas, champa, and similar varieties, provide shade in the summer and sunlight in the winter when their leaves fall. So planting such trees to the west and south-west of a building is a natural solar passive strategy. Evergreen trees provide shade and wind control round the year. They are best placed to the north and north-west of a building.

Surface to Volume Ratio

A compact building gains less heat during daytime and loses less heat at night. The compactness of the building is the ratio of its surface area to its volume, that is, Compactness = S/V (surface area/volume). In hot-dry climates the S/V ratio should be as low as possible to minimize heat gain. In warm humid climates the prime concern is creating airy spaces. This would require a higher S/V ratio.

Roof Treatment

Some simple roof treatments, other than roof insulation, for reducing the summer heat gain in buildings, are as follows.

White washing the roof before the onset of the summer. Spraying water on the roof. Sprinkling water at regular intervals can reduce heat gain through roof. Using shining and reflecting material for the rooftop.

Evaporative cooling

When water stored in a water body evaporates into the surrounding air, it lowers the ambient temperature. This phenomenon is known as evaporative cooling. The presence of a water body such as a pond, lake or sea near the building or even a fountain in the courtyard can provide the cooling effect. The most commonly used system is a desert cooler, which comprises water, evaporating pads, a fan, and a pump. External cooling through humidification can also be achieved by keeping surfaces of roofs moist using sprays or lawn sprinklers. Evaporative cooling is very effective in the hot and dry climatic zone, where humidity is low.

Passive Heating

In places in cold climatic zones, for example Shimla, where temperatures outside are lower than they are inside, heat flows away from buildings through their external envelopes and due to air exchange. In such climates, passive heating measures are adopted to provide thermal comfort and also to reduce the demand for conventional heating.

Two methods are popular for passive heating of buildings.

Direct gain method Sunlight is permitted into habitable spaces through an opening, which allows it to directly strike and heat the floor, walls or other internal objects. These, in turn, heat the air within the room.

Indirect gain method in this strategy, a thermal storage wall is placed between the glazing and habitable space. This prevents solar radiation from directly entering the living space. It is absorbed, stored, and then, indirectly transferred to the habitable space e.g. Trombe wall

Earth air tunnel, Solar Chimney, Wind towers, Dehumidifiers and desiccant cooling are some more passive features used effective in different climate zone.

Eco-Friendly Building- Case Study Project: The Energy and Resources Institute (TERI) Orientation:

The building is located in a long and narrow site, where the southern side has an open drain (Figure - 13). The primary winds blow from south to north.

The building was oriented along the east-west axis so as to have maximum exposure along north and south which is the most recommended orientation in solar passive architecture. The building opens towards the northern side, taking advantage of glare- free light. The wall towards the south is made into a blank wall, allowing the foul smelling breeze to flow over the building and is driven away (Figure- 14). On the south is an absorptive double wall with cavity which provides insulation from the south sun and heats up the air within .The walls cavity allows the hot air to rise (chimney action) and pull in fresh air from north (Figure- 24).

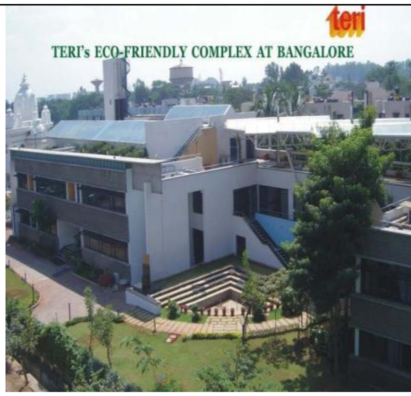
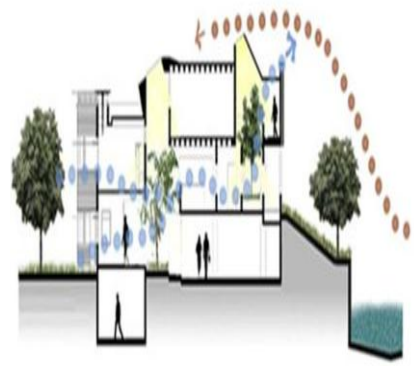
		

Figure 12 –TERI Building	Figure 13 - Site Plan of TERI showing longer side facing North-South	Figure 14 – Sectional Elevation showing Wind movements

Daylight:

By creating atrium spaces with skylights, the section of the building is designed in such a way that natural daylight enters into the building, considerably reducing the dependence on artificial lighting (Figure- 15).

The building opens towards the northern side, taking advantage of glare- free light (Figure-19). The entire fenestration has been conceptualized to minimize dependence of artificial lighting during the day (Figure- 16 and 17).

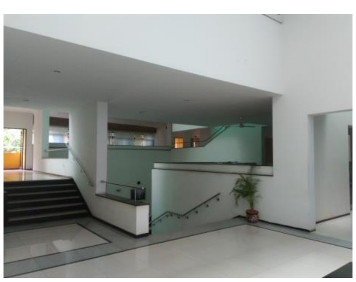


Figure 17 -Staircase and Common Corridor	Figure 18 –Green Barrier at East	Figure 19 - Vertical Fenestration and Pond at Main Entrance

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Figure 20 - Vertical Fenestration at Canteen</td>
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Figure 21– Roofing for Terrace Garden</td>
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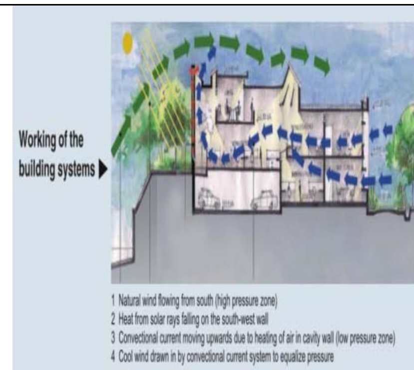
<td>
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<td>Figure 22 – Louvered at terrace</td>
<td>Figure 23 – North light and solar panels</td>
<td>Figure 24 – Sectional Elevation showing Solar Chimney action</td>
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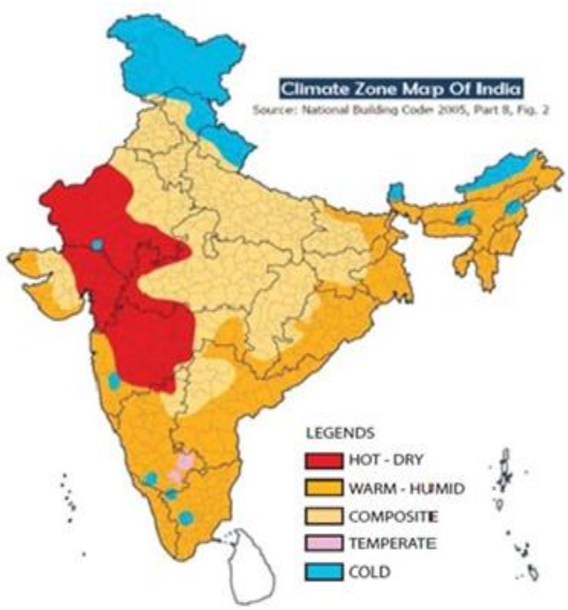
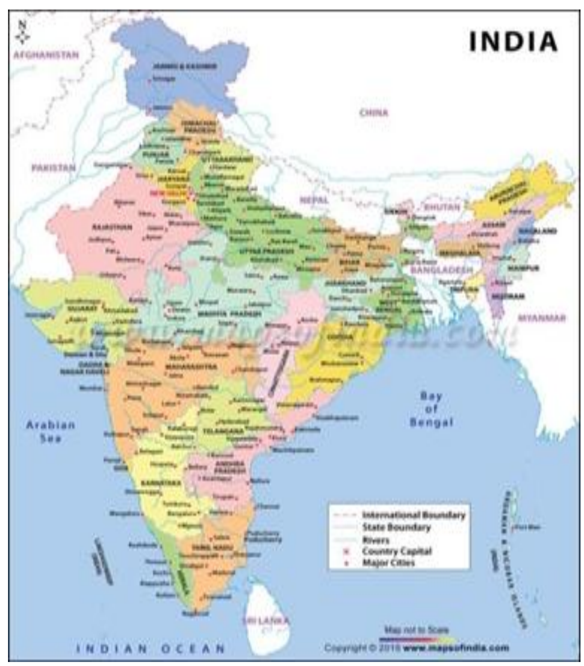
CASE STUDIES: DIFFERENT CLIMATE ZONES IN INDIA

Significance of Climate in Green Design
Knowledge of climatic conditions of a given location is vital for a good design.





Climatic requirements for buildings are generally same with few differences only due to local environmental conditions. Life patterns of people, activities and behaviour are influenced by the elements of climate. The basic elements viz. air temperature, solar radiation, humidity; rainfall and wind form the general climate of a place. Energy Conservation Building Code (ECBC) prepared by the Bureau of Energy Efficiency (BEE) sets minimum standards for external wall, roof, glass structure, lighting, heating, ventilation and air conditioning of the commercial building. ECBC provides minimum requirement for the energy efficient design and construction of the building. As per the climatic conditions, India has been divided into 5 climatic zones and ECBC takes these zones into consideration while building envelope design.

RESULTS AND DISCUSSION

The essence of passive solar architecture pertaining to the use of glass can be summarized as. South-facing glazing is considered as solar glazing. South-facing solar glass is a key component of any passive solar system. The system must include enough solar glazing for good performance in winter, but not so much that cooling performance in summer will be compromised. North facing glazing receive relatively little direct sun in summer, they do not have much of a shading problem. So if the choice was between an average sized north facing window and an east or west facing window, north would actually be a better choice, considering both summer and winter performance. East facing glazing are important in Indian housing because openings to the east have a special symbolism in most Indian cultures. But the openings should not be oversize, because the net energy benefit may be small, and, unfortunately, an east orientation can cause potential overheating problems in summer. Shading is advised. West facing glazing may be the most problematic, and there are few shading systems that will be effective enough to offset the potential overheating from a large west-facing window. Glass with a low shading coefficient may be one effective approach for example, tinted glass or some types of low-e glass that provide some shading while allowing almost clear views.

East and west glazing are likely to increase air conditioning needs unless heat gain is minimized with careful attention to shading and glazing system. Double glazings are advisable in all the climate zone of India. As many windows as possible should be kept operable for easy natural ventilation in summer. Glazing Products - Before selecting the glass, we need to look at the key performance parameters and select the best suited one depending on the building location

CONCLUSIONS AND FUTURE SCOPE

It is not an isolated pane of glass that is green, but the placement of glazing along the right direction that will make the building sustainable. The knowledge of passive architecture and the data of microclimate in the region will help to achieve the right location of glazing. The properties of glass have also become multifaceted, able to perform a wide variety of functions, like Solar Control to Thermal Insulation, which enable the building to be energy efficient.

Future Scope

i. Photovoltaics have the principal purpose of reducing energy consumption in buildings and generating energy from the sun. It mitigates the effects of climate change by helping to conserve energy in buildings and to assist with the generation of solar power. The detailed study on Photovoltachromic switchable glazing technology as facade for building needs to be taken up to enables the next generation of renewable energy.

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