Climate Responsive Envelope Of Healthcare Buildings In Composite Climate Of India

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Abstract: The building envelope, is the most important element in the energy consumption of a building, in case of large scale buildings it gains more importance due to the large amount of the surface area of building's facade.

In a context of global warming and our needs to reduce CO2 emissions, building envelopes will play an important role. A new imperative has been put forth to architects and engineers to develop innovative materials, components and systems, in order to make building envelopes adaptive and responsive to variable and extreme climate conditions especially for composite climate.

Envelopes serve multiple functions, from shielding the interior environment to collecting, storing and generating energy. This dissertation is an investigation into climate responsive architecture, specifically within the building envelope. It seeks to respond to local environmental conditions and enhance sensual qualities to generate a unique architectural environment by engaging interaction between people and the building's skin. By analyzing the wall assembly as an aperture for responding to the different weather conditions, the responsive envelope will engage air, light and water movement to harness energy and create a site-specific building envelope.

Keywords: Climate responsive architecture, building envelope, health care buildings, composite climate of India

I. INTRODUCTION

II. We spend 90% of our awake time indoors, in a variety of buildings. Thereby we increasingly miss the connection with nature and natural trigger to which our bodies are aligned. So, there is a need to create buildings that not only support the occupant's activity but also response to the nature in eco friendly manner. In this regards envelope of the building plays an important role.The building envelope need to be designed in such a way that works well with the elements of nature, achieves an experience of greater productivity and improved wellbeing for the users and at the same time improves the energy efficiency of the buildings.

III. In Indian contemporary architecture there is very less innovation has been made in the field of climate responsive building envelope design. As far as healthcare buildings are concerned which consumes a large chunk of energy consumption during its operation an energy efficient climate responsive building envelope will definitely contribute energy saving of healthcare buildings in India.This dissertation is principally focused on the analysis of the impact of climate responsive building envelope ofhealthcare buildings in one of the largest climatic zone which is composite climate of India.

IV. The future and emerging technologies of building envelope systems

V. can make a difference with the overheating risks due toclimate change and the reduction of energy demand for coolingin existing and new buildings. This dissertation takes two case studies of hospital buildings at different locations of India which falls under the composite climate. Energy simulations of these building has been done with and without modification with climate responsive elements and impact of the has been analysed in the form of energy use of envelope. After the analysis some parameters has been set for the designing of climate responsive building envelope in Indian composite climate.

2 .LITERARURE STUDY

2.1 BUILDING ENVELOPE DESIGN PRACTICE IN TRADITIONAL AND CONTEMPORARY ARCHITECTURE OF INDIA.

INDIAN TRADITIONAL BUILDING ENVELOPE:

VI. Traditionally Indians lived in the joint family system. Many occupants of the house and their interpersonal relationships demanded clearly distinguished spaces for different activities. There were private and public zones in the house with the courtyard as its nucleus. These houses were very high on the sustainable quotient. They were designed to suit the climate, the anthropometry, the Vaastu Shashtra and used local building materials and techniques for construction.

VII. Many theorists and distinguished architects like Hassan Fathy have promoted the underlying concepts on traditional architecture to form contemporary design. However, in the present scenario, the traditional building has been replaced by fast-growing concrete jungles, which are not sustainable or sensitive towards the natural calamities and microclimatic conditions.

VIII. When I taught History of Architecture for the first time, I was trying to explore and understand deeper meanings of concepts and stories which lead to the built Architecture. History, as it suggests, is the story which insights what happened in the past. There is a lot to acknowledge and interpret from our history and heritage, especially architecture, as history has the best design guidelines which respond aptly to the vernacular character of that place, the lifestyle of the users and building traditions of that time.

IX.

X. Indian contemporary building envelope:

XI. Upon becoming a sovereign country, free from British Rule, the people of India found themselves faced with questions they had never needed to answer before. Coming from different cultures and origins, the citizens began to wonder what post-independence India would stand for. The nation-builders now had the choice to carve out their own future, along with the responsibility to reclaim its identity - but what was India's identity? Was it the temples and huts of the indigenous folk, the lofty palaces of the Mughal era, or the debris of British rule? There began a search for a contemporary Indian sensibility that would carry the collective histories of citizens towards a future of hope.

XII. A building skin consists of vertical (facade) and horizontal (roof) components which protect the building from direct external environment and helps in maintaining comfortable interiors along with providing structure and stability to the building. Building skins are a vital component to resolve issues of responsive architecture as they are a medium through which intelligence can be imparted to a building system to respond to an environmental stimulus. Thus, key characteristic of an effective intelligent building skin is its ability to modify energy flows through the building envelope by regulation, enhancement, attenuation, rejection or entrapment.

XIII. A building skin is designed using a number of parameters such as environmental conditions, structural feasibility, and materiality, among others; all of which can be quantified as data. Since there is a large amount of data involved, computation becomes an essential part of dealing with the complex dynamics of design. Computation can be carried out through non-digital & digital processes aligned together and algorithms can be used of complex (and simple) problem solving. These problems include structural load calculations, material behaviour calculations, fabrication data extraction, etc. An algorithmic method of designing a building skin or a façade system can aid in controlling all the parameters and objective data that is embedded in design and a flexibility to use this data for creating a smart(er) system.

2.2 DESIGN REQUIREMENTS OF ENERGY EFFICIENT BUILDING ENVELOPES AS PER ECBC FOR COMPOSITE CLIMATE OF INDIA.

Energy Conservation Building Codes (ECBC) 2017

- Building Envelope mandatory Requirements Fenestration

- U-Factor (U-factors shall be determined for the overall fenestration product(including the sash and frame) in accordance with ISO-15099).

Solar Heat Gain Coefficient (in accordance with ISO-15099).

Visible light transmittance

Visible light transmittance (VLT) shall be determined for the fenestration product in accordance with ISO-15099 by an accredited independent laboratory.

Opaque Construction

- U-Factor (in accordance with ISO-6946).

- Solar Reflectance (in accordance with ASTM E903-96)

2.3 IMPACT OF HEAT EXCHANGE ON BUILDING ENVELOPE.

The temperature inside a building is affected by thebuilding design, orientation and envelope, which in turn areaffected by the solar radiation, ambient temperature,relative humidity and ventilation. The climatic stress onhuman inhabitants has been studied in accordance withcomfort limits. The hot climate regions are severe; it haslarge daily and annual cycles. It has about two or threecomfortable months, four cold months and six hot months.The building has to satisfy two contrasting functions:keeping the heat out in summer, and keeping the heat insidein winter. Consideration of the following criteria forcontrolling inner environment is quite necessary;

1. Selecting materials and a construction system on thebasis of low thermal transmittance (low U-value) andhigh thermal storage capacity in addition to theimplementation of constructional treatments to get adesired time lag within 8 to 14 hours for walls, and 20 to30 hours for the roof. Using well-insulated roofingmaterials to provide high time lag, low thermaltransmittance and high thermal capacity, or foaming aPortland cement mixture with a foaming agent such asaluminium dust to make insulated concrete roof slab canbe done.
2. Using the most common economical thermal isolationmaterials (11 cm) thick for the roof; (7 cm) thick forsouth-facing walls ;(8 cm) for south-east walls; and (10cm) for other orientations. Insulation material should belocated near the external layer of the walls, which shouldbe smooth and painted externally in light colours.
3. . Designing well shaded walls and windows, selectingsuitable window glass and size for each orientation.These areas should be minimal on the east and westelevations.
4. Using double roof, and walls skin, and the early ideas on"Filter" Architecture” to get high thermal protection.
5. Designing the building to be in thermal contact with theground, the idea of (sub ground level–basement) enablesbenefits from the cooled humid space more than ispossible at ground level.

2.4 BUILDING ENVELOPES ENERGY PERFORMANCE CALCULATION METHODS.

Building Envelope Trade-Off Method

The building envelope complies with the code if the Envelope Performance Factor (EPF) of theProposed Building is less than the EPF of the Standard Building, where the Standard Buildingexactly complies with the prescriptive requirements of building envelope. This method shallnot be used for buildings with WWR>40%. Trade-off is not permitted for skylights. Skylightsshall meet requirements ofThe envelope performance factor shall be calculated usingthe following equations.

EPF total= EPF(roof)+EPF(wall)+EPF(fenestration)

Table 4-16 Envelope Performance Factor Coefficients – Composite Climate

	Daytime Business, Educational, Shopping Complex		24-hour Business, Hospitality, Health Care, Assembly	
	C factor $_{U\text{-}factor}$	C factor $_{SHGC}$	C factor $_{U\text{-}factor}$	C factor $_{SHGC}$
Walls	24.3	-	48.1	-
Roofs	40.9	-	71.0	-
North Windows	21.6	201.8	41.0	367.6
South Windows	19.1	342.5	41.0	546.3
East Windows	18.8	295.6	38.4	492.2
West Windows	19.2	295.4	38.3	486.1

Table 4-17 Envelope Performance Factor Coefficients – Hot and Dry Climate

	Daytime Business, Educational, Shopping Complex		24-hour Business, Hospitality, Health Care, Assembly	
	C factor $_{U\text{-}factor}$	C factor $_{SHGC}$	C factor $_{U\text{-}factor}$	C factor $_{SHGC}$
Walls	27.3	-	55.9	-
Roofs	43.9	-	80.7	-
North Windows	23.7	238.2	49.1	414.4
South Windows	22.8	389.7	49.2	607.4
East Windows	21.6	347.4	46.2	556.2
West Windows	21.7	354.1	46.0	560.8

Table 4-18 Envelope Performance Factor Coefficients – Warm and Humid Climate

	Daytime Business, Educational, Shopping Complex		24-hour Business, Hospitality, Health Care, Assembly	
	C factor $_{U\text{-}factor}$	C factor $_{SHGC}$	C factor $_{U\text{-}factor}$	C factor $_{SHGC}$
Walls	24.5	-	51.2	-
Roofs	40.1	-	76.1	-
North Windows	20.7	230.7	43.6	401.5
South Windows	20.1	347.1	43.9	546.4
East Windows	19.0	301.8	41.1	490.6
West Windows	18.7	303.1	40.5	483.5

3. CASE STUDY

CASESTUDY 1:

MEDANTA GANGANAGAR HOSPITAL, SRIGANGANAGAR, RAJASTHAN (200 BEDDED)

About the building:

XIV. 200-bedded super speciality hospital. The hospital is located on the outskirts of Sri Ganganagar, on the Suratgarh-Hanumangarh Bypass Road.

XV.

XVI. Key details of the buildings are:

XVII. Built-up area: 1,65,000 Sq.ft.

XVIII. Climate zone : Composite

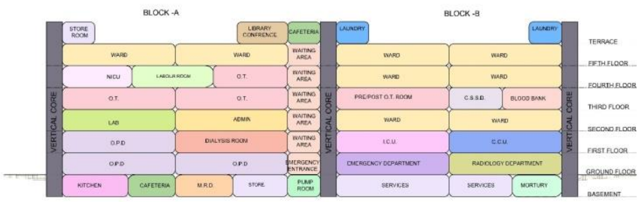
XIX. Name of the firm (architectural): Manchanda Associates, New Delhi

XX. Cost of project: Rupees 72 Crore

XXI. Year of completion: 2018

XXII.
XXIII. Climate analysis using Climate studio (Shri Ganganagar)
XXIV. IND_RJ_Ganganagar.421230_TMYx.2004-2018
XXV. Koeppen climate Zone: Arid Desert Hot
XXVI. ASHRAE climate zone: Very hot
XXVII. ECBC and NBC climate zone: Composite
XXVIII. Average annual temperature: 25 °C
XXIX. Annual total solar radiation: 2,108 kWh/m2
XXX. Heating Design Conditions
XXXI. Coldest month: January
XXXII. Coldest week: 12/17 - 12/23
XXXIII. Typical winter week: 11/12 - 11/18
XXXIV. Annual HDD for 18 °C is: 141
XXXV. Design temperature 0.04%: 4.5 °C
XXXVI. Cooling Design Conditions
XXXVII. Hottest month: June
XXXVIII. Hottest week: 6/ 3 - 6/ 9
XXXIX. Typical summer week: 5/13 - 5/19
XL. Annual CDD for 10 °C is: 5,732
XLI. Design temperature 99.6%: 42.3 °C
XLII.
XLIII. Plans and section :
XLIV. The H-Shape of the building helped in creating distinct zones for segregating independent departments while keeping the vertical circulation central. This ensured easy and unobstructed movement of patients, doctors and visitors, which is of prime importance in the functioning of any hospital. The H-Shape also enabled the addition of an additional block for future expansion.
XLV. Natural light and ventilation are essential elements for designing any building, especially hospitals. The orientation of the buildings has been kept such so as to maximize glazing on north and South faces while effectively blocking the hot sun on the Eastern and Western faces.

GROUND FLOOR PLAN : O.P.D. AND EMERGENCY



STACKING

XLVI.
XLVII.
XLVIII. Building envelope
XLIX. The facade of the building is interspersed with transparent and opaque elements composed of large glass panels and solid shafts. The two-tone grit finish, created using locally sourced Dholpur and Jaisalmer stone not only provide a permanent finish, but also gives the hospital a sharp look while creating an array of clean lines throughout the elevation.The energy efficiency systems includes use of energy efficient insulated glass to minimize heat gain while still maintaining large glazing for increasing day-lighting within buildings. Windows and structural glazing in aluminium with insulated and energy efficient double-glazed units to reduce heat gain.

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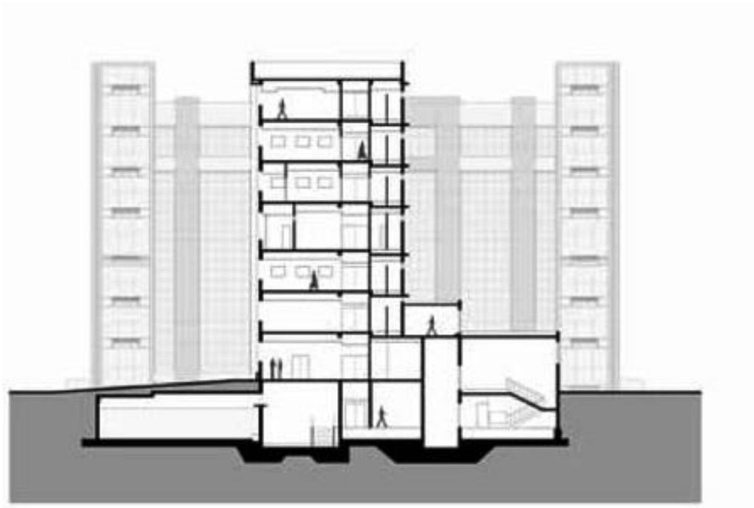
LX. 

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CASE STUDY 2 : BHAGWAN MAHAVEER CANCER HOSPITAL AND RESEARCH CENTRE, JAIPUR, RAJASTHAN (300 BEDDED)

About

300-bedded super specialty hospital. The hospital is located Jawahar Lal Nehru Marg, Bajaj Nagar, Jaipur, Rajasthan

Key details of the buildings are:

- Architects: Malik Architecture
- Location: Jaipur, India
- Climate zone : Composite
- Built up area: 75,000 sqft.
- Site area: 4.6 Acres.
- Year of Completion: 2001

Climate analysis using Climate studio (Jaipur, Rajasthan)

IND_RJ_Jaipur.Intl.AP.423480_ISHRAE2014
Koeppen climate Zone: Arid Steppe Hot (BSh)
ASHRAE climate zone: Very hot (1)
ECBC and NBC climate zone: Composite
Average annual temperature: 26 °C
Annual total solar radiation: 2,071 kWh/m2

Heating Design Conditions

Coldest month: January
Coldest week: 12/24 - 12/30
Typical winter week: 11/12 - 11/18
Annual HDD for 18 °C is: 141
Design temperature 0.04%: 7.5 °C

Cooling Design Conditions

Hottest month: June
Hottest week: 6/10 - 6/16
Typical summer week: 4/22 - 4/28
Annual CDD for 10 °C is: 5,732
Design temperature 99.6%: 42 °C

Building envelope:

To cope with the harsh extreme climate of the Rajasthan detailed study of sun directions has been done and consequent placement of fenestration (most of which are deeply shaded), thick stone walls for insulation used in the building.

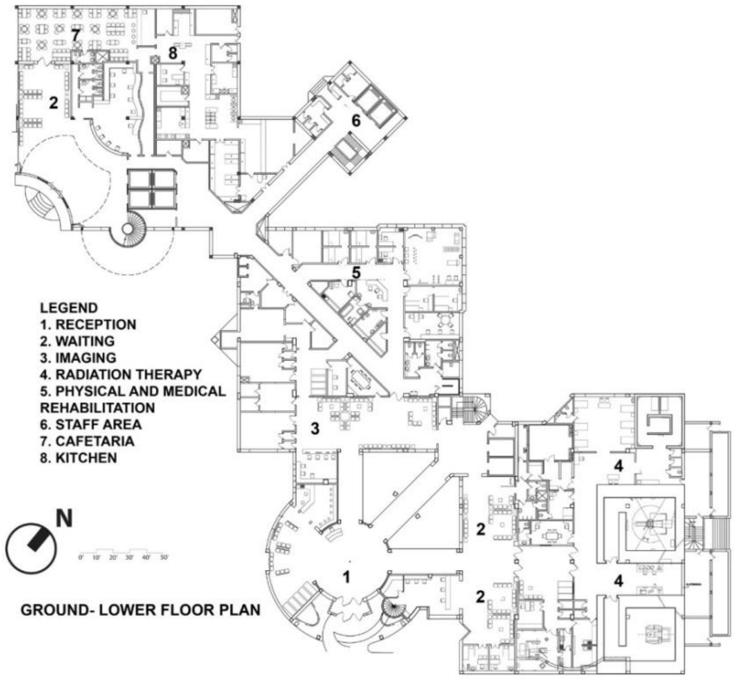
The for building envelope stones used are local Rajasthan sandstones viz. Dholpur and Agra-red. The two are inter-twined to accentuate the massing of the walls. Stone pergolas have been used to diffuse light. The structure is a combination of load-bearing stone walls and R.C.C. frame (long spans) with stone cladding. Flooring is a combination of Khaitan green stone, Jaisalmer-yellow and Makrana-white.

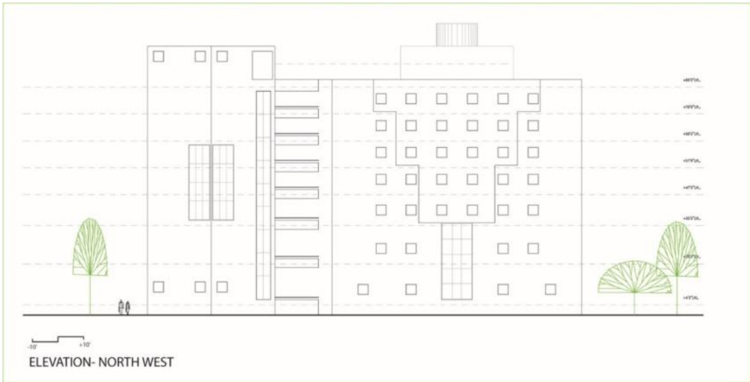
Plans and section:

The various departments both connect and branch out from the central spine and the diverse functions (OPD, in-patient, ICU, theatre suite, Admin) are sensitively placed such that they complement each other in the layout.

To conserve energy as well as optimise area usage, the plan facilitates the provision to shut off complete departments, viz. OPD/Complex Diagnostics, without affecting the other areas of the Centre.

Multiple 'courtyard' spaces have been created that gently filter suffused light into the circulation and waiting areas.





Inferences

Form & orientation:

Compact form with a low surface-area-to-volume ratio is being used for the building. It is kept as minimum as possible to minimize the heat gain through radiation and conduction. Square plans have been designed as it is more energy efficient than rectangular ones.

Building has been oriented with their longer axis (north-south) aligned perpendicular to the prevailing winds to facilitate maximum air-flow and cross ventilation through the building ensuring comfort for the users.East and west facade of the building has been minimized and a well-shaded facade and heavy thermal mass used in these directions.

Natural ventilation:

For good natural ventilation building openings are placed in opposite pressure zone. (Since natural ventilation relies on pressure to move fresh air through the building)

Maximum air movement is achieved by keeping the sill height at 85% of the critical height. The greatest flow per unit area of the opening is achieved by the inlet and the outlet of nearly the same size and at nearly the same level. Staggered windows are provided instead of linear one.

Cool roofs specifications:

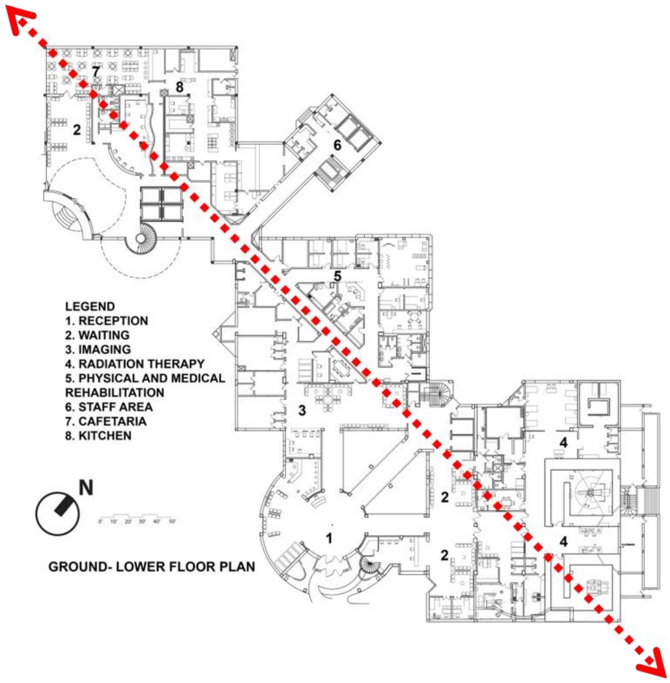
For the cool roof materials well graded broken piece of glossy glazed tiles (broken china mosaic), modified bitumen with plastic and a layer of reinforced material, RCC roof topped with elastomeric cool roof coating has been provide.

Thermal mass:

Dense thermal mass material (sandstone over brick masonry) with insulation layer has been used in the building. Denser the thermal mass material better it stores and releases heat.

Insulation:

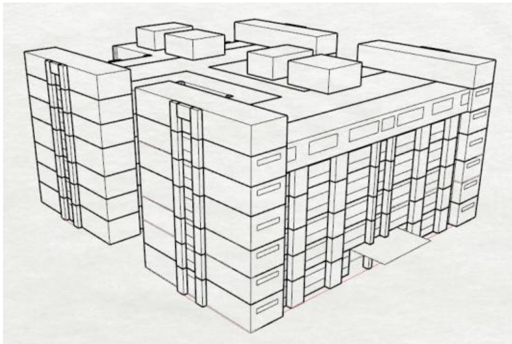
Building thermal insulation material has been chosen keeping in mint the following parameters: Thermal performance, lifetime performance, fire safety, moisture and condensation, air infiltration and environmental benefits.

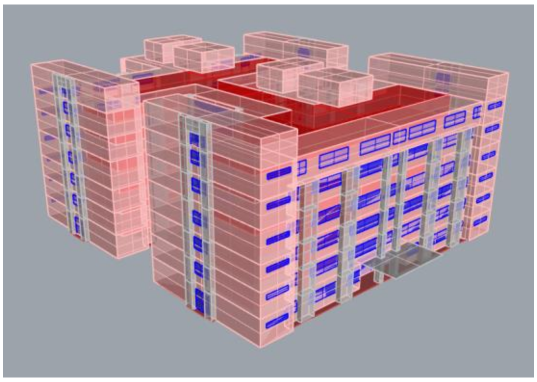


4. ENERGY SIMULATION AND ANALYSIS

Analysis of energy saving potential with the implementation of climate responsive building envelope.

Energy simulation: Thermal analysis of the building using Climate Studio with Conventional Building envelope





Areas of modifications in the envelope:
[1] Roof (Lower U-Value materials specifications)
[2] Facade (Lower U-Value thermal mass materials specifications for external brick wall)
[3] Fenestration (DGU glass with Low u value)
[4] Shading devices

(Orientation based shading strategies: a combination of vertical and horizontal shading devices protect from the sun in all directions. Vertical shading devices has been provided to protect sun at the sides of elevation such as East and West sides).Horizontal shading devices protect from the sun at high angles so it has been provided at North and South sides of the building

Comparative analysis on energy performance of building envelope of hospital building in composite climate before and after retrofitting:

"On performing modifications in building envelope and making other parameters constant 40% reduction in building energy consumption has been found in the simulation process."

5. CONCLUSION

[1] This paper has examined energy-efficient building envelope design decision-making in composite climate of India. In the dissertation it has been found that the informed design decisions can be achieved through the process of analyzing building energy use, highlighting exterior build environment, exploring window and wall systems and material properties, and identifying potential design measures. This process integrates energy modeling into the design which enables continual information exchanging, analyzing and comparing.
[2] Five representative design measures namely wall insulation, exterior wall color, window to wall ratio, window system and solar shading devices are selected to be examined in Climate. The measures of reducing the solar heat gain are more effective than those of reducing conduction through external walls. The results suggest that there is a large potential to significantly reduce energy consumption with readily available design measures and materials. Also, the dissertation emphasizes the importance of incorporating energy modeling into design decision-making in producing more energy-efficient buildings.
[3] Optimizing the performance of the building envelope is very important as it is the main interface between the outdoor and indoor environments can be a major focus for energy saving strategies in buildings.
[4] Climate responsive building envelopes present a considerable potential in this area to address comfort and energy demands in buildings through dynamic and adaptive performance.
[5] The responsive aspect of climate-responsive building envelope elements is the adaptive behaviour of such elements under changing conditions of the outdoor climate.

Recommendations

Climate responsive building envelope design measures for composite climate can be generally separated into two groups, namely architectural design measures and material design measures.

Architectural design measures:
[1] Optimize building form to minimize heat gains through surface;
[2] Orient building towards north-south exposures to take advantage of north–south day-lighting
[3] Turn long facades toward the prevailing breezes to enhance natural ventilation
[4] Employ solar shading devices to block direct solar radiation;
[5] Use innovative wall type, e.g. double skin wall;
[6] Proper design of window area and size (window to wall ratio
[7] Install wing walls to improve natural ventilation;
[8] Install light shelves to penetrate daylight deep into the building.

Material design measures:
[6] Insulate the exterior wall and roof to avoid hot and cold air infiltration in there respective seasons;
[7] Use high performance concrete for its thermal mass;
[8] Use reflective exterior wall/roof finishes to reduce solar heat gain;
[9] Use innovative construction materials, e.g. Fiber-reinforced polymer;
[10] Incorporate windows with low-e or reflective coating;
[11] Incorporate windows with tinted or multiple layers of glazing;
[12] Incorporate windows with thermally improved frame.

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