3RD INTERNATIONAL DESIGN RESEARCH CONFERENCE

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SHODHADITYA
Research Journal 2023

SHREE AMEYA PUBLIC CHARITABLE TRUST'S
ADITYA
COLLEGE OF ARCHITECTURE
ISO 21001:2018 CERTIFIED

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VISION, MISSION & QUALITY POLICY

VISION

- *To be globally recognized as an epitome of learning and innovation.*
- *Imparting multifaceted architectural education driven by social sensitivity and supported by state of the art of infrastructure.*

MISSION

- *To impart quality education that encourages students to be competent enough for best fit job roles.*
- *To provide faculty members with facilities to research, experiment and implement contemporary learning tools.*

QUALITY POLICY

“ We, the Management, Faculty and staff of Aditya College of Architecture are committed to offer excellence in architectural education, by pledging to our core value of Agility, Innovation, Integrity our academic environment and state of the art facilities and infrastructure to our students, thereby ensuring mutual respect and trust for them.

We will work as a team and interact with the students in pro-active manner to achieve our institutional quality objectives and fulfill all academic , statutory and regulatory requirements to continually enhance the satisfaction of our students. ”

Aditya College of Architecture established in 2013 is affiliated to Mumbai University, India. Since its inception, the college has continuously been working towards a vision to take architectural education ahead of traditional curriculum and achieve higher goals in grooming better professionals every year. The primary objective of the school is to create 'global practices with local concerns' to achieve excellence in architectural design, practice and profession.

ABOUT ACA

The campus has infrastructure comparable to the best in the world. An ideal environment for exploring new ideas that encourage creative and independent thinking of young minds. It also provides platform for promoting innovation and research for students and faculty. The pedagogy of the school is building professional capacity and cherished individual interest of the student.

With the vision that educating professional requires close coordination of industry and academic the institute encourages collaboration with eminent academicians and industry professions in the way of conducting workshops, seminars, and webinars in the present pandemic situation. The Institute has collaborated with Sri Lanka Institute of Architects by the way of exchange program and combine studios.

ABOUT IDRC

Theme:

Building Envelope

This year Aditya College of Architecture (ACA) brings its 3rd International Design Research Conference (IDRC 2023) with the theme 'Building Envelope'. A building envelope is everything that separates the internal building from the external environment. architecture comprises of various building elements including the roof, the fenestration, floors, and walls. At first glance, it defines the characteristics of the built form and imparts the aesthetic. More importantly however, it facilitates climate control within the indoor environment, reduces its dependence on mechanical systems and increases its economic viability. The building envelope is not just one component, but a variety of independent facets that create the system. Design intervention on any of its entities positively or negatively impacts the structures performance, thereby measuring its contribution towards a greener planet.

Few practices around the globe believe in developing building envelopes that supports policies and practices that will lead to government and business solutions that work for all, ultimately creating new industry standards and sustainable future for the world. Some believe that the facade design plays an important role in the functionality of a building. A carefully designed facade will also play a central role in determining the energy efficiency of the building.

Functions:

A building envelope serves many functions. These functions can be divided into 3 categories

Support:

To ensure strength and rigidity, providing structural support against internal and external loads and forces.

Control:

To control the exchange of water air, condensation, and heat between the interior and exterior of the building.

Finish:

This is for aesthetic purposes. To make the building look attractive while still performing support and control functions.

The IDRC conference intends to cover an array of topics that enables students, researchers, academicians, and practitioners, to express their thoughts, hypotheses and ideologies and demonstrate their designs through research and practice. It will also enable notable speakers to showcase their experience, expertise, and knowledge on the subject.

ABOUT IDRC

IDRC 2022-23 invited original research papers related to our theme "Building Envelope" based on the sub-themes mentioned below from undergraduate and post-graduate students, researchers, academicians and professionals belonging to the architecture and building construction industry. We received a positive response of abstracts from all categories which were reviewed by our expert review committee. The selected abstracts have been compiled. Full papers were later received and reviewed, and a few selected full papers will be presented in the conference, while all selected papers will be published in our journal, Shodhaditya Research Journal (ISSN No.: 2347-8403).

Building Envelope

Sub-themes:

1. *Building Thermal Envelope*
2. *Sustainable Building Envelope*
3. *Facade Designing*
4. *External Environment*
5. *Adaptive Building Envelope*
6. *Life Cycle Assessment For Alternative Building Envelope*

ADITYA COLLEGE OF ARCHITECTURE

ACA

3rd INTERNATIONAL DESIGN RESEARCH CONFERENCE

"Building Envelope"

Mumbai – January 21st, 2023.

ADITYA COLLEGE OF ARCHITECTURE 3rd INTERNATIONAL DESIGN & RESEARCH CONFERENCE		
Programme schedule - 21st January 2023.		
Session details	**Timings**	
Inauguration of the IDRC 2022 -23 in Banquet hall, ACA Campus; lighting of lamp and felicitations of dignitaries	09:30 am - 09:45 am	Ar. Varsha Swar, IDRC Co-ordinator.
Welcome Address by Principal	09:45 am - 10:00 am	Ar. Sarita Deshpande, Principal, ACA.
About IDRC	10:00 am - 10:15 am	Ar. Rasika Chodankar, IDRC Co-ordinator.
Address by Guest of Honour	10:15 am - 10:30 am	**Ar. Deepak Chitnis,** Head of Design, Lodha Group
Address by Chief Guest	10:30 am - 10:45 am	**Shri. Kedarnath Rao Ghorpade,** Independent Consultant, Former Chief Planner MMRDA.
Inauguration of the IDRC Compendium of selected abstracts by Chief Guest		
About IDC Review	10:45 am - 11:00 am	
Announcement of IDC winners		**Guest of honour** - Ar. Deepak Chitnis
Address by Key Collaborators	11:00 am - 11:15 am	**PEATA President (I)** - Ar. Samir Hingoo
Key Note Speaker 1	11:15 am - 12:00 am	**Ar. Damith Premathilake,** Founder DPA Studio, Sri Lanka.
QnA and Concluding remarks /Vote of Thanks		
Key Note Speaker 2	12:00 am - 12:45 pm	**Ar. Sanjay Patil, Director,** Principal Architect, Environ Planners
QnA and Concluding remarks /Vote of Thanks		
Key Note Speaker 3	12:45 pm - 01:30 pm	**Ar. Ujjwala Haware,** Haware Engineers & Buildings Pvt. Ltd.
QnA and Concluding remarks /Vote of Thanks		
LUNCH BREAK - 01:30 pm - 02:00 pm		
Introduction of review Committee	02:00 pm - 02:15 pm	Ar. Rasika Chodankar, IDRC Co-ordinator
Address by Reviewer		Dr. Roopal Deshpande, Principal - Smt. Manoramabai Mundle College of Architecture, Nagpur.
Research paper presentations	02:15 pm - 03:30 pm	**Paper presentations sequence:** 1) Rajratna Jadhav - Phd Student participants 2) Chris Thurlbourne - Phd Student participants 3) Sakshi Ghodake - UG Student participant
TEA BREAK - 03:30 pm - 03:45 pm		
Research paper presentations	03:45 pm - 05:15 pm	**Paper presentations sequence:** 1) Arsheen Palkar - PG student participant 2) Shraddha Kapadia - Academician 3) Pruthviraj Bhople - Practioner 4) Akshay Joshi - PG student participant
Valedictory	05:15 pm - 05:30 pm	Ar. Varsha Swar
Vote of thanks and end of the day's session		

ONLINE CONFERENCE DATES

January 21st, 2023.

VENUE

Aditya College of Architecture,
Aditya Educational campus,
R M Bhattad Road, Ram Nagar,
Borivali West, Mumbai,
Maharashtra 400 068.

REGISTRATION

12/9/2022

CALL FOR PAPERS

Abstract submission
3/10/2022
Full paper submission
10/12/2022

FURTHER DETAILS

REGISTRATION LINK

EMAIL

idrc@aditya-arch.edu.in

CALL

+ 91 22 6110 6135

CONFERENCE CO-ORDINATORS

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IN ASSOCIATION WITH

Council of Architecture
PEATA (I)
Indian Green Building Council

A Leader is one who shows great perseverance, integrity, determination. They are the ones with the ability to guide and encourage others to achieve their goal. However, it is the traits of mental strength, high moral character, authority, and ability to find new solutions that forces others to look up to them.

Aditya College of Architecture (ACA) is fortunate to have such a leader. Our chairman, Shri Harishchandra Mishra, a leader who is proactive and driven by his passion for education. One that effectively takes his team along with him to scale the heights of success.

It gives me immense pleasure to see how Aditya College of Architecture has flourished with its abundant academic knowledge, immense industry exposure, and innovative strategies in the field of education and research.

I heartily congratulate Aditya College of Architecture for organizing the 3rd International Design Research Conference 2023 (IDRC 2023) on the theme "Building Envelope." This year, IDRC aims to highlight the architectural need of the society by utilizing the concepts of building envelope design to derive at simple, sustainable, time-efficient, and cost-effective architectural design solutions.

We hope that IDRC 2023 will educate and nourish everyone with valuable message and insight. I wish all the prosperity and fortune to the institution and to the students who will take the baton ahead, to illuminate the world with their spark. On behalf of Aditya College of Architecture, I wish International Design Research Conference 2023 a grand success. May our team succeed in transferring knowledge.

Shri Harishchandra Mishra

Founder Trustee & Chairman

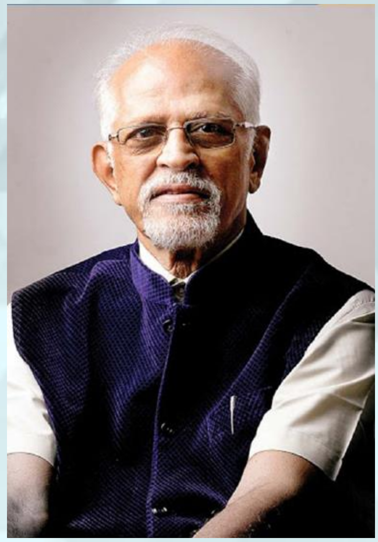
Message From The Founder Trustee

As a Mentor of Aditya Collage of Architecture for last 11 years, I take great pride to keep on record that the college, after successfully organizing International Design Competition consecutively for last 9 years and launching the 1st International Design Research Conference in 2020, is majestically organizing 3rd International Design Research Conference on January 21st, 2023.

The management, faculty and students deserve all praises and compliments for spending their enormous time and putting their efforts for the success of conference, in-spite of calamity of pandemic.

ACA is known for its vision and has been nurturing its students making them think out of the box. A plethora of themes for last all IDRCs and IDCs proves the truth. The theme selected for the 3rd IDRC 2023 - "Building Envelope" is the record very apt for current global situation.

Understanding the need of the time, ACA came forward and shouldered the responsibility to bring all concerned together to deliberate on the design challenges mentioned under respective sub themes.
I wish the Conference a grand success.



Ar. Gurunath Dalvi

Mentor & Advisor

Message From The Mentor

It gives me great pleasure as the Principal of Aditya College of Architecture (ACA), Mumbai, Maharashtra, to announce the 9th edition of ACA's International Design Competition 2022 and the 3rd International Design Research Conference - IDRC 2022-23.

ACA has been organizing the International Design Competition annually for the past eight years since its inception in the year 2013; and it provides an international platform for showcasing the works of young Designers and to establish connections amongst the global architectural student's community and academia.

As a part of this initiative, we have been hosting the IDC competition and IDRC conference. IDRC 2023, 3rd conference which focuses the theme ***BUILDING ENVELOPE****. The building envelope or a skin of a building is the physical separator between the interior and exterior of a building. The building envelope comprises of all the visible elements like facades, fenestrations, windows doors, roofs.*

The design of the envelope is very complex, and many factors must be evaluated and balanced to ensure the desired levels of thermal, acoustic and visual comfort together with safety, accessibility and aesthetic excellence. The building envelope contributes to the aesthetic view of the building and needs to meet certain architectural requirements and adhere to cultural preferences.

*Last year the conference was online due to pandemic. This year we are looking forward to a hybrid mode. Let us gear up to brainstorm upon the "****Building Envelope****".*

Ar. Sarita Deshpande

Principal

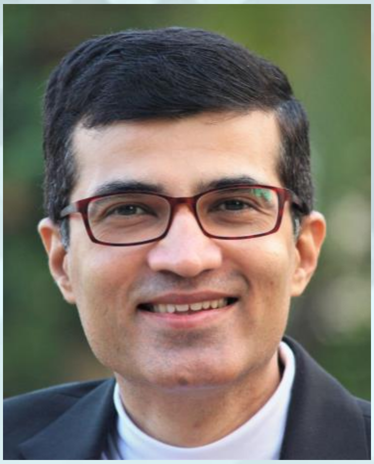
Message From The Principal

Ar. Deepak Chitnis is currently heading a strong team of 150 professionals, as the Head of Design department at Lodha Group. A graduate from the JJ School of Architecture, and as the head of the Design department, he's a key decision maker in the entire design process right from design conceptualization to execution of design at site.

Ar. Chitnis joined the Lodha Group in February 2007. He has supported, witnessed and been integral part of the top management of an incredible growth story of a real estate company. A strong believer in Organization Building, he's driven by ownership and performance, going beyond the departmental silos to create leaders with decision making abilities by motivating, leading, mentoring, imparting values and empowering his team and mentees.

Ar. Chitnis currently heads the design team for all projects undertaken by the Lodha Group across all portfolios and locations. He has completed various residential and commercial projects with an area of around 15 million sq.ft., across all segments. He is also responsible for supporting the Annual sales revenue of INR 6000 Cr. – INR 9000 Cr, leading the design process and deliverables of Annual construction spend to the tune of INR 3500 Cr to 4000 Cr.

Prior to his stint at the Lodha Group, he was a Senior Architect with the Oberoi Group, a Co-founder at the Collage Design Pvt. Ltd., and worked as an architect at Ratan J Batliboi Architects (RJBA).



Ar. Deepak Chitnis

Head of Design, Lodha Group

Guest of Honour's Profile

Kedarnath Rao Ghorpade is the former Chief Planner of Mumbai Metropolitan Region Development Authority. He has been engaged by large corporate houses as President and other senior positions. Currently he is the Chief Strategy Officer at Terracon Ecotech Pvt. Ltd., an environment consultancy firm. He is NABET accredited professional for land use and socioeconomic development. Shri Ghorpade has Master's Degrees in Geography and Urban and Regional Planning as well as Post Graduate Diplomas in International Housing, Local Economic Development and Environment Law. He is also a Visiting Faculty at the Amity University for Architecture, Interior Design and Planning, He was awarded Dutch Fellowship in 1991 and was also nominated for Eisenhower International Fellowship during 1989. Shri Ghorpade was engaged in large low-income shelter projects, formation of urban local bodies and capacity building, infrastructure planning, financing, coordination, and management, development management permissions and systems, heritage and environment management, EIA, SIA and FDP proposals, port development, Smart cities, expressways, urban rivers rejuvenation and restoration management. Large part of the professional experience is in projects financed by the World Bank, Asian Development Bank, UNESCO, Government of India, and Government of Maharashtra.

Shri Ghorpade is currently pursuing his PhD on Urban Sustainability from University of Mumbai. Shri Ghorpade has published numerous articles in national and international journals and has contributed articles for edited books. He is a regular speaker at national and international conferences. He was the Panel Discussant in Conference of the Parties to the United Nations Convention to Combat Desertification (COP14) during 2019. He was also a panel discussant at the celebration of 75 years of United Nations - UN75 initiative organised in 2020, by Confederation of Young Leaders, in the sphere of Public Diplomacy, International Relations, Government, Public Affairs and Public Policy.

Kedarnath Rao Ghorpade

Independent Consultant,
Former Chief Planner
MMRDA

Chief Guest's Profile

We here at ACA are proudly launching the 3rd International Design Research Conference (IDRC 2023), along with the constant success of our International Design Competition. It gives me an immense pleasure and I also feel honored to be a part of this venture while leading as well as working with a team of passionate and hard-working colleagues. For IDRC 2023, we decided to opt for a relevant and meaningful theme - ***Building Envelope****. The concept of* ***'Building Envelope'*** *has been a key, prominent component since ages in the architecture realm. According to C.E. Hagentoft in his book An Introduction to Building Physics, the building envelope acts as a physical barrier between the interior and exterior environments that enclose a structure.*

The 3rd IDRC 2023 conference has reached out to international extends, where architects and building scientists and researchers from India and other nations have been invited. We strongly appreciate our collaborations and associations with such industry stalwarts, whose work strongly sync with our theme at large.

Like last year, this year too, we have received immense response from the architectural fraternity. We are thankful to the enthusiastic participants and to the esteemed review committee for their continuous effort and commitment. The plethora of topics selected by the researchers based on the sub-themes of the conference highlight the need, significance and sensitivity felt by the community about this concept. It strengthens our ideas to nurture the ideas within ourselves as mentors, for upcoming generations.

Ar. Rasika Chodankar

Associate Professor

Message From The IDRC Coordinator

In its third consecutive year, we the team of IDRC are pleased to host IDRC again this time under the theme "Building envelope". Since its inception; it is the first time we are having the same in the physical mode and we have tried to reach out to international extents. We are thankful and appreciate our speakers, review committee member, our collaborations and associations for their effort and commitment.

For any built form, the primal feature that comes in contact with the human eye is its envelope. In a way, it establishes an identity of the entire structure, in the minds of the viewers. Building envelop is the physical barrier between the exterior and interior spaces/ settings enclosing a structure. it makes the building look appealing while also carrying out functions associated with control and structural support. Thus, it is an important component that separates the exterior façade of the building from its interior and thereby affects the ventilation, climate, energy consumption and protection of occupants and interiors. Thus, its designing is of vital importance; as if this is not designed well then it would result in other systems not working well and will affect the sustainability parameter as well.

A building envelope is commonly defined as the separation of the interior and exterior of a building. It helps facilitate climate control and protect the indoor environment. Overall, it is the entire exterior building system. As you all are aware of energy efficient bulbs, energy efficient appliances, and updated mechanical systems such as heating and cooling systems. If the building envelope is not in good shape all the updates to other systems will not matter. The reason for this is the building envelope can account for a substantial amount energy loss if not properly attended.

The benefits of a good building envelope include reduced stress, wear, and tear on mechanical systems. This results in turn to reduce energy bills. Unfortunately, the building envelope is not just only component, but a critical component and a variety of other independent parts that make the system. Hence, replacing one part of the system will increase your efficiency, but to a minimal degree if you do not address all parts of the system your efficiency will not be as high as it should be with all components operating efficiently.

*The theme for 2023 is '**BUILDING ENVELOPE**' that majorly focuses on exterior element of any building which allows an attempt to inculcate this need of the future and encourage young minds to embrace/inculcate these methods in their design. On behalf of our team, I, thank all our participants and readers to have build their trust upon us to deliver work and share.*

Message From The IDRC Coordinator

Ar. Varsha Swar

Assistant Professor

Message From The Publication In Charge

Ar. Disha Barik

Assistant Professor

Damith Premathilake received his Bachelor's Degree (B. Sc.) in Built Environment in 2001 and his Masters Degree in Architecture in 2006 from the University of Moratuwa, in which he received commendation for his final design projects. In 2008, he advanced professionally as a Chartered Architect by completing the AIA (SL) and completed his post graduate degree in Landscape Architecture at the University of Moratuwa in 2013.

He is an Associate Member of the Sri Lanka Institute of Architects and a Member of the Sri Lanka Institute of Landscape Architects. He is also an International Associate member of American Institute of Architects (AIA) and International Member of Royal Institute of British Architects (RIBA). At present he is a Council Member of the Sri Lankan Institute of Architects (SLIA). His contribution to the field extends to being a visiting lecturer at University of Moratuwa, Faculty of Architecture and City School of Architecture – Colombo.

His Architectural style has been renowned by being awarded both locally and internationally. World Architecture Community Awards in 2012, 2014 and 2022, winner of Architecture Asia awards for Emerging Architects in 2014, Young Architects of the Year 2016 and being a winner of the Ten Outstanding Young Persons of Sri Lanka in 2016 are some of the achievements which he has gained within his career as a young professional. Also, his practice published among the best 50 practices in the world by the book, "Fifty under Fifty-Innovators of the 21st Century, 2015".

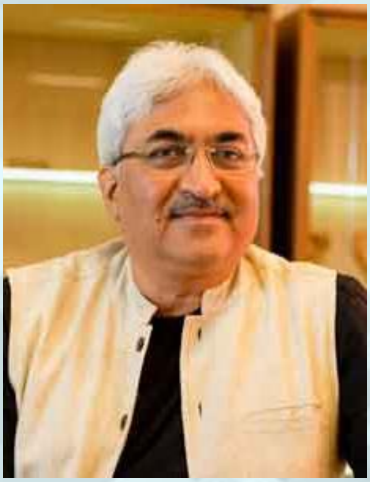
Ar. Sanjay M. Patil, the principal architect of the firm Environ Planners has graduated from Sir J.J. College of architecture. The firm has always worked towards environment conscious architecture seeking inspiration from nature and tradition. Respecting nature has always been an integral element of the firm's approach. The need of the hour being sustainable development, the firm's efforts is consciously directed towards application of energy efficient principles to the building design. The firm has always over the years has designed for various institutional, industrial, residential, projects with each of those holding their own distinctive identity. The approach, to craft an environment together has expressed the ability to integrate landscape (symbolizing nature) with the built environment, which amalgamates interior and exterior to create a series of interactive spaces. The firm takes up the inspiration from vernacular architecture and fuse with modern technology to get the desired results, where simplicity prevails and nest with the nature.

Ar. Sanjay M. Patil has been a recipient of various awards which includes Dharmasthala Manjunatheshwara award, Nomination for Aga Khan Award, 2009, 23rd and 25th JK Architect of the Year Award (AYA), 2013, Green Architecture Award in 2013 and 2015 respectively, ARCASIA Awards for Architecture 2017, Global Architecture & Design Awards 2018 to mention a few.

About Our Speakers

Ar. Ujjwala Haware

Founder, DPA Studio,
Sri Lanka



Ar. Sanjay Patil

Principal Architect,
Environ Planners

About Our Speakers

Ar. Ujjwala Haware

Director of Haware Engineers & Builders Pvt. Ltd., Secretary of New City Education Trust, Navi Mumbai

Ar. Ujjwala Haware has contributed to real estate industry for over 20 years. She has been felicitated with multiple awards including Iconic Redevelopment Project award by "CNBC Business for Project Grand Edifice (Dindoshi)". Also, by the former President of India, APJ Abdul Kalam.

She has completed her Bachelor of Architecture from Amravati University in 1997 with 2nd in the order of merit of Amravati University. She further pursued MBA from school of management IIT Powai, Mumbai. Currently she is the Director of Haware Engineers & Builders Pvt. Ltd. and Secretary of New City Education Trust, Navi Mumbai.

She has been working in Residential Projects, Commercial Complexes and Redevelopment Projects of almost 100 Buildings. in Mumbai. Her work also includes Info Tech Parks, Multiplexes, Shopping Malls, Mass Housing Projects in Navi Mumbai, Nano Housing Schemes etc.

About Our Reviewer

Dr. Roopal Deshpande

Principal, Smt. Manoramabai Mundle College of Architecture, Nagpur

Ar. Roopal Deshpande, architect-planner, doctorate and an academician for 19 years and currently Principal of Smt. Manoramabai Mundle College of Architecture, Nagpur. She was the PhD department coordinator at SMMCA between 2017 to 2022. She did her Masters in Environmental Planning from SPA, New Delhi in 2003 and was awarded PhD from Visvesvaraya National Institute of Technology, Nagpur in 2017. The title of her Doctoral research is "Investigating Privacy in Traditional and Modern Houses through Spatial Analysis". Along with B. Arch. she is faculty at M. Arch. (Architecture Education) and M. Arch. (Urban Design). She is Ad hoc-Chairman of Architecture Board of Studies (BoS) (Faculty of Science and Technology), RTMNU, Nagpur

Ar. Sarita Deshpande
Principal

IDRC TEAM

Ar. Rasika Chodankar
IDRC Head

Ar. Varsha Swar
IDRC In Charge

Ar. Disha Barik
Publication In Charge

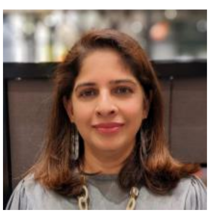
Ar. Pranita Daware

Er. Soham Chowdhary

Ar. Neha Tambe

Ar. Indrayani Bhute

IDC TEAM



Ar. Tej Wagh
IDC Coordinator

Ar. Anjuri Agrawal
IDC Coordinator

Ar. Manali Rane

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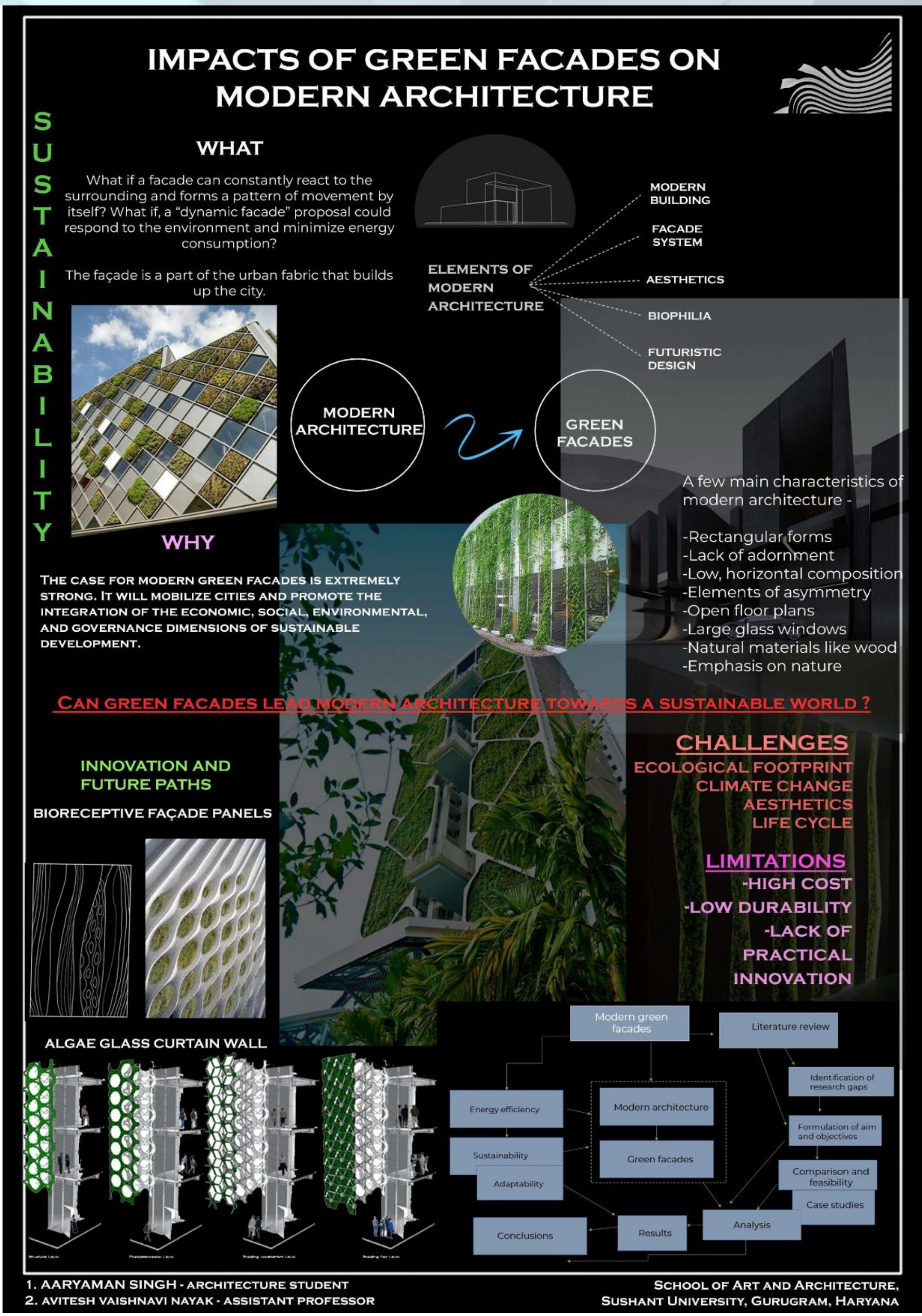
TABLE CONTENTS: RESEARCH PAPER

IMPACTS OF GREEN FACADES ON MODERN ARCHITECTURE

Aaryaman Singh – B.Arch Student1 , Avitesh Vaishnavi Nayak - Assistant Professor 2, aaryamansingh1910@gmail.com1 , aravitesh13@gmail.com2 School of Art and Architecture, Sushant University, Gurugram Haryana, India

ABSTRACT: *Modern architecture was an architectural movement or style centred on cutting-edge construction technologies, particularly the use of reinforced concrete, glass, and steel. The foundational goal of 21st century architecture is to create better structures that are inherently sustainable by utilising better materials and technologies. Facades are the outermost covering of a building which have the maximum interaction with the environment. A wall that is completely or partially covered with vegetation is known as a green façade. Green facades enhance the urban environment in terms of economy, environment, aesthetics, and physiology. There are many aspects associated with the built environment such as energy efficiency, pollution levels and ecological responsiveness, these issues need to be addressed to create element of the built of the modern environment. Analysing of different type of façade systems can lead towards a complex dynamic sustainable facades system that not just acts as the skin of the building but performs more functions. This study talks about the integration of modern architecture with green facades and the impacts of green facades in different climatic conditions. Outcomes of this study will be helpful to understand modern green facade systems and exploring new design innovations for a better and more efficient future.*

KEYWORDS : Sustainable buildings, Green facades, Passive design strategies, Modern Architecture, Aesthetics.


IMPACTS OF GREEN FACADES ON MODERN ARCHITECTURE
SUSTAINABILITY
WHAT
What if a facade can constantly react to the surrounding and forms a pattern of movement by itself? What if, a "dynamic facade" proposal could respond to the environment and minimize energy consumption?
The façade is a part of the urban fabric that builds up the city.
ELEMENTS OF MODERN ARCHITECTURE
MODERN BUILDING
FACADE SYSTEM
AESTHETICS
BIOPHILIA
FUTURISTIC DESIGN
MODERN ARCHITECTURE
GREEN FACADES
A few main characteristics of modern architecture -
-Rectangular forms
-Lack of adornment
-Low, horizontal composition
-Elements of asymmetry
-Open floor plans
-Large glass windows
-Natural materials like wood
-Emphasis on nature
WHY
THE CASE FOR MODERN GREEN FACADES IS EXTREMELY STRONG. IT WILL MOBILIZE CITIES AND PROMOTE THE INTEGRATION OF THE ECONOMIC, SOCIAL, ENVIRONMENTAL, AND GOVERNANCE DIMENSIONS OF SUSTAINABLE DEVELOPMENT.
CAN GREEN FACADES LEAD MODERN ARCHITECTURE TOWARDS A SUSTAINABLE WORLD ?
INNOVATION AND FUTURE PATHS
BIORECEPTIVE FAÇADE PANELS
CHALLENGES
ECOLOGICAL FOOTPRINT
CLIMATE CHANGE
AESTHETICS
LIFE CYCLE
LIMITATIONS
-HIGH COST
-LOW DURABILITY
-LACK OF PRACTICAL INNOVATION
ALGAE GLASS CURTAIN WALL
Modern green facades
Literature review
Identification of research gaps
Energy efficiency
Modern architecture
Formulation of aim and objectives
Sustainability
Green facades
Comparison and feasibility
Adaptability
Case studies
Conclusions
Results
Analysis
1. AARYAMAN SINGH - ARCHITECTURE STUDENT
2. AVITESH VAISHNAVI NAYAK - ASSISTANT PROFESSOR
SCHOOL OF ART AND ARCHITECTURE, SUSHANT UNIVERSITY, GURUGRAM, HARYANA

STUDYING THE IMPACT OF GEOGRAPHICAL LOCATION ON THE LIFE CYCLE ASSESSMENT OF A CASE BUILDING

Sakshi Ranjeet Ghodake, B. Arch student
Dr Bhanuben Nanavati College of Architecture, Karve Nagar, Pune

ABSTRACT: *Building envelope plays a critical role in making design decisions by determining its environmental impacts. Life Cycle Assessment (LCA) is used to holistically analyze the environmental performance of the whole building. The Life Cycle Assessment of a building based on similar material palette has different environmental impacts due to various aspects like location, operational costs etc. The present research work is aimed at evaluating the Life Cycle Assessment of a case, built at two different locations in India (Pune and Kolkata) with the help of sensitivity analysis used to generalize the method with respect to life cycle assessment parameters. The study will help understand various possibilities for reducing carbon footprint. Oneclicklca is used for this study of a hypothetical design case for evaluating the environmental impacts of the building during its construction and operation stage. The study will help to prioritize the optimization efforts on an informed basis and assess the individual processes against the larger perspective of the building's total life cycle.*

KEYWORDS: Life-Cycle Assessment, Building performance analysis, Cradle-to-gate, LCA parameters.

1.INTRODUCTION

The building sector contributes towards substantial benefits to the world's society and economy, but it is also a primary source of environmental impacts. It is estimated that 40% of the global greenhouse gas (GHG) emissions derive from the building sector, including the production of building materials and direct and indirect energy consumption (WBCSD, 2018). Hence buildings have become a focus of GHG emission reduction initiatives. A building uses energy throughout its life i.e. from its construction to its demolition. Direct energy is used for construction, operation, rehabilitation, and demolition in a building; whereas indirect energy is consumed by a building for the production of material used in its construction and technical installations (Aashish Sharma, 2010)**.** Life Cycle Assessment is a systematic analysis of potential environmental impacts of the products or services during their life cycle. The study of Whole Building Life Cycle Assessment is understood considering the parameters affected through the various stages of life cycle of a building. The main constant factor in the process of understanding the LCA of both the buildings is material and the changing factor is the building's geographical location. Sustainability of a material-based product is mainly dependent on materials used for the product itself or during its lifetime. A material selection decision should not only capture the functional performance required for a special application but should also consider the economic, social, and environmental impacts originated during the product life cycle (LY, 2007). In current scenario Life Cycle Assessment is a great practice to get hold onto valuable information on how to reduce buildings Global Warming Potential (GWP). While energy standards improve, it is also necessary to consider CO_2-eq. emissions related to the materials used for construction, as their share over the lifecycle of buildings increases (Röck, 2021)**.** LCA is a method which helps calculate carbon emissions associated with materials and construction processes throughout the whole life cycle of the building. The study ensures focussing on the most important aspects of WBLCA while not overloading the necessary inputs, and clarifying which parameters should be examined in depth to obtain the desired results for reduced carbon footprint of building.

1.1 AIM

This research study is aimed to study the impact of geographical location on the Life Cycle Assessment of a case building, built at two different locations in India (Pune and Kolkata).

1.2 OBJECTIVE

This study will help define the sensitive parameters which have the most impact on Life Cycle Assessment of the case.

Learning to prioritize the variables which needs to be considered while designing for the case project.

1.3 SCOPE AND LIMITATION

This study is held in context with institutional spaces. Design from curriculum project suitable for this study is selected which will be assessed partially with the scope involving from cradle-to-grave assessment. This process involves various Building Life Cycle Model categories like:

1) (A1-A5) = Upfront carbon emissions
2) (B1-B7) = Operational carbon emissions

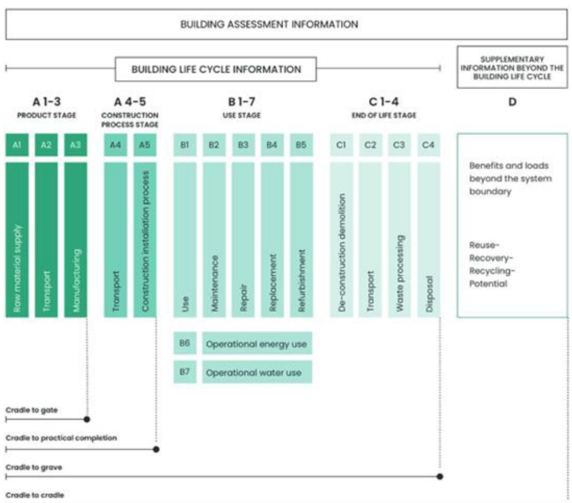


Fig.2 Life Cycle scope specified according to standardized module designation (https://oneclicklca.com)

2.0 RESEARCH QUESTIONS

a. How does the LCA of a structure with same building components change at different geographical locations?
b. What is the impact of material transportation at both cases on cost estimation?
c Which parameter has the most impact on LCA of the case buildings?

2.1 SIGNIFICANCE

Life cycle assessment (LCA) is a tool used for the quantitative assessment of a material used, energy flows and environmental impacts of products. It is used to assess systematically the impact of each material and process. The LCA of a building when designed with same products at same climatic regions should give approximately same results for both cases. Since, this is not the case and it is observed that there is drastic change in the life cycle assessment of both cases (as shown in results), there is a need to understand what causes this scenario or which parameters have major impact on the cases.

2.2 LITERATURE REVIEW

Researchers have understood the importance of early design stages when reducing buildings' life- cycle environmental impact. Numerous researchers have shown that the earlier decisions are made in the design process and the fewer the changes to these decisions at later stages, the greater is the potential for reducing the building's environmental impact. For example, by selecting an environmentally preferred building shape and orientation during the early design stages (Cofaigh EO, 1999) , were able to reduce a baseline design's environmental impact by 40%. Providing designers with early-stage environmental impact performance feedback was demonstrated by (Schlueter A, 2009) to have strong effects on design choices, resulting in less energy intensive buildings and increasing awareness of ways to reduce energy consumption. The most frequent input parameters are weather, building-level design parameters, building envelope I (e.g., walls, roof), building envelope II (e.g., windows), ventilation/infiltration, building HVAC/mechanical systems, and occupant behaviors. (Zhihong Pang, 2019) The building/urban energy consumption and the occupant thermal/visual comfort are the most interested outputs. (Pushkar S, 2005) Used LCA methodology to group design variables into four clusters then show each variable's environmental impact bounds for each phase in a building's life cycle. Common building material and dimensioning alternatives were considered. Sensitivity analysis was conducted using different fuel sources and production methods, in order to show the range of material quantity impacts for each life-cycle stage.

2.3 BUILDING LIFE CYCLE STAGES

The different periods of a building's life are known as its life-cycle stages. They are referred to as product, construction, use, end-of-life and benefits beyond the system boundary. The standardized module designations for each life-cycle stage, from A1 to D, is shown below (Fig.1) The processes involved in the life-cycle stages of a building releasing gaseous, solid, and liquid emissions into the air, water, or soil can negatively impact the environment and humans. In this case the life cycle stage from A4-B7 is studied.

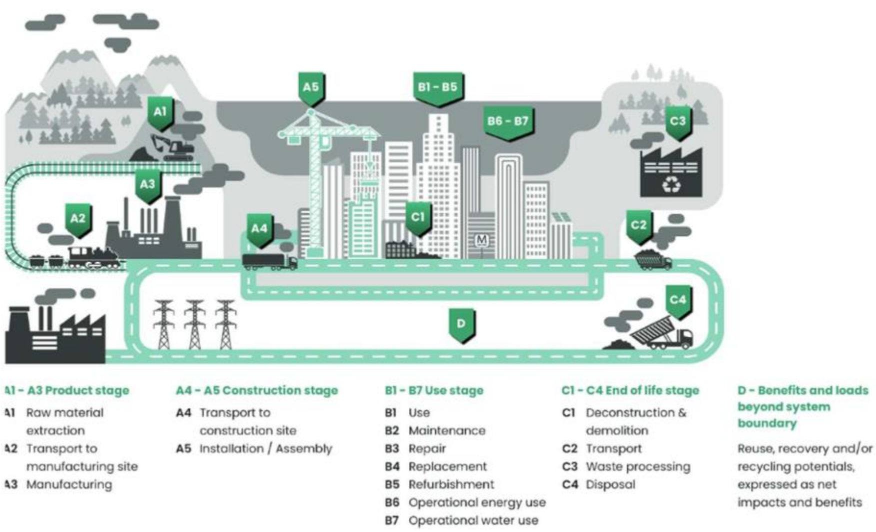


Fig.1 Life Cycle stages of a building.
(https://oneclicklca.drift.click/building-lca-ebook)

2.4 BUILDING LIFE CYCLE ASSESSMENT

GHG emissions from construction and energy consumption in buildings result in a tremendous negative environmental impact. LCA studies comprise Embodied Energy (EE) and Operational Energy (OE) consumption during building life cycle. The studies usually consider maintenance during the operation and maintenance phase .The application of LCA has become very common in recent years. The number of published research papers about LCA related to buildings has more than doubled in the last five years (Anand, 2017) .However, previous studies used LCA to compare only one aspect of the building separately, for instance, building envelope or explicit materials or building systems and control (Hammad, 2018). There is limited research combining all aspects of the building simultaneously as the study of LCA is holistically intensive and studying each element of the research needs intricate process. In this research the LCA is defined based on the Global Warming Potential (GWP), which is CO2 equivalent.

2.5 BUILDING ENVELOPE MATERIALS

The selection of building materials is always a very demanding process in design. In this case the building is proposed of reinforced concrete framed structure and the other materials are also chosen such that they are easily available in both the cities.

2.6 COST ESTIMATION

The building cost estimation of the cases will help compare the amount of cost required throughout the construction process which will give incentives on the transport and installation factor of building LCA. As shown in table basic cost estimation of Kolkata is more than that of Pune as the rates of materials differ according to the states.

Table 1: Abstract cost estimation

Sr No.	Particulars	Pune	Kolkata
		Amount (Rs Millions)	Amount (Rs Millions)
1	Civil Works	10.10	10.42
2	Internal Works	3.42	5.66
3	MEP Services	11291.29	11630.16
4	Equipment & Furnishing	1.27	1.31
5	Contingency	0.00	0.00
TOTAL PROJECT COST		11306.08	11657.55

3.0 INTEGRATING SIMULATION IN LCA

Several software tools have been developed for using LCA to assess building's environmental impact at the early design stages. For example, the Athena Eco Calculator (J. Basbagill*, 2013) provides environmental impact estimates of buildings based on minimal inputs.

However, these tools provide no sensitivity analysis showing how building component's environmental impacts vary over a range of design alternatives. The data used in the existing LCA tools are mostly based on built-in life cycle inventory databases. However, building energy consumption is not only determined by building materials, but also by building profile and location (Hana, 2013). For this study simulation software's like Early Phase Integrated Carbon Assessment (Epic), 1clicklca for evaluating building LCA using the Environmental Product Design Consideration

SYSTEM BOUNDARY is a description of activities within the product's life cycle phases that are included and excluded. Here the geographical indicators and its variables are related to the inputs, the processes and the outputs involved in the building life cycle process.

PRODUCT SYSTEM is the entirety of all activities within the system boundary that are associated with the functional unit.

1. **Functional Unit:** is the reference unit for scaling the system. The Life Cycle assessment of Building A (Pune) will act as a functional unit for Building B (Kolkata) and vice-versa.
2. **Reference Unit**: is the amount of product needed to provide functional unit, expressed in mass, energy, area, volume, etc.
3. **Operational Carbon*:*** emissions associated with energy used (B6) to operate the building or in the operation of infrastructure.
4. **Screening LCA**: a type of LCA that provides an early, rough estimation and assessment of environmental impacts by considering the most relevant materials and resources using average data.
5. **Upfront Carbon**: emissions caused in the materials production and construction phases (A1-5) of the life-cycle before the building or infrastructure is used.

4.0 RESEARCH METHODOLOGY

This research involves of methodologies like studying the variables and parameters that impact the LCA of the case building, creating quantitative data using simulation software like Early Phase Integrated Carbon Assessment (Epic), 1clicklca for evaluating building LCA using the Environmental Product Design configurations.

4.1 CASE DESCRIPTION

A hypothetical building from curriculum projects is chosen with institutional context. The case is proposed to be built in Research Institute, Pune and Patuli, Kolkata. This study ensures that although the geographical location changes, the climatic region remains the same, i.e., warm and humid. This will help to fairly analyze other parameters as the variables now won't be affected by climatic conditions which otherwise would affect several factors like in humidity level, wind speed, precipitation complying in change of material choice, adaptive comfort, air-conditioning usage at extreme levels, passive strategies, etc. The case comprises of reception and waiting area, computer room, library stack area, reading area, digital library room and toilets.

Table 2. Area description

Description	Area
Built-Up Area	2700 sq m
Floor Area	900 sq m
No. of grade above ground floor	2

4.2 CASE DETAILS

Building type: Educational building Nmber of occupants: 400
Hours of operation: Library & Computer Centre - 8AM-7PM, 7 Days/week (by ECBC)

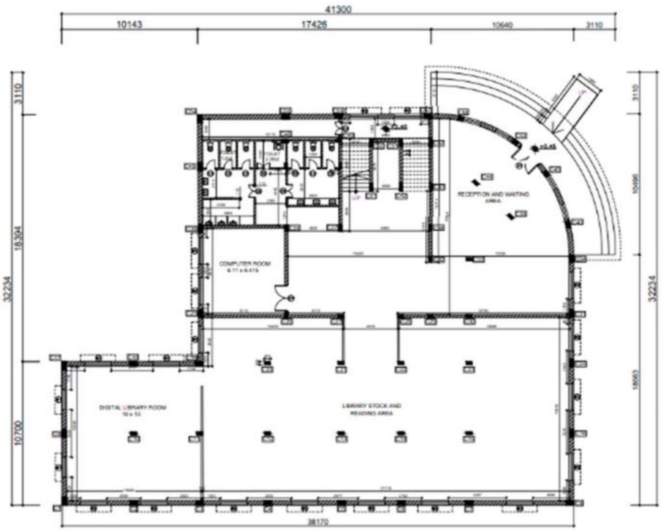


Fig.2 Plan of case building

Study of Variables and Parameters

Given Table.1 shows a matrix of various components on the y direction and building life cycle stages from construction stage (A4-A5) to use stage (B1-B7) on x direction. From this table the dependent and independent variables can be analyzed. This table is made considering the case building at different locations with different factors affecting the life cycle stage of the building or the variable. The dependent variables determines the components or stages that can change, or they have an impact of changing the geographical location of the case building.

Independent variables determines the components or stages which won't change or are not affected by the change of geographical location of the case building. For example, the materials or the components are the independent variables which will remain constant throughout the process. In Construction stage as the geographical location changes cost of the material at each location varies including the expense of transportation on the materials on site. For construction and installation process the cost of labor; requirement of water, equipment changes; in fact, for foundation the type of soil will determine the type of foundation and how deep the foundation would be taken according to the soil strata. The orientation of the building on site at different locations according to microclimate will impact the glazing type and Solar Heat Gain Coefficient (SHGC).As the built case is an Institutional Library the use of HVAC at both locations is assumed to be same because although the climatic zone of these two cities is warm and humid but they are moderate in nature. Hence, the requirement of air conditioning is less and even if required it would be during the summer season which mostly will have less occupancy load, therefore less air conditioning load and less energy consumption.

Table.1 Dependency of variables considering the building life stages.

1	Components	Construction Stage (A4-A5)		Use Stage(B1-B7)						
2		Material transport to project site(A4)	Construction & installation process(A5)	Use(B1)	Maintanance (B2)	Repair(B3)	Replacement(B4)	Refurbishment(B5)	Opertational Energy use(B6)	Operational water use(B7)
3	Foundation		Soil profile							
4	External Wall assembly				Paint, plaster					
5	Insulation									
6	Internal wall assembly				Paint, plaster					
7	Wall to Window Ratio									
8	Glazing									
9	Window frame									
10	Door									
11	Slab									
12	Flooring tiles									
13	Roof assembly									
14	HVAC system									
15	Fittings, equipments									
16	Water n sewage services									

Independent variable

Dependent variable

Table.2 Dependent parameters and their variables.

same	changes				
material	location	topograhy	soil profile (foundation)		
services	electricity grid	unit rates			
	transport distance of materials				
	micro climate	wind direction n velocity	rain pattern		
	thermal performance of building	temp	moisture content	density	
	glazing parametrs	wwr	thermal transmittance	shgc	orientation

The study of Table.1 is derived from the understanding of Table.2 which determines the dependent parameters and their variables. The main parameters which remain constant are materials and the services provided to both the cases. The major impact of changing geographical location is seen due to change in topography, soil profile; the electricity grid changes which impacts change in unit rates of both the cities;

BASE TARIFF:

Consumer Category	Fixed Charges (Rs/ connection/month)	Energy Charges (Paise/kWh)
LT I - Domestic		
Consumption less than 30 Units Per Month (Below Poverty Line)	Rs 3 per service connection	40
Consumption more than 30 Units Per Month		
0-100 Units	Single Phase: Rs. 30 per service connection;	200
101- 300 Units	Three Phase: Rs. 100 per service connection;	370
301-500 Units	Additional Fixed charge of Rs. 100 per 10 kW load	500
Above 500 units (Only balance Units)	or part thereof above 10 kW load shall be payable.	575

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Fig.5 Electricity rates in Pune.

Sl No	Type of Consumer	Applicable Tariff Scheme: Consumer category	Name of the Tariff Scheme	Consumption per month in KWH		Energy Charge P/kWh: Summer	Monsoon	Winter	Demand Charge (Rs./ KVA/ month)	Optional Tariff Scheme: Consumer category	Name of the Tariff Scheme	Consumption per month in KWH		Energy Charge P/kWh: Summer	Monsoon	Winter	Demand Charge (Rs./ KVA/ month)
22	Bulk Supply at single point to Co-operative Group Housing Society for providing power to its members or person for providing power to its employees in a single premises	Rate S(CO)	Normal	All Units		787	785	783	34	Rate S(cot)	Normal - TOD	06.00 hrs- 17.00 hrs	All Units	760	758	756	34
												17.00 hrs- 23.00 hrs	All Units	835	833	831	
												23.00 hrs- 06.00 hrs	All Units	693	691	689	
23	Common Services of Industrial Estate	Rate E (CT-CS)	Normal - TOD	06.00 hrs- 17.00 hrs & 20.00 hrs.- 23.00 hrs	All Units	795	793	791	384	NOT APPLICABLE							
				17.00 hrs- 20.00 hrs	All Units	1104	1101	1098									
				23.00 hrs- 06.00 hrs	All Units	651	650	649									
24	Traction (25 KV)	Rate T (A)	Normal	All Units		738	736	733	360	NOT APPLICABLE							
25	Traction (132 KV)	Rate T (B)	Normal	All Units		738	736	733	360	NOT APPLICABLE							
26	Metro Rail, Airports under RCS-UDDAN	Rate T (M)	Normal	All Units		716	711	706	105	NOT APPLICABLE							
27	Short-term Supply	Rate S(ST)	Normal - TOD	06.00 hrs- 17.00 hrs	All Units	770	768	766	384	NOT APPLICABLE							
				17.00 hrs- 23.00 hrs	All Units	1073	1071	1069									
				23.00 hrs- 06.00 hrs	All Units	527	525	523									
28	Private Educational Institutions	Rate E (C-EI)	Normal	All Units		812	810	808	384	Rate E (ct-ei)	Normal - TOD	06.00 hrs- 17.00 hrs	All Units	800	798	796	384
												17.00 hrs- 23.00 hrs	All Units	879	877	875	
												23.00 hrs- 06.00 hrs	All Units	730	729	728	

Fig.6 Electricity rates in Kolkata.

The micro climatic change leads to different variables like change in wind direction and velocity, rain fall pattern (annual rain fall in Kolkata is 1656 mm and annual rain fall in Pune is 1200 mm) (https://en.climate-data.org/) which shows that Kolkata has heavy rains compared to Pune; the thermal performance of the case building will also be affected by variables like change in temperatures, moisture content, density of materials, etc.; glazing parameter is also affected by change in window to wall ratio (WWR) which depends on orientation and micro climatic factors, thermal transmittance and solar heat gain coefficient.

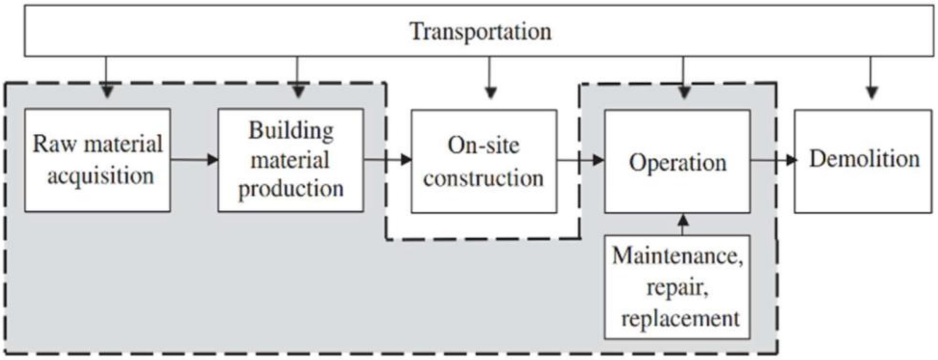

Fig.7 Building life-cycle phases for reducing embodied Impacts of early-stage designs.
(http://dx.doi.org/10.1016/j.buildenv.2012.11.009)

According to above observation it can be said that operational phase is limited to embodied impacts due to maintenance, repair, and replacement of building components lead by various factors.

Table.3 Description of Building Assemblies:

Building Assembly	Specification
Structure	Reinforced concrete
Foundation	Reinforced concrete
Envelope	Lightweight concrete blocks
Internal Walls	Lightweight concrete blocks
Roof	Reinforced concrete slab
Ceiling	Reinforced concrete slab
Doors and windows	Wooden Flush Door Aluminium framed window
Glazing	Insulated double glazing
Finishes	

4.3 BILL OF QUANTITY (BOQ): BOQ is one of the methods used to be considered as a parameter to study the life cycle assessment of a building because cost is an important factor in the building industry. As shown in Table (Annexure) the cost estimation of Kolkata is more than that of Pune as the rates of materials differ according to the states in Maharashtra and West Bengal. This factor could also include the tax variable of both the cities.

For example, for detailed study the cost of transportation for both the bases is calculated. The observation of it is that the transportation cost of materials in Kolkata is more compared to Pune, this happens be due to many reasons like change in cost of material, tax on goods, cost of transportation per km which varies according to the manufacturer and construction site distance.

Item Description	Transportion cost	
	Pune	Kolkata
Rubble Soling	4159.8	4367.79
Backfilling+ Compaction	3234	3395.7
Antitermite treatment	9624	10105.2
PCC Plinth M10	27436	28807.8
PCC For Footing M10	37335	39201.75
Foundation, Raft,Plinth beams, shear walls	23028	24179.4
RCC(M35 grade) (Col)	30540.8	32067.84
RCC (M30 grade) (slabs)	41500	43575
Reinforcement ,TMT Fe 500	10000	10500
Shuttering Area	13473.6	14147.28
200mm Thick AAC Wall	14445	15167.25
insulation	10350	10867.5
150 mm Thick AAC Wall	10000	10500
Glass façade with frame	2500	2625
200 mm Thick AAC Wall	23382	24551.1
150 mm Thick AAC Wall	10350	10867.5
Top terrace tiles	6500	6825
Flooring - Polished Kota	6800	7140
Ceramic Toilets	6300	6615
D1(entrance door for toilet)	1526	1602.3
Cabling	8118	8523.9
Light Fittings	8118	8523.9
Internal Wiring	5412	5682.6
Earthing & Lightning Protection	2700	2835
Fixtures and Fittings	3000	3150
Drainage	20000	21000
Furninshing	11280	11844
Total	**351112.2**	**368667.81**

Table.4 Cost estimation of transportation.

5.0 RESULT

The following Table.5 & Table.6 are the results of the simulation of Life Cycle Assessment held on (oneclicklcaapp.com) which gives report of the product cradle to gate (A1-A3) carbon impacts as well as material efficiency for both the cases respectively. Biogenic carbon is not deducted from totals. In estimating energy and carbon coefficients, country-specific (Indian) conditions regarding raw materials and energy sources are considered. In terms of building life stages the Co2 equivalent of concrete is high in construction materials for both the cases as shown in the tables. Also comparing the complete construction stage it is observed A1 and A5bc have the highest carbon emission values from the range of A1-A5. The total carbon coefficients of Pune case are 621214 tCO2e whereas for Kolkata case it is 615033 tCO2e. This clearly shows that the carbon emissions of Pune are more compared Kolkata which could be because of various factors that have been already discussed in the study in variables and parameters.

Table.5 CO_2e Results of Pune case building.

Section	Result category	Global warming t CO_2e	Global warming kg CO_2e/m²	Mass of raw materials t	Mass of raw materials kg/m²
1	Ready mix concrete (A1-A3)	192.62	224.73	1039.92	1213.3
2	Precast concrete (A1-A3)	565010.53	659211.91	574043.5	669750.9
3	Steel (A1-A3)	37.61	43.88	57.31	66.86
4	Bricks (A1-A3)	7.18	8.38	4.95	5.77
5	Glass (A1-A3)	12.99	15.15	3.7	4.31
6	Insulation (A1-A3)	36.59	42.69	6.35	7.4
7	Other materials (A1-A3)	5604.02	6538.35	6706.55	7824.7
A1-A3	Construction Materials	570901.88	666085.5	582313.7	679399.95
A4	Transport to the building site	1347.02	1571.6		
A5	Construction/installation process	42783.68	49916.79	46571.67	54336.34
A5a	Site operations & site waste handling	60.85	70.99	3217	3753.35
A5b	Site waste transportation				
A5c	Construction site - material wastage - materials	42622.91	49729.21	43354.67	50582.98
A5d	Construction site - material wastage - transport	99.92	116.58		

Table.6 CO_2e Results of Kolkata case building.

Section	Result category	Global warming t CO_2e	Global warming kg CO_2e/m²	Mass of raw materials t	Mass of raw materials kg/m²
1	Ready mix concrete (A1-A3)	210.93	246.1	1039.92	1213.3
2	Precast concrete (A1-A3)	575735.2	671724.66	574043.5	669750.9
3	Steel (A1-A3)	40.04	46.72	57.31	66.86
4	Bricks (A1-A3)	3.43	4	4.95	5.77
5	Glass (A1-A3)	12.99	15.15	3.7	4.31
6	Insulation (A1-A3)	17.59	20.52	6.35	7.4
7	Other materials (A1-A3)	502.59	586.39	251.3	293.2
A1-A3	Construction Materials	576523.13	672643.95	575858.46	671868.46
A4	Transport to the building site	1332.25	1554.37		
A5	Construction/installation process	43359	50588.03	46281.66	53997.97
A5a	Site operations & site waste handling	60.85	70.99	3217	3753.35
A5b	Site waste transportation				
A5c	Construction site - material wastage - materials	43198.88	50401.22	43064.66	50244.62
A5d	Construction site - material wastage - transport	99.26	115.81		

5.1 MATERIAL MASS CLASSIFICATION

In both the cases External walls and façade have contributed with maximum percentage of total embodied carbon, mainly due to its high share of total material mass (As shown in Table.7 & 8). Given the fact that a large proportion of Indian buildings are built with reinforced concrete and that total embodied energy and carbon of a building are proportional to the number of materials used, a major factor which should be taken into consideration in construction decision making is the choice of construction practices and designs that save the quantities of materials (Ramya Priyangani Kumanayake1, 2018). As finishing materials such as ceramic tiles and paint area negligible in mass, their contribution to total embodied energy is low, i.e., 0.01% in both cases.

Table.7 Classifications in Mass (kg) of Materials in Pune case building

Item	Value	Unit	Percentage %
External walls and facade	450,000,000	kg	72.16 %
Internal walls and non-bearing structures	170,000,000	kg	27.0 %
Water consumption	3,200,000	kg	0.52 %
Foundation, sub-surface, basement and retaining walls	840,000	kg	0.14 %
Floor slabs, ceilings, roofing decks, beams and roof	750,000	kg	0.12 %
Columns and load-bearing vertical structures	300,000	kg	0.05 %
Other structures and materials	82,000	kg	0.01 %
Windows and doors	9,700	kg	0.0 %

Table.8 Classifications in Mass (kg) of Materials in Kolkata case building

Item	Value	Unit	Percentage %
External walls and facade	450,000,000	kg	71.39 %
Internal walls and non-bearing structures	170,000,000	kg	26.71 %
Floor slabs, ceilings, roofing decks, beams and roof	7,500,000	kg	1.19 %
Water consumption	3,200,000	kg	0.51 %
Foundation, sub-surface, basement and retaining walls	840,000	kg	0.13 %
Columns and load-bearing vertical structures	300,000	kg	0.05 %
Other structures and materials	80,000	kg	0.01 %
Windows and doors	11,000	kg	0.0 %

5.2 CONTRIBUTION OF BUILDING ELEMENTS

In order to analyze embodied energy and carbon of the building with respect to main building elements the material quantities given in Table.9 & 10. The concrete elements have the highest share in material mass as well as embodied energy and carbon, which can be attributed to the high quantity of concrete used for walls and framing the structure. Considering the climate being warm and humid, insulating the building components is a must to break the bridging phenomenon which will help to tackle the potential risk of condensation. But the amount of insulation used is negligible compared to the envelope components hence the embodied carbon emissions are almost zero.

Table.9 Global warming tCO2e- Resource types of Pune case building

Item	Value	Unit	Percentage %
concretePrecast	620,000	t CO_2e	99.86 %
buildingTechnology	320	t CO_2e	0.05 %
concreteReadyMix	230	t CO_2e	0.04 %
earthMasses	87	t CO_2e	0.01 %
flooring	68	t CO_2e	0.01 %
constructionSite	54	t CO_2e	0.01 %
metal	43	t CO_2e	0.01 %
gypsumPlasterCement	22	t CO_2e	0.0 %
insulation	18	t CO_2e	0.0 %
Other resource types	44	t CO_2e	0.01 %

Table.10 CO2e Results of Kolkata case building

Global warming t CO_2e - Resource types

Item	Value	Unit	Percentage %
concretePrecast	610,000	t CO_2e	98.99 %
earthMasses	5,400	t CO_2e	0.88 %
buildingTechnology	320	t CO_2e	0.05 %
concreteReadyMix	210	t CO_2e	0.03 %
flooring	68	t CO_2e	0.01 %
constructionSite	54	t CO_2e	0.01 %
doorsWindows	42	t CO_2e	0.01 %
metal	40	t CO_2e	0.01 %
insulation	38	t CO_2e	0.01 %
Other resource types	51	t CO_2e	0.01 %

5.3 ANALYSIS COMBINING THE CONSIDERED LIFE STAGES.

The complete Life Cycle Assessment results in terms of carbon emissions is shown in figures below. As seen in the Fig.8 carbon emissions are considered from current year till 2055. The baseline case of both the structures are given in annexure for reference. In case of Pune as shown in Fig the embodied carbon emissions are same throughout the life of the building but the operational carbon emissions starts reducing consequently till the year 2055 hence making the net emissions reduce over the time span approximately 32 years. This shows that using sustainable practices while designing will help reach the goal in the given time span.

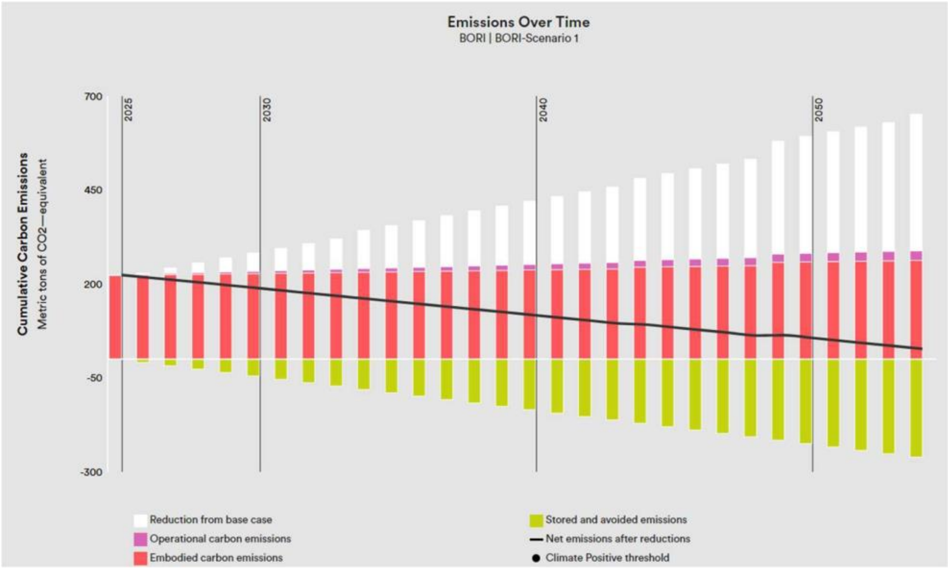

Fig.8 Carbon Emissions throughout the building life**.**

In case of Kolkata as shown in Fig.9 the operational carbon emissions reduces with the same pace as Pune case building does but this case achieves zero net emissions earlier compared to Pune case building. This phenomenon occurred because the microclimate of Kolkata case building has warm and humid climate hence the design strategies, materials, orientation, thermal transmittance, window to wall ratio and overall thermal performance of building is responding to the warm and humid climate which makes the emissions drastically change into a stable reduced state corresponding to the climatic threshold. Whereas this response is not seen in Pune case (emissions reduced in a steady pace) because the microclimate for this site is moderate hence the strategies or variables could be held in a different way to gain the drastic response as the case of Kolkata building does.

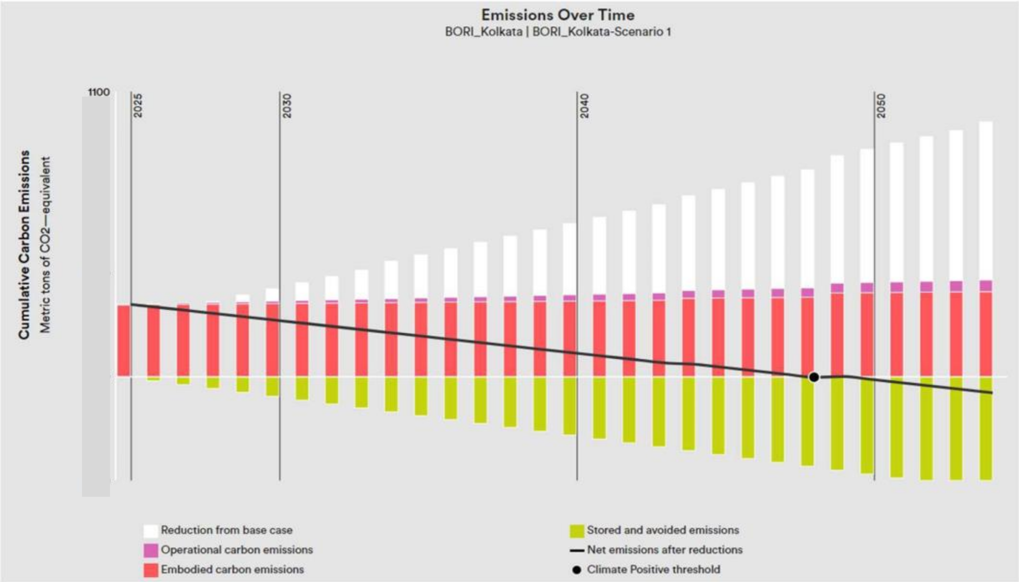

Fig.9 Carbon Emissions throughout the building life.

6.0 CONCLUSION

The cradle-to-gate life cycle assessment and carbon emission study of the educational building was for Pune and Kolkata. The total carbon coefficients of Pune case are 621214 tCO_2e whereas for Kolkata case it is 615033 tCO_2e. Concrete in both cases being the main structural material, contributed to maximum amount of embodied energy and embodied carbon. Therefore in design and material related decision making, materials which are used in buildings in mass quantities as well as materials with high energy intensities should be taken into account. The results achieved for both cases vary a lot considering the operational energy emissions being the key variant for approaching such results. Emissions from building production, operation and end-of-life stages are highly interdependent. As discussed before during the study of variables and parameters that though the geographical locations and building components remain the same, the Life Cycle Assessment of the both cases were hugely corresponding to the dependent variables and parameters, i.e. the location, topography, soil profile, electricity rates, transportation costs, wind direction, rain patterns, thermal performance of building, orientation of building, window to wall ratio, thermal transmittance, solar heat gain coefficients, etc. This study makes designers more concerned towards the approach of studying the parameters which are more leaned to the contextual research while making design choices. We should focus at early life stages of building on the decisions that achieve a large embodied impact reduction and defer less important decisions to the design development stage.

6.1 ACKNOWLEDGEMENT

I would like to express my special thanks of gratitude towards Ar. Namrata Dhamankar for her guidance who gave me this opportunity to accomplish this study which also helped me in doing a lot of research and gaining knowledge regarding the topic and its various aspects that are to be dealt in reality.

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KOLKATA

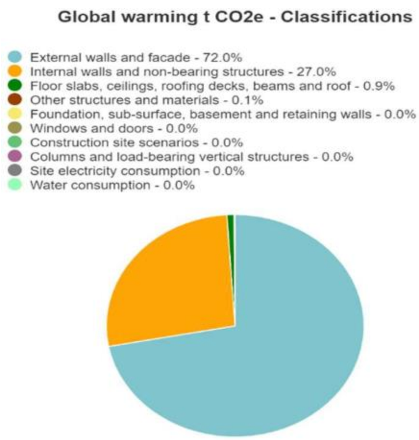

Fig.11 Classifications

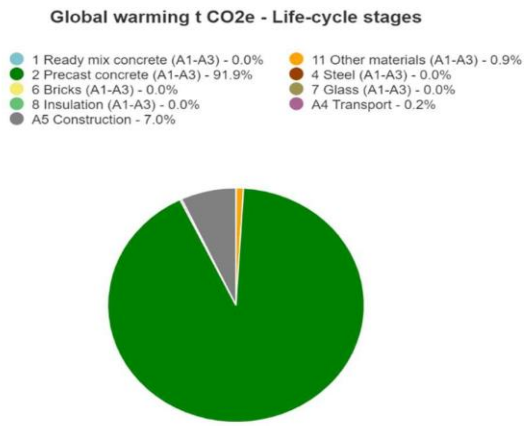

Fig.12 Life Cycle stage wise Co2e

PUNE

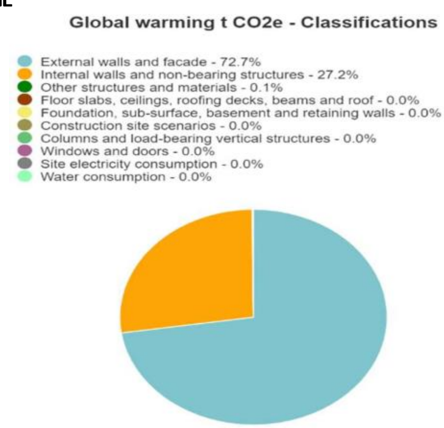

Fig.13 Classifications

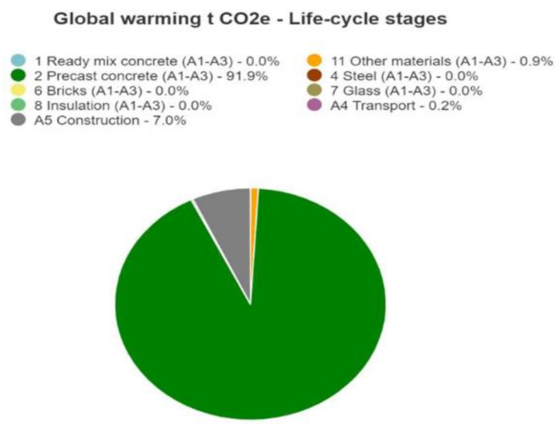

Fig.14 Life Cycle stage wise Co2e

ANNEXURE

No.	Item Description	Unit	Estimate for Pune Case Building				Estimate for Kolkata Case Building			
			Quantity	Rate (Rs)	Amount (Rs. Millions)	Cost per sqm. (Rs)	Quantity	Rate	Amount	Cost per sqm
A. CIVIL WORKS										
1	**EXCAVATION**									
1.1	Excavation In Soil	Cu.m	256.5	1500	0.38	142.12	256.5	1575	0.40	149.22
1.2	Excavation In Hard rock	Cu.m			0.00	0.00			0.00	0.00
1.3	Rubble Soling	Sq.m	231.1	350	0.08	29.89	231.1	360	0.08	30.74
1.4	Backfilling+ Compaction	Cu.m	115.5	550	0.06	23.47	115.5	570	0.07	24.32
1.5	Antitermite treatment	Sq.m	962.4	200	0.19	71.11	962.4	210	0.20	74.66
2	**RCC WORK**									
2.1	PCC Plinth M10	Cu.m	144.4	3800	0.55	202.66	144.4	3914	0.57	208.74
2.2	PCC For Footing M10	Cu.m	196.5	3800	0.75	275.80	196.5	3914	0.77	284.07
2.3	Foundation, Raft,Plinth beams, shear walls	Cu.m	121.2	3800	0.46	170.21	121.2	3914	0.47	175.32
2.4	RCC(M35 grade)	Cu.m	119.3	5300	0.63	233.58	119.3	5459	0.65	240.59
2.5	RCC (M30 grade)	Cu.m	415.0	5000	2.08	766.65	415.0	5150	2.14	789.65
2.6	Cement Bags	Sq.m		525	0.00	0.00		541	0.00	0.00
2.7	Reinforcement ,TMT Fe 500	M.Ton	30.3	68000	2.06	761.22	30.3	70040	2.12	784.05
2.8	Fabrication of Reinforcement	Sq.m		23000	0.00	0.00		23690	0.00	0.00
3	**SHUTTERING WORK**							-		
3.1	Shuttering Area	Sq.m	962.4	280	0.27	99.55	962.4	288	0.28	102.54
4	**FAÇADE WORK**							-		
4.1	100mm Thick AAC Wall	Sqm	1834.3	535	0.98	362.55	1834.3	551	1.01	373.43
4.2	150 mm Thick AAC Wall	Sqm		190	0.00	0.00			0.00	0.00
4.3	External Plaster	Sqm	1834.3	450	0.83	304.95	1834.3	464	0.85	314.10
4.4	Glass façade	Sqm	1834.3	90	0.17	60.99	1834.3	93	0.17	62.82
4.5	External Aluminum Cladding	Sqm	246.4	2500	0.62	227.58	246.4	2575	0.63	234.41
	SUB- TOTAL (A)				**10.10**	**3,732.33**		-	**10.42**	**3,848.67**
B. INTERNAL WORKS								-		
5	**INTERNAL WALLS , FINISHES**							-		
5.1	200 mm Thick AAC Wall	Sqm	866.5	535	0.46	171.27	866.5	551	0.48	176.41
5.2	Internal Plaster - Walls	Sqm	446.3	450	0.20	74.20	446.3	464	0.48	176.41
5.3	Painting of Internal Wall +Ceiling	Sqm	1312.8	110	0.14	53.35	1312.8	113	0.21	76.43
6	**WATERPROOFING**							-		
6.1	Toilet	Sqm	265.2	650	0.17	63.69	265.2	670	0.18	65.60
6.2	Top terrace	Sqm	962.4	650	0.63	231.10	962.4	670	0.64	238.04
7	**TILING WORK**							-		
7.1	Flooring - Polished Kota	Sqm	2441.5	680	1.66	613.37	2441.5	700	1.71	631.77
7.2	Ceramic 12 x 12 Toilets	Sqm	265.2	350	0.09	34.29	265.2	361	0.10	35.32
8	**DOORS**							-		
8.1	D1(entrance door for toilet)- 0.9 *2.1	Sqm	10.9	2800	0.03	11.30	10.9	2884	0.03	11.64
	SUB-TOTAL (B)				**3.39**	**1,252.57**		-	**3.82**	**1,411.61**
C. MEP SERVICES								-		
11	**HVAC**							0		
11.1	Chilled Water Piping	BUA Sqm	2706.2	27000	0.00	0.00	2706.2	27810	0.00	0.00
12	**ELECTRICAL & ALLIED SERVICES**									
12.1	Panels / Distribution Boards & Switch Gears – Main Panels / Distribution Boards & Switchgears – Sub Distribution	BUA Sqm	2706.2	75000	202.97	74985.59	2706.2	77250	209.05	77235.16
12.2	Cabling	BUA Sqm	2706.2	60	0.16	59.99	2706.2	62	0.17	61.79
12.3	Light Fittings	BUA Sqm	2706.2	50	0.14	49.99	2706.2	52	0.14	51.49
12.4	Internal Wiring	BUA Sqm	2706.2	30	0.08	29.99	2706.2	31	0.08	30.89
12.5	Earthing & Lightning Protection	BUA Sqm	2706.2	15	0.04	15.00	2706.2	15	0.04	15.45
13	**PLUMBING & SANITATION**									
13.1	Fixtures and Fittings	BUA Sqm	2706.2	150	0.41	149.97	2706.2	155	0.42	154.47
13.2	Internal Drainage	BUA Sqm	2706.2	2000	5.41	1999.62	2706.2	2060	5.57	2059.60
13.3	External Drainage	BUA Sqm	2706.2	2000	5.41	1999.62	2706.2	2060	5.57	2059.60
13.4	STP and ETP	BUA Sqm	2706.2	1200000	3247.44	1199769.46	2706.2	1236000	3344.86	1235762.55
13.5	Water Treatment and Distribution	BUA Sqm	2706.2	700000	1894.34	699865.52	2706.2	721000	1951.17	720861.49
13.6	Domestic & Flushing water lift pumps, tank, panels	BUA Sqm	2706.2	625000	1691.38	624879.93	2706.2	643750	1742.12	643626.33
13.7	Rainwater Storage system	BUA Sqm	2706.2	590000	1596.66	589886.65	2706.2	607700	1644.56	607583.25
14	**FIRE FIGHTING**									
14.1	Plant Room	BUA Sqm	2706.2	950000	0.00	0.00	2706.2	978500	2648.02	978312.02
14.2	Fire Hydrant System	BUA Sqm	2706.2	400	2570.89	949817.49	2706.2	412	1.11	411.92
14.3	Sprinkler System	BUA Sqm	2706.2	500	1.08	399.92	2706.2	515	1.39	514.90
14.4	Fire Extinguishers & Buckets	BUA Sqm	2706.2	46	1.35	499.90	2706.2	47	0.13	47.37
15	**IBMS AND SECURITY SYSTEM**									
15.1	Fire Alarm System	BUA Sqm	2706.2	65	0.00	0.00	2706.2	67	0.18	66.94
15.2	Public Address System	BUA Sqm	2706.2	38	0.18	64.99	2706.2	39	0.11	39.13
15.3	Access Control System	BUA Sqm			0.10	37.99		0	0.00	0.00
15.4	CCTV System	BUA Sqm	2706.2	70	0.00	0.00	2706.2	72	0.20	72.09
15.5	Building Management System	BUA Sqm			0.19	69.99		0	0.00	0.00
	SUB-TOTAL (C)				**11,218.22**	**41,44,581.61**		-	**11,554.90**	**42,68,966.43**
D. EQUIPMENT & FURNISHING								-		
17	**Office Interiors:**		2706.2	470	1.27	0.00		0		
	SUB-TOTAL (D)				**1.27**	**0.00**			-	-
E. LANDSCAPE & SITE DEVELOPMENT										
18	**SITE DEVELOPMENT**									
	SUB-TOTAL (E)				-	-			-	-
	TOTAL				**11232.98659**				**11569.13492**	

Fig.10 Bill of Quantities

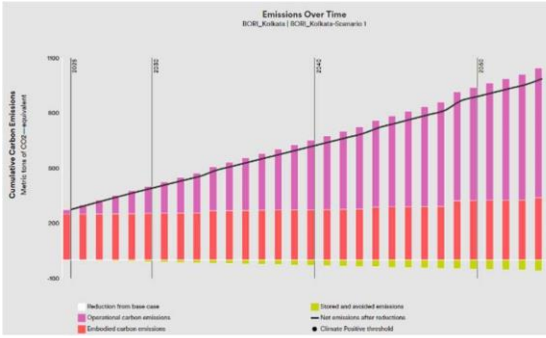

Fig.15 baseline case.

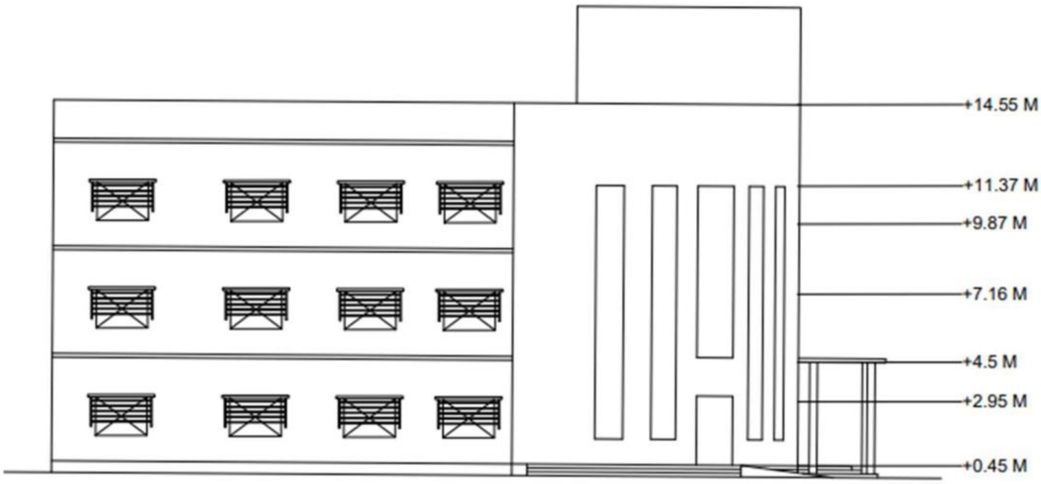

Fig. 16 North elevation

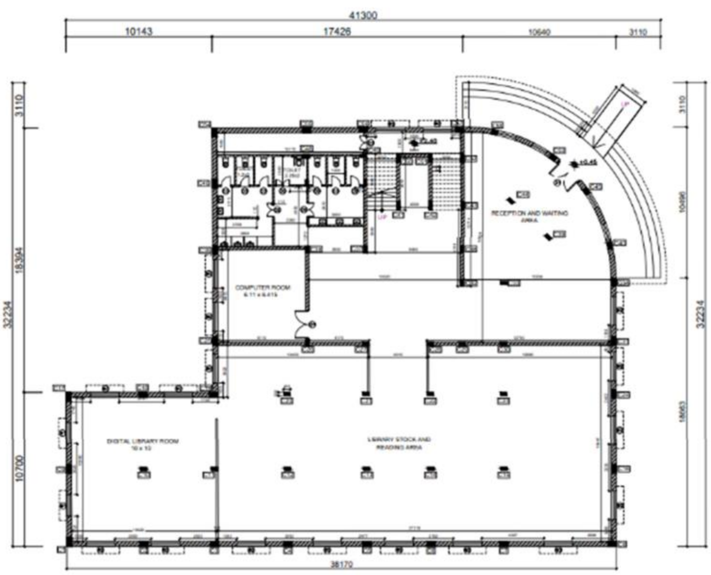

Fig. 18 Ground floor plan

FAÇADE DESIGN AND MATERIALS PLAY AN IMPORTANT ROLE IN FUNCTIONALITY OF A BUILDING

. Ar. Arsheen Palkar, Ar. Muktai Gaikwad, and Ar. Akshay Joshi

ABSTRACT:*A façade plays a vital role in any building. A good façade grabs attention due to its unique style and stands out from the surrounding buildings. A well-designed façade and material selection helps the building to be sustainable and energy efficient. The facades work as an interface between the interior and exterior of a building. An architect is exposed to various building materials that enhance the appearance of building envelope such as ventilation elements, windows, glazing, aluminum features, etc. and gives protection in reference to external environment. Building materials add personality and character to a building and gives life to any structure. Facade design was started with use of materials like stone, mud, and bricks which were sustainable and now it has updated with newer materials like aluminum, glass, copper finishes, etc. which is leading to rigid facades. The above research paper shows a significant information about façade materials in high rise buildings.*

KEYWORDS: Materials, Function, façade design, sustainable

INTRODUCTION/BACKGROUND

The urban environment around the world is affected due to rapid development of infrastructure. So, there is a need to improve the performance of internal space with respect to sustainability and energy efficient building practices. These internal spaces are formed by façade of the building. Façade is a front surface of a building and is called as a vertical building envelope in literature. Facades are designed to be visually attractive as it is a first visual element you perceive of a building, acting as a boundary of interior and exterior space. Facades are designed to work as an interface between the living space and external climate, influencing comfort and energy efficiency. Facades of a building functions as a connector or limiter between the outdoor and indoor conditions and plays an important role in protecting indoor climate from these negative conditions and maintain comfort level of indoor climate. Façade of a building fulfil various functions like lightening, ventilation, insulation for warm and cold air conditions, avoiding mechanical damage and energy conservation. Due to persistent development of infrastructure and the associated challenges of maintaining a sustainable environment, there is a need to use more efficient and durable construction materials for designing facades with a less negative environmental impact. It focusses of the research is to study sustainable façade materials that will help to improve the thermal insulation of the building envelope and reduce building energy demand for heating and cooling purpose. The modern façade design gives a unique appearance to the building. Hence, it is important to select a proper façade cladding material as it affects the final shape of a building, project cost, and sustainability of a building. While choosing a building material with respect to sustainability, it is necessary to consider the lifespan of a material, from its origin to its disposal. The use of sustainable façade materials produces far less waste than other types of materials which leads to less energy consumption and less impact on the environment. It optimizes energy usage and enhance indoor environment quality. A sustainable building façade material maximizes daylight, provide appropriate air quality, optimizes acoustic performance.

AIM/PURPOSE

The aim of the research is to study and recommend sustainable façade materials that can be more efficient and durable with a less negative impact.

OBJECTIVES

1. To study the properties and applications of various sustainable building materials in a building envelope.
2. To study and provide design recommendations for façade materials based on desired energy performance of the façade system.
3. To analyze different façade materials that are less harmful for environment and can help in reducing carbon emission from building envelope.
4. To identify and evaluate the criteria of sustainability in various façade materials with respect to buildings thermal comfort and energy consumption.

RESEARCH METHODOLOGY

In this research paper qualitative research method is been used. A systematic literature review is been studied through internet and secondary data from relevant published academic literature from journals, blogs, articles and research papers. The data in the quantitative research is the data that focuses on various types of sustainable façade materials that are described descriptively and are supported by photographs to reinforce the arguments put forward. The basic concept and working of façade materials are investigated through literature study and online media. The qualitative analysis is conducted to observe to work for different types of materials which have been used in the facades for high rise buildings around the world.

SUSTAINABLE ADVANCES IN BUILDING FAÇADE MATERIALS

A new archetype of facades is designed which interact with the external environment by the integration of new materials and technologies. Some façade materials use passive technologies such as solar shading and thermal mass. This research paper will present sustainability and thermal comfort as important criteria in selecting façade systems in order to face global climate challenges and meet the energy saving targets. This research paper aims to analyse different building's façade cladding systems and developing sustainable façade design ideas for selecting energy efficient façade cladding materials for high rise building around the world. A detailed study of new sustainable materials and technologies of different façade systems along with its importance has been carried out to learn how these approaches can be implemented to make a building sustainable and energy efficient.
The materials are been described as follows:

FABRIC FACADES: SMART WRAPS

Fabric facades are also known as smart wraps. it is a new generation facade material as they give saving in weight and consumption of fabric facade material is economical and sustainable. it can be used for building new facades or for renewing old facades. this material has various design options with perforations and colors. these meshes are made for long lasting cladding applications from hard sharp edges to smooth and sculptural curvatures. the key characteristics of these mesh is their resistance, durability, and permeability. these are high strength meshes and light weight that recreates natural forms and generate innovative and eye-catching architecture. Fabric facades can be used as curtain wall facing with air space that provide spreading of light.

Fig 1: Fabric Facades used at UC Neuroscience Institute

Fabric facades play an important role for the building envelope as they allow more light inside the building and offers energy efficiency improvement, as they are composed of transparent and translucent materials.

The three common types of fabric façade materials are:
1. PVC coated polyester fabric.
2. PTFE coated polyester glass fabric.
3. ETFE foil fabric.

ETFE foil are used in multi-layer cushions whereas PVC and PTFE coated polyester fabric are always found in single- and double-layer application. The cost of installation can be reduced up to 50% because of their light weight. A building can benefit from huge energy savings with reduced solar heat gain, as fabric facades reflect solar heat gain. A building's carbon emission can be reduced by lower operational energy usage both in the summer as well as in winter. In summer it will help to maintain the building cooler and in winter it will provide an effective thermal jacket to a building.

DOUBLE-SKIN FAÇADES

The double-skin facades have two layers; an insulated wall and second is sheltering layer that shields the inner wall from the weather. The translucent metal mesh is used to create a second skin that allows air movement. It allows to pass inside the natural light in building and provides shade and reduces direct exposure of sun inside the building.

The inner wall is made of insulation layer and façade cladding is done on exterior wall. For air circulation throughout the day, air vents can be provided at top and bottom of the wall. It can be opened and closed according to season and time of day.

The air gap in the wall creates way for natural ventilation and results in decrease of heat of sun rays and enhance the indoor thermal comfort. This feature also protects the building materials and structural system from weather and rain, as well as reduces humidity and moisture which evaporates quickly from air gap. It allows to ventilate outer surface of building naturally and reduces use of fan and air compressors.

Fig 2: Double Skin facades - Metal mesh skin, The Hague, Netherlands

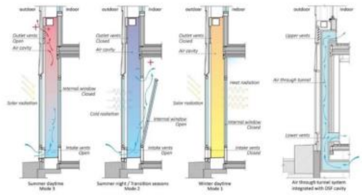

Fig3: Breathable façade insulation

SUSTAINABLE GLASS FAÇADES

Dynamic glazing façade is a smart system that controls the color or tint of the glass and works according to weather and time of the day. As the sun radiates during daytime, the glass will be tinted to reduce the solar impacts automatically using intelligent controls and sensors or manually by BMS integration, or mobile device. The best level of natural light can be chosen for comfort of occupants by using dynamic glass. This glazing solution increase the visual comfort and improves daylight. It enhances the workplace. Right selection of glazing systems can have great impact on sustainability in all aspects including energy efficiency, occupant comfort and wellbeing, thermal comfort, visual comfort, and carbon reduction.

The importance of using glass panels in high rise buildings is:

1. They provide natural sunlight to enter the building, as a result affects the buildings overall energy consumption.
2. The digitally controlled glass panels control the color or tint of the glass and works according to weather conditions and time of the day.
3. Glass panel helps in reducing up to 35% of energy consumption of a building, therefore resulting in saving significant amount of energy bills.
4. The glass requires minimal levels of water for manufacturing process.

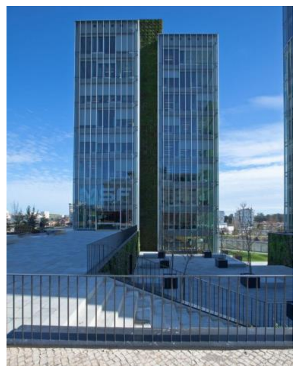

Fig 4: Sustainable glass facades – Natura Towers, Lisbon, Portugal

CERAMIC FACADES

Ceramic cladding enhances the aesthetic look of the building. It is highly durable, easy maintenance, environmentally friendly and enhance the look of the building. These claddings do not get damaged easily as they are highly resistant to extreme weather conditions. The ceramic cladding façade are not affected by rain or increasing pollution level and can last for long years without any visible wear and tear. The ceramic tiles can be easily cleaned and usually does not stain. It helps to save loss of heat as it has good thermal insulation properties. It also helps to maintain an optimum temperature in a building. Ceramic facades help in reducing the carbon footprints in the environment as it can be easily recycled. The light exterior color has high level of ability of a surface to reflect solar radiation and helps to avoid the urban heat island effect. The anti-bacterial properties will withstand any weathering, pollution, and moss formation, and have significantly low maintenance costs.

Fig 5: Ceramic facades – Ilot Queyries, Bordeaux, France

The importance of using ceramic facades in high rise buildings is:

1. They are made from the natural raw material ceramic which is eco-friendly in nature.
2. It is free of heavy metals and other harmful additives which can cause harm to the environment.
3. A ceramic brick facade offers optimum thermal, fire and sound insulation in a space which is required to make a space live able.
4. It is a good investment for many years as ceramic doesn't have any side effects on the facade which over time will lose none of its original beauty.
5. Rear ventilation ensures a balanced, healthy indoor climate and contributes positively to the overall issue of climate protection.

CLAY FACADES

Clay facades tiles are made of terracotta that can be cladded on exterior walls of any building. Clay façade tiles like facing bricks or clay facades tiles have been use for many years. Clay facades are highly resistant to the exterior environment and are outcome of sophisticated technology and advanced firing processes.

Fig 6: Clay ventilated facades

Clay facades retain the color for longer period of time as compared to paint, which can look smudged with dust and dirt. A properly executed clay façade tiles are excellent heat insulator. Clay façade tiles are highly durable and last for decades as it has high weather resistance power. It has high heat buffering capacity and it minimizes loss in winter and prevents overheating during summer.

The importance of using clay facades in high rise buildings is:

1. One of the eco-friendly materials utilized nowadays to elevate a business structure is terracotta.
2. The use of this outstanding component to a house layout is a source of fascination for contemporary architects. It is entirely natural and constructed of clay.
3. Your building's skin will be shielded against UV radiation, extreme weather, wind, snow, etc. by using a clay façade.
4. The structures with clay facades will improve their energy efficiency. Less energy will be required to regulate the internal temperature because it won't rise to the usual level.
5. Clay found in nature resists fire. The most recent fire procedures were used to create these clay tiles. The substance hardens, creating a superior coating on the top surface that prevents fire from spreading.

SOLAR SHADING FACADES

Solar shading façade are series of horizontal or vertical aluminum blades. It helps to control solar heat gain and amount of sunlight in a building. The solar shading blades are designed to control the level of sun enter the building, which helps in lower the temperature in building. It gives a good and comfortable ambience for occupiers, and it leads to reduce in greenhouse effect

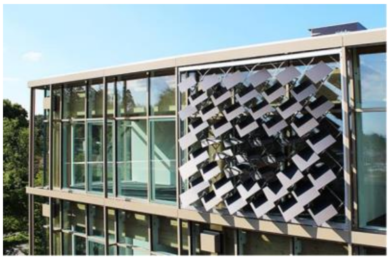

Fig 7: Solar shading facades – NEST Hilo EMPA, Switzerland

During winters, the sun sits lowers in the sky, whilst still maintain the partial shading. The internal environment of the building structure benefits from the natural warmth of the sun. Use of solar shading panels on external façade of a building is hugely beneficial to both the environment and the buildings overall operating costs. It is of great significant to reduce the need of air-conditioning during the summer as well as reduces energy consumption.

The importance of using solar shading facades in high rise buildings is:

1. Solar shading facades assist in distributing day light and reduce ongoing electricity expenses. Sometimes the extreme heat makes it difficult for them to focus on their task, which reduces production.
2. These issues can be resolved, the light can be harnessed for the benefit of building occupants, and the aim of increasing staff productivity at a cheaper cost can be accomplished.
3. During the solar heat control period of 9 am to 5 pm, solar shading devices limit the direct heat entering the building envelope and give diffused day light, reducing the need to turn on the lights.
4. Sun louvres, sun control systems, and vented facades all contribute to "energy efficiency and energy savings as well as lower maintenance costs" and the preservation of "Good Indoor Air Quality."
5. The evolution of solar shading facades has started from stones canopies, brick honeycomb walls, timber, concrete fins, steel, terracotta, aluminum.

CONCLUSION

1. Sustainable building façade materials fulfils various functions like lightening, ventilation, and insulation for warm and cold air conditions, avoiding mechanical damage and energy conservation.
2. Sustainable façade materials help to reduce carbon footprints of the buildings and gives less negative impact on environment.
3. Use of sustainable façade materials not only improve the thermal insulation of the building envelope and reduce building energy demand for heating and cooling purpose, but also meet the demand of sustainable development.
4. Sustainable new materials and technologies interact with external environment by using passive technologies such as solar shading and thermal mass.
5. The core function of façade in a building envelope is to work with nature rather than resisting its influences.
6. Today's architects not only have to take into consideration the technical and aesthetic aspect of a building but also its uniqueness in design and at the same time be energy efficient.

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COMPARATIVE ENVELOPE ANALYSIS BETWEEN TRADITIONAL ANDCONTEMPORARY CONSTRUCTION FOR ENERGY EFFICIENCY IN A HOTEL IN MATHERAN

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ABSTRACT: *Buildings are usually skin dominated, having smaller internal heat generation as compared to the heat gain/loss through the envelope (Givoni 1998). The building envelope can contribute up to 73%of the total heat gain/loss (DOE 2004). Energy efficient building envelopes can reduce dependency on fossil fuel and environmental pollution. This paper explores the analysis of thermal performance of envelope in a hotel in Matheran with respect to energy efficiency. The essence of tourism in Matheran is environment and so to conserve its quality, there is a need to induce environmentally sound development and operations. All this underlines the implementation of green sustainable measures and need to achieve greater efficiency in existing hotel envelopes as no new construction is allowed in Matheran. It is very important to investigate heat gain parameters for different envelopes based on their material characteristics. Thus, the objective is to make a comparative analysis of two different building envelopes, the traditional load bearing Laterite stone construction and contemporary RCC framed brick structure(traditional and contemporary) in the Matheran hotel and determine the most energy efficient one from their energy-saving potential. Both the envelopes are investigated through ECOTECT and eQUEST software's simulation modelling for thermal performance. The analysis of the simulations implied that the traditional construction building envelope has better thermal performance, thus more energy efficient. Further, the study concludes by making the contemporary envelope more energy efficient by modifying it (roof, wall and fenestration properties) and simulating the same for better thermal performance.*

KEYWORDS: Building envelope, thermal performance, energy efficiency, simulation

INTRODUCTION / BACKGROUND

Energy has recently become a major issue because of growing concerns of CO2 and other greenhouse gas emissions, and depletion of fossil fuels. One of the leading contributors to this issue is the hospitality industry as there is rapid growth of tourism which poses an increasing threat to the environment as hotels are very content-specific facilities, due to the presence of different functional areas which leads to more energy consumption, the consequence of which certainly is environmental degradation. Thus, this paper explores the analysis of thermal performance of envelope of a Hotel in Matheran with respect to energy efficiency.

NEED OF THE STUDY

Over the past few decades, tourism has seen significant increase in Matheran due to its close proximity to Mumbai and Pune. Even after Matheran being declared as an Eco-sensitive zone (ESZ) in 2003, the number of newly built hotels and local houses being converted into home stay accommodations has increased even though a ban imposed by the State Government on any new construction. A serious spurt in tourists puts tremendous stress on its infrastructure facilities accentuated with unregulated growth of new and existing hotels. This influx has exerted tremendous pressure on Matheran's ecologically fragile area thereby increasing energy demands in the form of electricity, fuel & wood, oils to run this facilities. The essence of tourism in Matheran is Environment and so to conserve its quality and attractiveness, there is a need to induce environmentally sound development and operations. All this underlines the implementation of measures in the energy consumption management which will lead to more energy efficient hotel operation, reduction in costs while enhancing the comfort and quality of services. There isa need to achieve greater energy efficiency of existing hotel facilities as no new construction is allowed in Matheran.

AIM/ PURPOSE

The aim is to attain maximum energy-efficiency in the hotel in Matheran by making a comparative analysis of two different building envelopes (traditional and contemporary) and determine the most energy efficient one from their energy-saving potential. Further, making the contemporary envelope more energy efficient by applying strategies individually or in combination.
To accomplish this, the objectives of the study are as follows:

1. Investigating energy-saving strategies for hotel and their energy-saving potential from the previous research
2. Making a comparative analysis between two different envelopes in the hotel, those are traditional load bearing Laterite stone construction and contemporary RCC framed brick structure.
3. Applying the same to the simulation model of the hotel.
4. Determining the best envelope in terms of energy saving from the analysis of the simulation.
5. Further, making the contemporary envelope energy efficient by using green strategies.

IMPORTANCE OF THE RESEARCH

Envelope thermal performance for energy efficiency is a method of determining average heat gain through envelope. It is a parameter that measures the energy efficiency of the building without inhibiting the design options as it is retrofitting of the existing hotel which is the need of the hour for Matheran due to its declaration as an eco-sensitive zone in 2003 because of which no new construction is permitted. For a particular location, climate factors may not vary but architectural factors may vary. Therefore, it is very important to investigate heat gain parameters for both the envelopes based on their material characteristics.

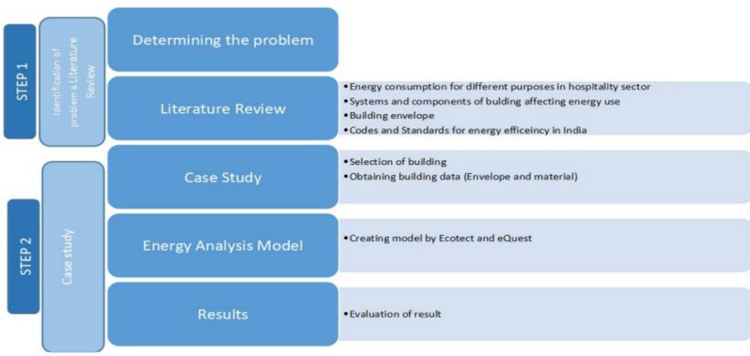


Fig 1: Structure of study
Source: Author

ENERGY IN HOSPITALITY SECTOR
Hotels are large consumers of energy and fossil fuels to provide high quality services to guests which can be effectively reduced without compromising the quality of services, thus cost savings.

ENERGY CONSUMPTION FOR DIFFERENT PURPOSES
A hotel can be seen as the architectural combination of three distinct zones, all serving different purposes:

Three distinct zones of hotel		
Guest Rooms	**Public areas**	**Service area**
(Bedrooms, bathrooms/showers, toilets) Individual spaces with extensive glazing, utilization and varying energy loads	(Reception, lobby, bars, restaurants, meeting rooms, swimming pools) Spaces with high rate of heat exchange with the outdoor environment (high thermal losses) and high internal loads (occuants, equipments and lighting)	(Kitchen, offices, store rooms, laundry, staff facilities, machine rooms and other technical areas) Energy intensive areas typically requiring advanced air handling (ventilation, cooling, heating)

Table 1: Important zones of a hotel
Source: Author

HOTEL ENERGY CONSUMPTION IS INFLUENCED BY PHYSICAL AND OPERATIONAL PARAMETERS

Physical paramters

- Size, structure and design of building
- Geographical and climatic conditions
- Age of the facility
- Type of energy and water systems installed
- The way systems are operated and maintained
- Types and amount of energy and water resources available locally
- Energy use regulations and cost

Operational parameters

- Operating schedules for different functions
- Number of facilities (restaurants, kitchens, in-house laundries, swimming pools and gyms, business centres, etc.)
- Services offered
- Occupancy rates
- Variations in customer preferences relevant to indoor comfort, on-site energy conservation practices

Fig 2: Physical and operational parameter that influence energy consumption in hotel
Source - Author

PASSIVE FACTORS AFFECTING ENERGY CONSUMPTION

Planning and orientation of building- Climatic aspects like outdoor temperature, outdoor humidity and solar radiation affect the building design. To reduce the energy consumption of buildings over their lifespan, it is necessary to properly design, site and shape buildings and incorporate efficient heating, cooling, and ventilation and lighting strategies. (Green building illustrated by D. K. Ching)
It is estimated that buildings can reduce energy consumption on an average between 20-50% by incorporating appropriate design interventions in the building envelope, heating, ventilation and air conditioning (HVAC, 20-60%), lighting (20-50%), water heating (20-70%), refrigeration (20-70%) and electronics and other (e.g., office equipment and intelligent controls, 10-20%) (United Nations development program).

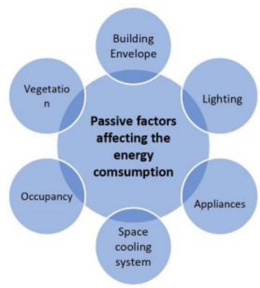


Fig 3: Passive factors affecting energy consumption
Source - Author

BUILDING ENVELOPE

The term 'Envelope' refers to the outer shell of the building. This envelope includes elements such as walls, windows, doors, roof. Designing the building from the outside in i.e, from the perimeter of the building site, towards the building, through its envelope, and to its core has many benefits. By incrementally adding layers and ensuring the integrity and continuity of each of these layers, various energy loads can be substantially reducing.
The important components of the building envelope that affect the performance of the building are-

External walls	Roof	Fenestration	Shading devices	Building colour and texture
•Major part that is exposed to external environment •Heat storing capacity and heat conduction property of wall material impacts internal thermal comfort •Should be reflective and light coloured (can save energy for cooling by 12%)	•Receives the most of solar radiation as its shading is not possible •Shape of the roof •Large overhangs to protect walls and openings from radiation and precepitation •Made of material with low thermal capacity and high reflectivity •Techniques to reduce heat gain - green roofs, reflective roof tops, cool roofs.	•Energy efficient windows and glazing to improve indoor air quality and providing proper insulation •Factors like U-value, solar heat gain coefficient (SHGC) and visible light transmittance(VLT) •Double glazed windows acts as good insulators and provides thermal resistance better than single glazed windows •Low-e glass	•Shading devices reduce solar heat gain in east, west and south facades thus reducing energy consumption for cooling • They also shield walls and windows from water intrusion and protect building materials from deterioration caused by sun's untraviolet rays	•Outer surface of external walls should be reflective and light coloured •Affects the amount of solar energy absorbed •Smooth, light-coloured finishes tend to reflect more than dark, rough finishes •Light colour has high emissivity and thus preferred where solar radiation is high.

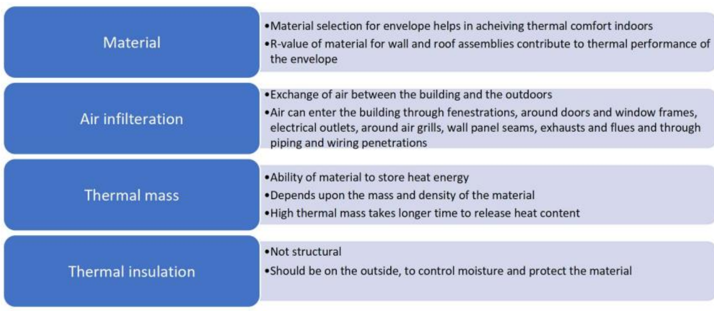
Table 2: Components of building envelope
Source - Author

Building envelope characteristics such as building geometry and orientation, properties of materials, type and quality of construction, and its interaction with the outdoor conditions, impact the heat gain and loss through the envelope, thus affect the energy required for space heating and cooling.

Approach Method	Benefits	Environmental Benefits	Comments
Improvement through the design of building envelope considering ECBC compliance method for building envelope and roof.	• Less energy consumption • Control the building energy use in design stage • Encourage climate responsive building planning and design • Predict the future energy demand for air conditioning • Suggest ways to improve energy efficiency in building through ECBC compliance	• Reduced GHG emissions • Provides options and encourages people to use energy efficient building integrated system	It's better to improve the energy efficiency in design stage rather than in occupancy stage

Table 3: Environmental benefits of energy efficient approaches
Source - Author

CHARACTERISTICS OF EXTERNAL WALL IN BUILDING ENVELOPE



SIMULATION SOFTWARE FOR ENERGY-EFFICIENT BUILDING DESIGN

Energy simulation is a computer-based analytical process that helps designers to evaluate the energy performance of a building and make it more energy efficient by making necessary modifications in the design. Software used in analysis

ECOTECT

Ecotect can calculate heating and cooling loads for models with any number of zones or any type of geometry. One can assign detailed material properties to all objects as well as annual hourly operational schedules to occupancy, internal gains, etc.

eQUEST

eQUEST allows to perform detailed comparative analysis of building designs and technologies by applying sophisticated building energy use simulation techniques.

INTRODUCTION OF STUDY AREA - MATHERAN

The hill station located between Mumbai-Pune urban belt and situated at a distance of about 64 km South-East of Mumbai (Karjat Taluka, District Raigad) and another metropolis, Pune lies at a distance of about 125 km. Matheran Eco-sensitive area (ESA) encompasses 214.73 sq. Km of land in and around it. More than 60 % of the area of Matheran comes under 'reserved forest' category. Located at latitude18.9866° N and longitude 73.2679° E.

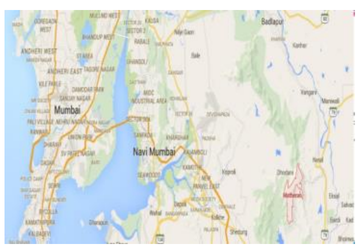


Fig 4: Location of Matheran
Source – Wikipedia

Fig 5: Matheran Map
Source – Maps of India

Due to its high altitude, it experiences comparatively cool winters than its surrounding major cities. The winter months are from November to February, during which the day temperature ranges between 280C– 310C and the night time temperature can drop to about 12°C - 13oC. The annual rainfall is more than3800 mm mainly from June – September. The summer months are very warm and the temperature may rise up to 330C – 340C while the nighttime temperature can decrease to mid-twenties.

Climate data for Matheran													[hide]
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	28 (82)	30 (86)	31 (88)	32 (90)	33 (91)	32 (90)	30 (86)	30 (86)	29 (84)	33 (91)	31 (88)	29 (84)	30.7 (87.2)
Average low °C (°F)	13 (55)	14 (57)	16 (61)	19 (66)	22 (72)	22 (72)	21 (70)	21 (70)	20 (68)	19 (66)	17 (63)	13 (55)	18.1 (64.6)
Average precipitation mm (inches)	2.0 (0.079)	1.5 (0.059)	2.3 (0.091)	4.1 (0.161)	25.1 (0.988)	773.9 (30.469)	2,035.6 (80.142)	1,461 (57.52)	658.6 (25.929)	168.1 (6.618)	31.5 (1.24)	3.8 (0.15)	5,167.5 (203.446)

Table 4: Climatic data of Matheran
Source – Government of Maharashtra

LOCALE OF STUDY- HOTEL WOODLANDS

The case study building, Hotel Woodlands is sited in the interiors of Matheran and thus, it is open from all sides and surrounded by trees. It is interesting to study because of two different types of envelope designs and strategic location. A 4.5m wide road flanks the north-western side of the plot. The property is a G+1 full-service hotel with restaurant, party hall, gaming area and over 33 guestrooms of 2, 3 and 4-bedded occupancy with the gross floor area of 1715 m². The main building was originally constructed during late 19th century and the remaining buildings in 1980's, but the hotel underwent a light renovation nearly 15 years ago that didn't focus on energy conservation. The proximity of the surrounding trees has both positive and negative effects as they create windbreaks by impeding desirable breezes and block daylight from penetrating and positive, because the surrounding trees provide shade to many areas.

PLANNING AND ORIENTATION

The long axis of the building runs north-east to south-west, i.e. the facades on the north-west and south-east are bigger than the north-east and south-west elevations. The orientation of the case study building is tilted to the recommendation by TERI. It states that the best orientation for buildings in tropical climates is longer axis of the building to lie along north-south direction to avoid solar heat gain. Protection from solar heat gain on the west and east were not the guiding factors while orienting the building, but follows the layout of the site. It is all about getting open spaces in front of maximum numbers of rooms.

Fig 5 : Plan Hotel Woodlands, Matheran
Source – Author

BUILDING ENVELOPE OF THE HOTEL

The energy performance of building envelope components, including external walls, floors, roofs, ceilings, windows and doors, is critical in determining how much energy is required for heating and cooling.

OPAQUE COMPONENTS

1.External Walls
The building has two types of construction, the traditional one has 350mm thick Laterite stone external wall and the other contemporary one is RCC framed made of 230mm burnt brick. Both external and internal walls have a cement plaster of 18mm and 12 mm respectively over the brick as well as Laterite stone wall and internally the walls are finished with paints. Some exterior walls are painted with light yellow color for uplifting the facade. According to Cheung et al. (2005) it is possible to save 12% on cooling energy by using white or light color external wall finishes.

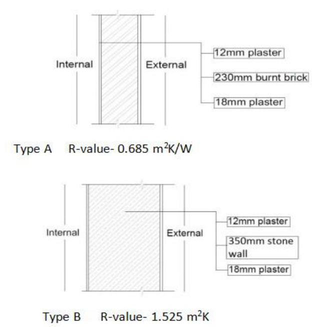


Fig 6: Types of wall construction
Source – Author

2. Roof

The traditional Laterite stone building has pitched roof with wooden frame and M.S. sheets as roof covering and an attic, while the roof in contemporary framed structure is about 150 mm thick RCC with 50mm brick bat as waterproofing course and 20mm PCC.

The roof is an important element of design when it comes to conserving energy because this part of the building receives most of the solar radiation and its shading is not easy. Vijay Kumar et al. (2007) claim that Indian concrete roofs in single or two story buildings with 150 mm thickness of reinforced cement concrete (RCC) and a water proofing course having 75–100 mm thick lime brick mortar, account for about 50%- 70% of total heat transmitted into the occupant zone and are responsible for the major portion of electricity bill in air-conditioned buildings.

Fig 7: Types of wall construction
Source – www.woodlandsmatheran.com

3. Fenestration System

Natural lighting and ventilation

The windows on the north-east and north-west are not effective in allowing day light and airflow because of their sizes. As a result, the lights in these units need to be kept on mostly throughout the day.For proper cross ventilation, Handbook on energy conscious buildings by J.K. Nayak and J.A. Prajapati recommend windows located diagonally opposite to each other. However, none of the guest rooms in this building have provision for cross-ventilation through two pairs of windows located on side walls. As all the rooms of this case study building do not have windows on opposite walls for cross-ventilation, the solution would be to have two windows, side by side, on the same wall instead of one, as suggested in Handbook on energy conscious buildings by J.K. Nayak and J.A. Prajapati.

Fig 9 : Single windows in guest rooms
Source – Author

Fig 8 : Windows of guest rooms
Source – Author

Rooms	Window orientation	Floor area (in SQM.)	Window size (in SQM)	Wall area (in SQM.)	WFR (Window to floor ratio)	WWR (Window to wall ratio)
Room 1&3	N-W	30.5	2.88	18.7	0.094	0.15
Room 2	N-W	30.5	4.32	18.9	0.14	0.22
Room 4	N-W	16	2.4	13.5	0.15	0.177
Room 5	N-E	37.7	1.8	13.5	0.047	0133
Room 6	S-W	38	3.6	28.8	0.094	0.125
Room 7	S-E	32.5	0.6	12.3	0.018	0.048
Room 8	N-E	44	5.4	23.7	0.122	0.227
Room 9&10	S-E	25.6	3.6	13.5	0.14	0.266
Room11&12 Room18&19	N-E	18	1.8	13.5	0.1	0.133
Room 13	S-E	29.5	3.6	13.5	0.12	0.266
Room 14	N-W	16.6	3.6	15.6	0.21	0.23
Room 15,16&17	N-W	15.6	2.25	10.5	0.14	0.214
Room 20	N-E	20.9	3.6	14.7	0.17	0.24
Room21&23	N-W	18	1.8	13.5	0.1	0.133
Room22&24	S-E	18	1.8	13.5	0.1	0.133
Room25&26	N-E	18	1.8	13.5	0.1	0.133
Room27&29	N-W	19.5	1.8	10.8	0.09	0.166
Room28&30	S-E	24.8	1.8	10.5	0.072	0.171
Room 31,32&33	N-W	15.6	2.25	10.5	0.14	0.214

Table 5: Windows to floor area ratio (WFR) and window to wall area ratio (WWR) of guestrooms

Table 5: Windows to floor area ratio (WFR) and window to wall area ratio (WWR) of guestrooms
Source: Author

Another solution might involve having two windows, one at sill level and the other above lintel level as recommended by the same book. This concept would increase the prospect of fan-induced ventilation and stack ventilation. Size and location - The windows are operable with wooden frame and have 6 mm thick frosted glass and fixed grills. The window to floor area ratio (WFR) of each guest room was calculated by dividing the area of the window by the area of the floor. Similarly, the window to wall area ratio in the guest room was calculated by dividing the window area by wall area. Analysis of the results shows that the highest and the lowest window to wall area ratios (WWR) are of 0.26 and 0.13, respectively. The values for some of the guest rooms are below the recommended value as suggested by Lipping et al. (2007) that the optimum window to wall ratio should be equal to 0.24. Even though the value of some guestrooms are above the recommended value (0.26), the windows do not admit adequate light because of the obstruction of the trees on the south-east. The window in all remaining guest rooms has a WWR below the recommended value of 0.24(from 0.13-0.23) as none of the windows extend from the skirting to the lintel level (2 meters).

SUMMARY

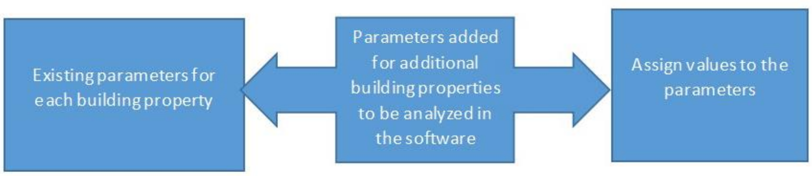
Table below summarizes the main characteristics of the case study hotel building and the sources that helped in comparison of those characteristics.

Characteristics		**Source**
Location	Chinoy Road, Matheran, Maharashtra 410102	
Orientation	Oriented in 207° N direction and the front faces North-West	TERI-Best orientation- longer axis north south
Conditioned floor area	792 sq.m.	
No. of floors	G + 1	
Building shape	'U' shape with one wing smaller	TERI- EPI of Circular building form is lowest
Height	15ft. old building, 10ft. new building (floor to ceiling)	TERI- less is better as it lessens the surface area to floor area ratio i.e. Area ratio
No.of rooms	33 rooms	
Other spaces	Reception area, dining area, party hall, toilets, gaming area, pantry, kitchen, store rooms, staff facility	
Surroundings	No building shades, tree shades, paver blocks surrounding the building (Reflectance-0.2)	Best is green grass surrounding the building (Reflectance- 0.26)
Construction		
Construction type	Main building- Load bearing	As per ECBC,
Exterior wall	Laterite stone wall 1 ½ "thick	U factor-0.261 W/m²K
	18mm plaster on the exterior	R- value of insulation alone – 3.5 m²K/W
	12 mm plaster on the interior	
Roof	Low pitched roof with gable	
	Corrugated M.S. sheets	
	No shingles	
	EPS insulation R-4	
	Gypsum false ceiling	
Interior Floors	Vitrified tiles	
Windows	Gross window area: 12% of conditioned floor area (equivalent to 112 sq.m.), distributed equally for all the rooms	As per ECBC, vertical fenestration U-factor- 3.3 W/m²K Window wall ratio-0.31-0.4, so VLT-0.2
	Single pane window with 6mm frosted glass (U = 5.8 W/m²K, SHGC = 0.82 Wooden frames (U factor-2.8 W/m²K, frame conductance = 0.47, frame width = 60mm)	Maximum SHGC- 0.25
Doors	1mX2.1m (U value-2.8 W/m²K)	
Exterior shading	No shading and overhangs on windows	
Construction type	New building-Framed structure with brick wall	
Exterior wall	Brick wall 230 mm thick	
	Internal walls 150 mm thick	
	18mm plaster on the exterior	
	12 mm plaster on the interior	
Roof	R.C.C. flat roof – 150mm	
	Water proofing course -50mm	
Interior Floors	Vitrified tiles	
	½" gypsum board ceiling	

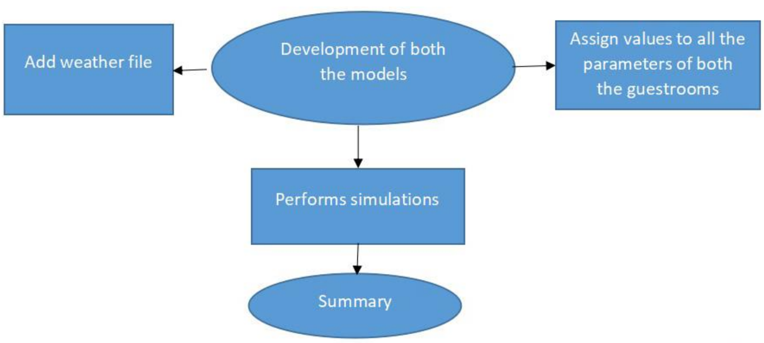
Table 6: Summary of the case study hotel building
Source - Author

METHODOLOGY

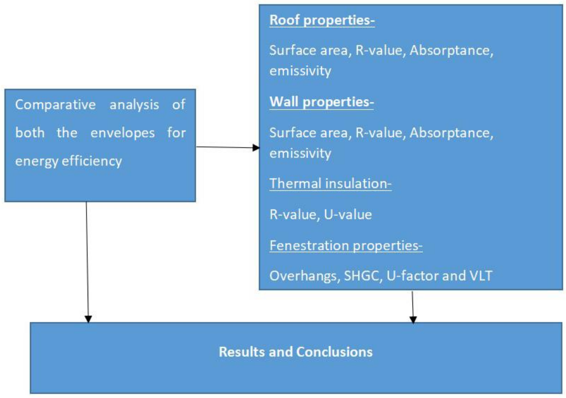
Methodology adopted included development of the Ecotect simulation model of the whole resort, simulation model of two guest rooms in eQuest with same orientation but different material characteristics and taking one envelope forward with energy-efficient measures.



DEVELOPMENT OF EXISTING HOTEL MODEL IN ECOTECT



DEVELOPMENT OF ENVELOPE OF TRADITIONAL AND CONTEMPORARY CONSTRUCTION OF TWO GUESTROOMS IN eQuest



DETERMINING THE ENERGY EFFICIENT ENVELOPE FROM BOTH THE ENVELOPES

Development of simulation model
Parameters for various building characteristics, such as the building geometry, location, building envelope components, the values were assigned to these parameters were as per the materials used on site.
The hotel was modeled in Ecotect software and simulated for hourly temperature profile, passive gains and monthly degree days. The hourly temperature profile shows the inside temperature of each zone to determine the critical time of the day, passive gains shows the heat gains through all the parameters which helps in determining the parameter to focus on in curbing the heat. The monthly degree days determines the cooling requirement.

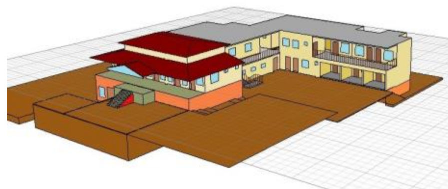


Fig 10: Hotel model on Ecotect
Source - Author

HOURLY TEMPERATURES PROFILE FOR HOTTEST DAY

Hourly temperature graphs display the internal temperatures against the outside temperature of all visible thermal zones in the model over a 24-hour period.

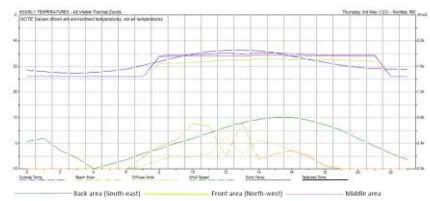


Fig 11: Hourly temperature profile for whole hotel
Source - Ecotect thermal analysis software

The inside temperature of the front zone remains less compared to the back zone and the middle zone as shown in the bar charts below-

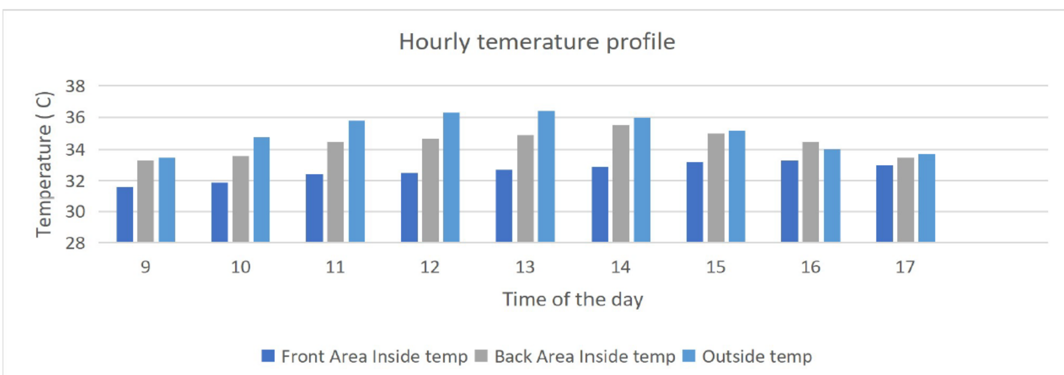


Fig 12: Comparative bar chart for hourly temperature profile, **Source** - Author

PASSIVE GAINS BREAKDOWN

The Sol-air or indirect heat gain is maximum, if insulation is applied and color of the wall and roof elements change to white, then the passive gains breakdown may reduce further.

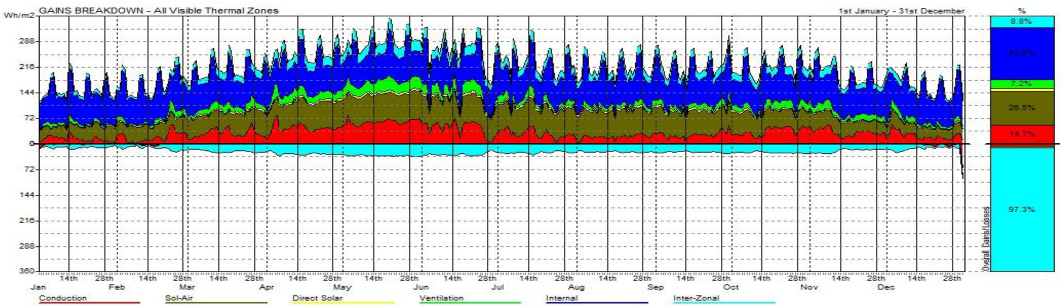


Fig 13: Graph for passive gains breakdown for whole hotel, **Source -** Ecotect thermal analysis software

COMPARATIVE ANALYSIS OF BOTH ENVELOPES FOR ENERGY EFFICIENCY

For the comparative analysis of both envelopes for energy efficiency, two guestrooms one with traditional load bearing Laterite stone construction 350mm thick and other contemporary RRC framed with 230mm brick wall with similar orientation, size, shape, window area were selected. The building configuration, envelope and system characteristics were selected for the analysis. The energy-saving potential of these two guestrooms were analyzed using eQuest simulation.

The building properties analyzed are listed in the table:

For analyzing the effect of changing characteristics of different building systems and components, the corresponding parameters were assigned different values. Three building systems and components that includes:

1. Building configuration,
2. Roof and walls and
3. Fenestration.

Also, the hourly temperature profile, hourly heat gains/losses, monthly loads /discomfort, temperature distribution, fabric gains were plotted to analyze the effect of thermal mass associated with certain measures.

Properties	Values used for traditional guestroom (Laterite stone wall)	Values used for contemporary guestroom (brick wall)
Building configuration	1:2 width to depth ratio, one-story	1:2 width to depth ratio, one-story
Roof and wall properties		
Absorptance	Roof-64 (Red galvanized sheet) Wall-0.4 (Laterite stone)	Roof-0.7 (R.C.C. slab) Wall-0.4 (Red clay bricks)
Emissivity	Roof-0.88 (Red galvanized sheet) Wall-0.7 (Laterite stone)	Roof-0.54 (R.C.C. slab) Wall-0.7 (Red clay bricks)
Insulation	**Roof-R-value-4.68 m^2.K/W** Air film outside-R-0.06 Al sheets-R-value-0.14 Wooden floor – R-0.6 Expanded polystyrene-R- 3.75 Air layer inside-R- 0.13 **Wall-R-value-1.52 m^2.K/W (Laterite stone)** Air film outside-R-0.06 18mm outside plaster-R-0.025 380mm laterite stone wall-R-1.28 12mm inside plaster-R-0.02 Air layer inside-R-0.14	**Roof-0.424 (R.C.C. slab)** Air film outside-R-0.06 20 mm PCC-R- 0.03 50mm Brick bat – R – 0.08 150mm RCC slab-R-0.104 12mm inside plaster-R-0.02 Inside ceiling air layer-R-0.13 **Wall-R-0.685 m^2.K/W (Red clay bricks)** Air film outside-R-0.06 18mm outside plaster-R-0.025 230mm brick wall-R-0.44 10mm inside plaster-R-0.02 Air layer inside-R-0.14
Construction Type	Load bearing construction with 380mm thick laterite stone wall and wooden frames with Al commercial sheets with 20mm expanded polystyrene under the board insulation	R.C.C. framed structure with 230mm brick wall and 150mm thick slab with brick bat and PCC
Fenestration		
Window distribution	Windows (12% of floor area), only on the front side (North-west)	Windows (12% of floor area), distributed in two orientations (North-east & South-east)
Exterior shading	Verandah projection acts as shading	No overhangs
Glazing U-factor	1.09 (6mm frosted glass)	1.09 (6mm frosted glass)
Glazing SHGC	0.72(6mm frosted glass)	0.72(6mm frosted glass)

Table 7: List of building properties analyzed
Source - Author

ROOF AND WALL PROPERTIES

The amount of heat gain/loss through the building envelope depends on the R-value, absorptance and emissivity of the exposed surfaces. The roof and walls contribute to different amounts of heat gain/loss due to the difference in the angle of incident solar radiation. Therefore, the effect of R-value, absorptance and emissivity was analyzed for both, the roof and walls.

Properties of roof/wall	Old Traditional building		New Contemporary building		As per ECBC	
	Wall	Roof	Wall	Roof	Wall	Roof
Solar reflectivity	0.6	0.36	0.6	0.3	>0.7	>0.7
Surface emissivity	0.7	0.88	0.7	0.54	>0.75	>0.75
Absorptance	0.4	0.64	0.4	0.7	0	0
Insulation (Resistance R-value)	1.525 m2.K/W	4.68 m2.K/W	0.685 m2.K/W	0.42 m2.K/W	2.1 m2.K/W	3.5 m2.K/W

Table 8: Roof and wall properties assumed for simulation , **Source** - Author

FENESTRATION PROPERTIES

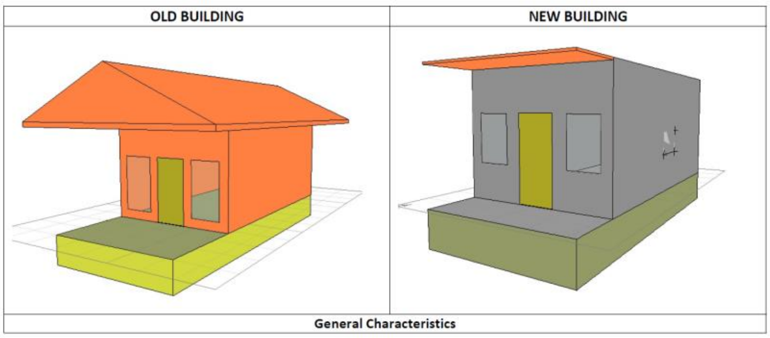
The heat gain/loss through the windows depends on the shading, window distribution on different orientations, U-factor and SHGC of the windows. The lower values of U-factor are associated with double pane, low-e or triple pane glazing, and the higher values are associated with single pane glazing, which is the case in the existing building. Similarly, the lower values of SHGC are associated with reflected or tinted glazing, and the higher values are associated with clear glazing. But in the traditional and contemporary envelopes the fenestration properties remains the same.

Fenestration Properties	Old Traditional building	New Contemporary building	As per ECBC, WWR≤40%
U-value	1.09 W/m2.K	1.09 W/m2.K	3. 3W/m2.K
SHGC	0.72	0.72	0.25

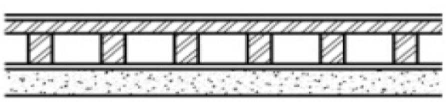
Table 9: Fenestration properties assumed for simulation, **Source** - Author

COMPARATIVE CHART OF BOTH THE ENVELOPES

From the analysis of energy-saving potential of different measures like walls and roof and fenestration properties, comparative analysis is performed on both the guest rooms to check the most efficient envelope for energy savings.



Roof assembly

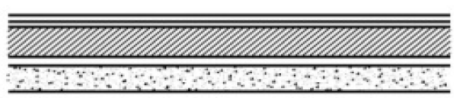


Metal corrugated sheet+1/2" plywood+wooden floor+expanded polystrene, **R=4.68 m².K/W**

Material	Resistance R-value (m².K/W)
Outside air film	0.06
Metal corrugated sheet	0.14
Wooden floor	0.6
Expanded polystrene	3.75
Inside air film	0.13

ECBC recommended R value for roof assembly= 3.5 m².K/W

Roof assembly

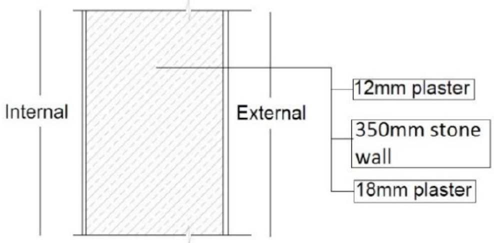


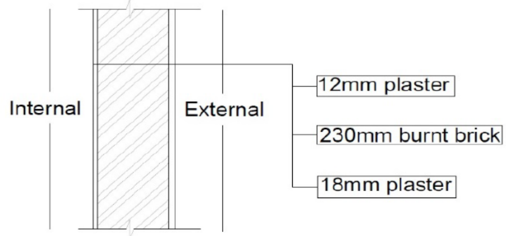
20mm PCC+50mm (avg. thickness) brickbat coba +150mm RCC slab + 12mm plaster, **R=0.424 m².K/W**

Material	Resistance R-value (m².K/W)
Outside air film	0.06
20mm PCC	0.03
50mm brick bat	0.08
150 mm RCC slab	0.104
12 mm plaster	0.02
Inside air film	0.13

ECBC recommended R value for roof assembly= 3.5 m².K/W

Wall assembly	Wall assembly
18mm plaster+350mm stone wall+12mm plaster, **R=1.525 m²/K/W**	18mm plaster+230mm brick wall+12mm plaster, **R=0.685 m².K/W**





Material	Resistance R-value (m^2.K/W)	Material	Resistance R-value (m^2.K/W)
Outside air film	0.06	Outside air film	0.06
18mm plaster	0.025	18mm plaster	0.025
380mm stone wall	1.28	230mm brick wall	0.44
12mm plaster	0.02	12mm plaster	0.02
Inside air film	0.14	Inside air film	0.14

ECBC recommended R value for wall assembly= 3.5 m².K/W	ECBC recommended R value for wall assembly= 3.5 m².K/W
The thickness of stone wall acts as thermal mass, which curbs down the heat more.	

Solar reflectivity	Solar reflectivity
Roof-The solar reflectivity of Terra cotta color aluminum sheet **= 0.36** Wall-The solar reflectivity of the wall= 0.6 ECBC recommended solar reflectivity for roof= >0.7	The solar reflectivity of cement plaster (PCC) **= 0.2-0.3** The solar reflectivity of the wall = 0.6 ECBC recommended solar reflectivity for roof= >0.7
Emissivity	**Emissivity**
The emissivity of Terra cotta color aluminum sheet **= 0.88** The emissivity of the wall = 0.7 ECBC recommended emissivity for roof= >0.75	The emissivity of cement plaster (PCC)**= 0.54** The emissivity of the wall = 0.7 ECBC recommended emissivity for roof= >0.75
Solar absorptance	**Solar absorptance**
The solar absorptance depends on the color of the surface Solar absorptance=1- Solar reflectivity For roof = 1-0.36 = **0.64**	The solar absorptance depends on the color of the surface Solar absorptance=1- Solar reflectivity For roof = 1-0.30 = **0.70**
For wall = 0.4 ECBC recommended solar absorptance as 0	For wall = 0.4 ECBC recommended solar absorptance as 0
Fenestration properties	
U- value	**U- value**
The U- value of the window assembly (Single pane, frosted glass with wooden frame) = 1.09 W/m².K ECBC recommended U-value = 3.3 W/m².K	The U- value of the window assembly (Single pane, frosted glass with wooden frame) = 1.09 W/m².K ECBC recommended U-value = 3.3 W/m².
SHGC	**SHGC**
The solar heat gain co-efficient = 0.72 ECBC recommended SHGC = 0.25	The solar heat gain co-efficient = 0.72 ECBC recommended SHGC = 0.25

Table10: Comparative analysis of both the envelopes, **Source** - Author

ANALYSIS OF THE RESULT

As discussed, simulations were performed on the existing traditional and contemporary guestrooms. The following sections provide the analysis of the results. The thermal analysis was done in Ecotect and eQuest. In general, the traditional guestroom which is made up of 350mm Laterite stone has R-value of 1.52m2k/W and has higher thermal mass as compared to the 230mm thick brick wall. Also, though the roof is corrugated aluminum sheet, but the traditional guest room has an attic as well as roof insulation of 1” EPS. Thus, it resulted in significant savings. The contemporary guestroom is a RCC structure with 230mm thick brick wall without insulation. The roof is also RCC without insulation, thus even though with same building configuration, orientation, shape, size, the energy saving is less. The graph below corresponding to the peak summer month (May) demonstrated that when the outside temperature was the highest, the cooling electricity use in the contemporary guestroom was 1.21 times higher than in the traditional guestroom. Thus, the total energy required for space cooling in traditional guestroom is 1109kW for a year which is less than the energy required for cooling the same area in contemporary guest room 1288kW. Thus, the contemporary envelope requires 15% more energy than the traditional one.

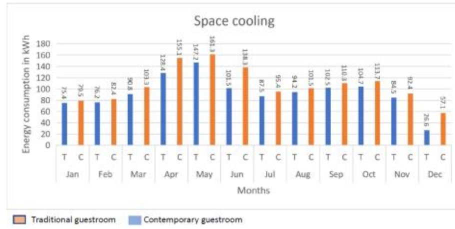


Fig 14: Monthly energy consumption by end-use for space cooling

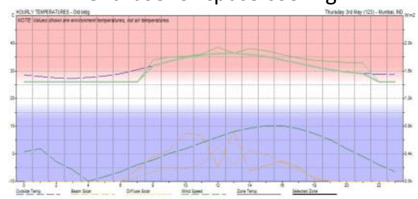


Fig 15: Hourly temperature profile of Traditional envelope, **Source -** Ecotect thermal analysis software

THERMAL ANALYSIS IN ECOTECT

This helps in evaluating the hourly temperature profile, hourly gains and losses, passive gains breakdown which will help in the comparative analysis of both the envelopes.

Hourly Temperature Profile For Average Hottest Day (Thursday 3rd May).The hourly temperature profile of both the traditional and contemporary envelopes show that the traditional guestroom tends to be cooler than its contemporary counterpart during morning 6am to evening 9pm. Thus, the traditional guestroom keeps cool by around 5% than the contemporary guestrooms. The difference in the temperature is due to the high thermal mass of the traditional envelope walls which is a 350mm Laterite stone wall with R-value of 1.525 m2k/W which is more compared to the contemporary envelope wall of 230mm brick with 0.685 m2k/W. Also, the R- value of the roof assembly is more 4.68 m2k/W than that of the contemporary one which is 0.424 m2k/W. The reflectance of the aluminum sheet roof of the traditional envelope is more compared to the PCC finish roof of the contemporary one. The emissivity of the traditional roof is also more than the contemporary one. This all helps in maintaining the temperature of the traditional envelope than the contemporary one.

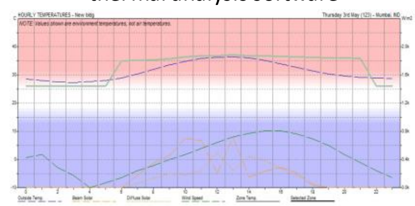


Fig 16: Hourly temperature profile of Contemporary envelope
Source - Ecotect thermal analysis software

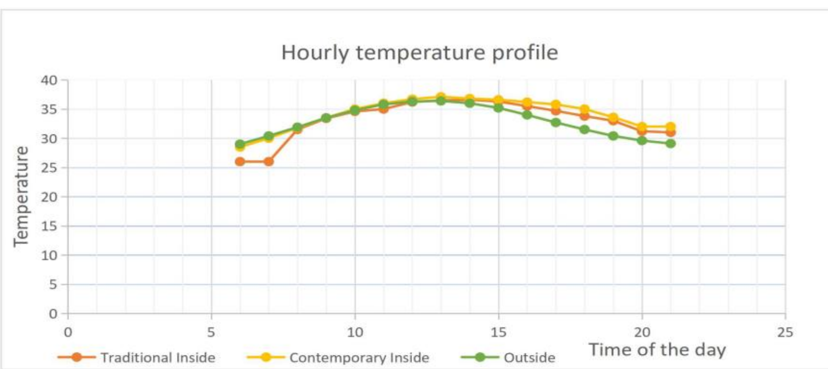


Fig17: Comparative of Hourly temperature profile of both the envelopes
Source - Ecotect thermal analysis software

Traditional guestroom				Contemporary guestroom			
Hourly temperature profile							
HOURLY TEMPERATURES - Thursday 3rd May (123)				HOURLY TEMPERATURES - Thursday 3rd May (123)			
HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)	HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	26.0	28.5	-2.5	00	26.0	28.5	-2.5
01	26.0	28.0	-2.0	01	26.0	28.0	-2.0
02	26.0	27.5	-1.5	02	26.0	27.5	-1.5
03	26.0	27.3	-1.3	03	26.0	27.3	-1.3
04	26.0	27.6	-1.6	04	26.0	27.6	-1.6
05	26.0	28.1	-2.1	05	26.0	28.1	-2.1
06	26.0	29.0	-3.0	06	35.0	29.0	6.0
07	26.0	30.4	-4.4	07	35.1	30.4	4.7
08	33.9	31.9	2.0	08	35.4	31.9	3.5
09	35.0	33.5	1.5	09	35.8	33.5	2.3
10	35.3	34.8	0.5	10	36.4	34.8	1.6
11	36.1	35.8	0.3	11	36.7	35.8	0.9
12	36.2	36.3	2.2	12	36.7	36.3	0.4
13	36.5	36.4	0.1	13	37.1	36.4	0.7
14	36.6	36.0	2.1	14	36.8	36.0	0.8
15	36.4	35.2	2.2	15	36.8	35.2	1.6
16	36.0	34.0	2.0	16	36.7	34.0	2.7
17	34.7	32.7	2.0	17	36.4	32.7	3.7
18	33.8	31.5	2.3	18	36.2	31.5	4.7
19	33.4	30.4	3.0	19	36.1	30.4	5.7
20	33.2	29.6	3.6	20	36.1	29.6	6.5
21	33.0	29.1	3.9	21	35.9	29.1	6.8
22	26.0	28.9	-2.9	22	26.0	28.9	-2.9
23	26.0	28.8	-2.8	23	26.0	28.8	-2.8

Table 11: Comparative of Hourly temperature profile of both the guestrooms
Source - Ecotect thermal analysis software

The hourly heat gains / losses of both the traditional and contemporary envelopes show that the fabric gain in traditional guestroom tends to be less than its contemporary counterpart. This gain is more during morning 7am to 6pm. There is gradual gains in the traditional guestroom due to high thermal mass of the walls and EPS insulation in roof. But in contemporary guestrooms the slope of fabric gains is steep after 7am due to lack of insulation on wall as well as roof.

It is seen from the above table that the gains is more due to sol-air i.e., indirect solar gains in both the envelopes but is much more in the contemporary envelope.

Traditional Guestroom			Contemporary Guestroom		
Passive gains breakdown			Passive gains breakdown		
FROM: 1st January to 31st December			FROM: 1st January to 31st December		
CATEGORY	LOSSES	GAINS	CATEGORY	LOSSES	GAINS
-----------	-------	------	-----------	-------	------
FABRIC	4.4%	6.1%	FABRIC	2.2%	13.8%
SOL-AIR	0.0%	8.4%	SOL-AIR	0.0%	20.1%
SOLAR	0.0%	6.7%	SOLAR	0.0%	2.5%
VENTILATION	5.0%	7.5%	VENTILATION	0.8%	6.2%

Table 12: Comparative passive gains breakdown for both the envelopes
Source - Ecotect thermal analysis software

CONCLUSION

The analysis of the simulations above implied that the traditional guestroom is more energy efficient than the contemporary one. Compared to the contemporary construction, the traditional stone construction resulted in 17% energy savings due to its wall's thermal mass and insulation in the roof. Further study leads the contemporary guestroom to a more energy efficient envelope by changing its roof and wall and fenestration properties like the R- value of wall and roof, emissivity and absorptance parameters as per Table 8.The heat gain and loss from roof and wall contribute to a higher portion of building energy use in a one-story structure. Therefore, improving roof and walls also has energy-saving potential. Thus, the best way to make the contemporary guestroom more energy efficient is to insulate it and over the deck insulation is much better than under the deck as it does not allow the heat to enter the structure.

GREEN ROOF APPLICATION

The following points are considered for selecting green roof for retrofitting of the existing contemporary guestroom-

1. Building Energy Consumption
2. Biodiversity and habitat
3. Roof life
4. Air quality
5. Storm water runoff reduction
6. Aesthetics and recreation

The thermal properties of the green roof is mentioned in the table below-
Increasing insulation is more effective energy-saving measure for surfaces with a high absorptance and a low emissivity. Therefore, green roof seems the most appropriate insulation.

Insulation	Thickness (m)	Thermal conductivity(k)	R-value (m2.k/W)
Gravel drainage layer (estimated as sand)	0.06	0. 27	0.24
Total assembly	0.1		2.15
Polyisocyanurate Insulation	0.05	0.02	2.13
RCC roof	0.175	1	0.42
Total	0.425	1.29	5.6

Table 13: Thermal parameters of green roof

WALL INSULATION

For wall insulation, EIFS (External insulation and finish system) was used for simulation as it is over the deck insulation which curbs the heat entering the building structure itself. Following points were considered for selecting EIFS.

1. Over the deck insulation
2. Green rated
3. Moisture resistant.
4. More energy efficient than under the board insulation

The thermal properties of EIFS is mentioned in the table below:

Material	R value
230 mm brick wall	0.68
EIFS	4
Total	4.68

Table 14: Thermal parameters of EIFS

The graph above shows that by applying the insulation on the wall and the roof, the hourly temperature profile has changed in the insulated contemporary envelope as compared to the contemporary one.
Because of this insulation, the hourly temperature profile of the envelope becomes 12% cooler than its contemporary counterpart. Also, the average temperature inside goes down from 32.8oC to 28o C even though the average daily temperature outside is 31.3oC i.e. 8% less temperature than the outside Temperature. Thus, it is seen in thermal analysis parameter that the insulated contemporary envelope responses much better than the contemporary envelope and is a better option to be utilize in Matheran which will help reduce the cooling costs and because of green roof, it will help in maintaining the ecology of the area.

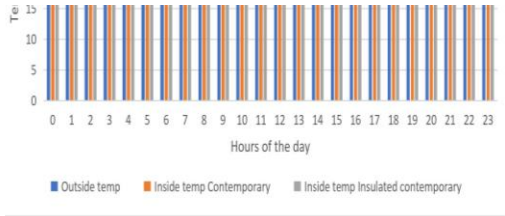


Fig 18: Comparative of hourly temperature profile for contemporary and insulated contemporary envelopes

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HEALTH & WELL-BEING IN SUSTAINABILITY FRAMEWORKS
A STUDY OF THE LIVING BUILDING CHALLENGE WITH REFERENCE TO WELL V2 AND FITWEL

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ABSTRACT: *SDG 3 of the United Nations' 2030 Agenda for Sustainable Development relates to Good Health & Well-being of people. There are specific sustainable development frameworks developed for the health and well-being of building occupants. Further, sustainability frameworks like the Living Building Challenge (LBC) among others, have also included health and wellbeing within their frameworks. This paper examines the Living Building Challenge with relation to two frameworks specifically designed to achieve health\and well-being--WELL Building Standard of the International WELL Building Institute (https://www.wellcertified.com/),and FitwelBuilding Standard developed by the Center for Disease Control of the United States of America (https://www.Fitwel.org/).It is seen that LBC focuses on building design, ecology, and environment, while Fitwell has structured its standard on activity and infrastructure and addresses behavioral design strategies. WELL v2, on the other hand, focuses on the health of the individual user and is structured around concepts of individual elements and health-affective categories. It is found that the Living Building Challenge does not address several criteria laid down in WELL v2 and Fitwell. LBC has limited itself to only some aspects of health and wellbeing, viz. ventilation, air quality, reduction of emission of pollutants and toxins from materials and cleaning chemicals, daylight, and natural views. Other criteria are met indirectly through the framework's sustainability Imperatives. The concepts of Movement, Sound, Mind, Nutrition and Innovation of WELL v2 are almost completely absent in LBC. Similarly, Fitwell's criteria of physical activity and movement, food and emergency preparedness do not find a place in LB. However, LBC makes a unique contribution toward the effort of achieving health and well- being in its Beauty + Biophilia Imperative through which it aims to imbibe the sense of beauty in a building design and its process using biophilic design and other interventions. In the end it is seen that for higher achievement of health and well-being in a building, LBC seems deficient compared to WELL v2 and Fitwell.*

Keywords: Health & Well-being, Living Building Challenge, WELLv2, Fitwell

INTRODUCTION

The global movement of sustainability is now consolidated with numerous sustainability frameworks established in most countries. Author Giselle Sebag in her article Measurement Tools Identify Practices to Support Employee Health and Corporate Sustainability Goals identifies a "triple bottom line" of people, profits and planet that the corporate world imbibes (Sebag, 2018). While sustainability addresses the planet as part of the "triple bottom line", Sebag says that people are still part of the equation. Most people spend most of each working day at their workspace. Studying workspaces, therefore, seems to be imperative to enhancing health prospects of building occupants. Additionally, SDG 3 of the United Nations' 2030 Agenda for Sustainable Development (https://sdgs.un.org/goals, n.d.) relates to Good Health & Well-being of people. It is in this context that several health and well-being frameworks emerged in the last few years.TwoamongthemaretheWELLv2BuildingStandard(https://www.wellcertified.com/,n.d.) and the Fitwell Building Standard (https://www.Fitwel.org/, n.d.). Further, existing sustainability frameworks like the Living Building Challenge among others, have also included health and wellbeing within their frameworks. Whether or not a sustainability framework addresses health and well-being adequately as compared to the two frameworks of WELL v2Building Standard and Fitwell Building Standard that are dedicated to health and well-being is an issue that needs study. Accordingly, this paper studies the Living Building Challenge with respect to the criteria laid down in WELL v2 and Fitwell.

SCOPE AND LIMITATIONS

This study limits itself to the following scope:
1. Due to time limitations, I will focus only on workspaces under the frameworks.
2. This study does not consider documentation required for submitting a project for certification.
3. The process, method, point system, cost, schedules, and time required for processing and certification are also not considered.
4. This study limits itself only to comparing the qualifying criteria of the frameworks.

RESEARCH METHODOLOGY

In this paper, I study the Living Building Challenge with respect to the criteria laid down in the WELL v2 building standard and Fitwel building standard. LBC is a green building standard. However, most green building standards also include specific criteria related to health and well-being. I use these criteria of health and well-being for the comparison. However, there are other criteria within LBC that address sustainability but may also apply to health and well-being. I use these criteria also. I identify equivalence in the 10 concepts of WELL v2 and the 12 sections of Fitwel in the study. Due to space constraints, I only provide an overview of whether or not the intent is similar. At the end, the results of the study are discussed, and conclusions are drawn. WELL, v2 Building Standard (https://www.wellcertified.com/, n.d.)Conceptualized and initiated by the International WELL Building Institute, the WELL Building Standard for health and well-being claims to have been developed over 10 years backed by the latest scientific research. The Standard claims to integrate "scientific and medical research and literature on environmental health, behavioural factors, health outcomes and demographic risk factors with leading practices in design, operations and management." (WELL Building Standard, n.d.). It also "references existing standards and best practice guidelines set by governmental and professional organizations" (WELL Building Standard, n.d.). The WELL Building Standard prioritizes the health of occupants of buildings and lays out a way for creating and certifying spaces that help keep occupants healthy in body and mind when indoors and within a community or neighborhood.

PRINCIPLES OF THE WELL BUILDING STANDARD

WELL v2 claims to be founded on the following principles:
1. Equitable
2. Global
3. Evidence-based
4. Technically robust
5. Customer-focused
6. Resilient

PROJECT TYPES AND CONCEPTS

There are two types of projects to which WELL Certification can be applied:
1. Owner-occupied projects where the project is occupied by the owner
2. WELL Core projects where the owner occupies a small portion of the project, and the rest is leased out to one or more tenants.

Each of these two types of projects must fulfil laid down criteria across 10 concepts to be eligible for a certification. Each concept consists of features that offer specific health-related benefits or enhancements. Within the 10 concepts are 24 preconditions which are necessary to be achieved, and 98 possible optimizations.

The 10 concepts are:
1. Air
2. Water
3. Nourishment
4. Light
5. Movement
6. Thermal Comfort
7. Sound
8. Materials
9. Mind
10. Community
11. Innovation

FITWELL CERTIFICATION SYSTEM (https://www.Fitwel.org/, n.d.)

Fitwell claims to be the world's leading certification system for health and well-being of occupants and users of buildings and sites. Created by the US Centers for Disease Control (CDC) and US General Services Administration, the system is said to be generated by expert analysis of more than 5600 academic research studies. The Center for Active Design is tasked with promoting the system all over the world, while CDC continues to be the research and evaluation partner. The certification encourages design strategies and policies in buildings and sites for lowering stress levels, reducing injury and mitigating risk of disease with the aim of increasing productivity.

FITWEL'S SEVEN HEALTH IMPACT CATEGORIES

Fitwell claims to have an impact on seven health areas as below:
1. Impact on Surrounding Community Health
2. Reduce Morbidity and Absenteeism
3. Supports Social Equity for Vulnerable Populations
4. Instils Feelings of Well-Being
5. Enhances Access to Healthy Foods
6. Promotes Occupant Safety
7. Increases Physical Activity

FITWEL STRATEGIES

Fitwell has a total of 55 strategies under 12 areas of intervention that address specific health behavior's and risks.
The 12 areas of intervention are listed below:
1. Location
2. Building Access
3. Outdoor Spaces
4. Entrances and Ground Floor
5. Stairs
6. Indoor Environments
7. Workspaces and Dwellings
8. Shared Spaces
9. Water Supply
10. Prepared Food Areas
11. Vending Machines and Snack Bars
12. Emergency Preparedness

FITWEL ENHANCEMENTS

Almost each of Fitwell's strategies has an enhancement policy or standard document in addition to what is listed here. The following are the enhancement policy or standard documents in addition to the standard document:
1. Fitwell Indoor Air Quality Policy Standard
2. Fitwell Enhanced Indoor Air Quality Policy
3. Fitwell Enhanced Indoor Air Quality Testing Policy
4. Fitwell Food & Beverage Standard
5. Fitwell Meeting and Events Catering Standard
6. Fitwell Integrated Pest Management Standard
7. Fitwell Water Management Program Standard
8. Fitwell Enhanced Stakeholder Collaboration Protocol
9. Fitwell Health Programming and Services Protocol
10. Fitwell Health Promotion Signage Protocol
11. Fitwell Contagious Disease Preparedness Protocol
12. Fitwell Enhanced Cleaning, Disinfecting, and Maintenance Policy
13. Fitwell Enhanced Green Purchasing Policy

FITWEL CERTIFICATION

There are two types of Fitwell Certification:
1. New Construction Certification
2. Existing Building Certification

New Construction has two types of certifications:

a) Design Certification: Design certification is for buildings in the process of design that are yet to be built or are in the process of being built but not yet occupied.

b) Built Certification: Built certification is for buildings that are already built and occupied.

LIVING BUILDING CHALLENGE (INTERNATIONAL LIVING FUTURE INSTITUTE, 2019)

The Living Building Challenge (LBC) building standard is a green building framework developed by the International Living Future Institute. It claims to define the most advanced measure of sustainability in the built environment. It seeks to "rapidly diminish the gap between current limits and end-game positive solutions..." (International Living Future Institute, 2019). In other words, it seeks to raise the bar of achieving sustainability in building design and execution.The LBC continually obtains feedback from project teams who have adopted the Challenge to improve the standard. Hence, it claims to be a standard based on the current critical high- level goals and experiences within the industry. In that sense, it claims to surpass the best practices to set aspirational standards. The standard is scalable and claims to use Duany Plater-Zyberk's New Urbanism Transect model for rural to urban categorizations.

PETALS

The LBC has seven performance categories which they call "Petals". The Petals are as below:
1. Place
2. Water
3. Energy
4. Health + Happiness
5. Materials
6. Equity
7. Beauty

Each of these Petals has Imperatives under its domain. There are a total of 20 Imperatives of which 10 are Core Imperatives and are necessary adherences to obtain the Core certification. The Living Building Challenge certification requires meeting all the 20 Imperatives.

APPLICABILITY

LBC has identified four difference typologies to which it can be applied:
1. New Building
2. Existing Building
3. Interior
4. Landscape or Infrastructure

COMPARISON OF THE COMBINED WELL v2-FITWEL FRAMEWORK WITH THE LIVING BUILDING CHALLENGE

As mentioned, I use a combination of WELL v2 and Fitwell from a previously paper written by me to compare with LBC. The focus of this research is for newly built workspaces. While LBC does not categorize criteria for building typologies, for WELL v2 I used the 'Owner Occupied' (WELL v2 Concepts and Features, 2022) project type which covers all building types where a project owner (as opposed to the building owner who may be different) occupies the entire building. For Fitwel I used the 'Multi-Tenant Whole Building' (Fitwell v2.1 Scorecard Worksheet - Multi-Tenant Whole Building, 2021) under New Constructions category.

The LBC is structured around seven Petals, each of which addresses one aspect of sustainability in building design. WELLv2 and Fitwell, on the other hand, are structured around human health and well-being and not sustainability in building design. Fitwell has structured its standard based on activity and infrastructure. Sebag, in her article says that Fitwell, being evolved by the Centers for Disease Control of the United State of America, is more invested in collective public health and addresses behavioral design strategies in an effort to improve public health. Hence, its standard is divided into sections accordingly. WELLv2, on the other hand, focuses on the health of the individual user (Sebag, 2018) and is structured around concepts of individual elements and health-affective categories. It focusses on the user as an individual. LBC, due to its focus on sustainability, appears to focus on building design, ecology and the environment rather than on modifying behavior, movement or addressing public health. WELLv2 and Fitwell specify and detail each part of a concept or requirement under each strategy while LBC club's multiple criteria together under its Petals. LBC has 20 Imperatives including 10 Core Imperatives under seven Petals that encompass a whole range of requirements for sustainability design including for health and well-being. WELLv2, on the other hand has 213 such parts within 10 Concepts and one concept for innovation, addressing carbon and other miscellaneous requirements. Fitwell has 73 Strategies under its 11 sections for achieving health and happiness. These numbers indicate the detail to which each criterion has been specified. The numbers vary based on the objectives, approach and structure adopted by each of the frameworks as has been mentioned above. In LBC, only the Petal titled "Health + Happiness" addresses human health in a building. Under this Petal, LBC claims to want to foster environments for optimization of physical and psychological health and well-being. There are three Imperatives under this Petal. Each has the mentioned criteria as conditions for achievement. Below, I discuss each of these Imperatives and their criteria with reference to WELL v2 and Fitwell.

1. Imperative 9: Healthy Interior Environment: This Imperative aims to promote good indoor air quality and a healthy indoor environment. It calls for the following compliances:
2. Compliance with ASHREA 62 that provides quantitative standards for ventilation and indoor air quality in different building typologies. WELLv2 addresses this criterion under Ensuring Adequate Ventilation, Mitigation of Construction Pollution, Increasing Outdoor Air Supply, Improving Ventilation Effectiveness, Managing Combustion, Managing Pollution and Exhaust and Improving Air Supply. Fitwell addresses this criterion through its strategies of Indoor Air Quality Policy, Chemical Storage Ventilation.
3. Prohibits smoking indoors and outdoors within 25' of any opening or vent. WELL, v2 addresses this criterion by prohibiting indoor and outdoor smoking as well as under Providing Tobacco Cessation Resources, Limiting Tobacco Availability, Offering Substance Use Education and Providing Substance Use and Addiction Services.
4. Fitwell addresses this criterion under Tobacco- and Smoke-Free Spaces, Tobacco- and Smoke-Free Signage, and Tobacco and Smoke-free Environment.
5. Calls for the development of a Health Indoor Environment Plan that addresses cleaning protocols, prevention of particulate matter and toxins through entry points, and implementation of one method of improving air quality. WELL v2 addresses this criterion under Meeting Thresholds for Particulate Matter, Meeting Thresholds for Organic Gases, Meeting Thresholds for Inorganic Gases, Meeting Enhanced Thresholds for Particulate Matter, Meeting Enhanced Thresholds for Organic Gases, Meeting Enhanced Thresholds for Inorganic Gases, Meeting Thresholds for Radon, Designing Healthy Entryways, Implementing Particle Filtration, Implementing Ultraviolet Treatment for HVAC Surfaces, Reducing Respiratory Particle Exposure, Improving Cleaning Practices, addressing Surface Hand Touch. Fitwell addresses this criterion under Entryway Systems, Bathroom Cleaning Protocol, Break Areas Cleaning Protocol, developing an Indoor Air Quality Policy. Provision of outside views and day light to a minimum of 75% of occupied spaces.
6. WELLv2 addresses this criterion under Implementing Daylight Plan, Integrating Solar Shading, and Conducting Daylight Simulation. Fitwell addresses this criterion under Providing Natural Daylight, Views of Nature, and Operable Shading. Provision of direct exhaust to kitchens, bathrooms and janitorial spaces. WELL, v2 addresses this criterion under Improving Ventilation Effectiveness. Fitwell addresses this criterion under Chemical Storage Ventilation.
7. Imperative 10: Healthy Interior Performance: This Imperative aims to demonstrate the present situation about high-quality indoor air and a healthy indoor environment. Compliances required are:
8. Providing results of indoor air quality test from one to six months after occupancy or providing readings from an indoor air quality monitoring system approved by International Living Future Institute.
9. WELLv2 addresses this criterion under Promoting Air Quality Awareness. Fitwell addresses this criterion by sharing Indoor Air Quality Testing Results.
10. 90% of interior building products to comply with CDPH Standard Method v1.1-2010 or equivalent for emission of VOCs. WELLv2 addresses this criterion under Select Compliant Interior Finishes, Select Compliant Architectural and Interior Products, Limit VOCs from Wet- Applied Products, Restrict VOC Emissions from Furniture, Architectural and Interior Products, Select Products with Disclosed Ingredients, Select Products with Enhanced Ingredient Disclosure, Select Products with Third-Party Verified Ingredients, Select Materials with Enhanced Chemical Restrictions. Fitwell addresses this criterion in its Indoor Air Quality Policy and Green Purchasing Policy.

11. Implementing a cleaning protocol that uses products in compliance with EPA safer Choice Label or equivalent.
WELL, v2 addresses this criterion under Improve Cleaning Practices, Select Preferred Cleaning Products, and Address Surface Hand Touch. Fitwell addresses this criterion under Bathroom Cleaning Protocol, Break Areas Cleaning Protocol, and Green Purchasing Policy.

12. 95 % of spaces to provide views and daylight.
WELL, v2 addresses this criterion under Implement Daylight Plan, Integrate Solar Shading, and Conduct Daylight Simulation.
Fitwell addresses this criterion under Natural Daylight, View of Nature, and Operable Shading.

13. Adequate operable windows for natural ventilation for at least six months.
WELL, v2 addresses this criterion under Increased Outdoor Air Supply, Improve Ventilation Effectiveness, and Provide Operable Windows.
Fitwell addresses this criterion in its Fitwell Enhanced Indoor Air Quality Policy.

14. 1Occupants to have the ability to regulate their local air flow and temperature.
WELL, v2 addresses this criterion under Operable Windows, Manage Window Use, Thermostat Control, Personal Cooling Options, Personal Heating Options, Allow Flexible Dress Code, and Support Outdoor Nature Access.
Fitwell meets this criterion in its Thermal Control Criterion.
Providing varied sensory experiences and flexible options for working such as sit/stand options.
WELL, v2 meets this criterion under Height-Adjustable Work Surfaces, Chair Adjustability, Support at Standing Workstations, Workstation Orientation, and Active Workstations.
Fitwell meets this criterion under Active Workstations.

15. Providing varied sensory experiences and flexible options for working such as sit/stand options.
WELL, v2 meets this criterion under Height-Adjustable Work Surfaces, Chair Adjustability, Support at Standing Workstations, Workstation Orientation, and Active Workstations.
Fitwell meets this criterion under Active Workstations.

16. Imperative 11: Access to Nature: This Imperative aims to provide occupants with direct connection to nature, and to assess Health + Happiness Imperatives.
Adequate and frequent interaction with nature is to be provided in the interior and exterior of the project.
WELL, v2 meets this criterion under Outdoor Nature Access, Connection to Nature, Nature Access Indoors, and Nature Access Outdoors.
Fitwell meets this criterion under Outdoor Space Amenities, Walking Trail, Outdoor Fitness Area, and Restorative Garden.

17. Post-occupancy evaluation of health benefits in the project including benefits of fresh air, daylight and access to nature to be done within 6 to 12 months of occupation.
WELL, v2 meets this criterion under Facilitating Stakeholder
Charette, Select Project Survey, Administering Survey and Reporting Results, Utilizing Enhanced Survey, Utilizing Pre- and Post-Occupancy Survey.
Fitwell meets this criterion in its Occupant Satisfaction Survey.

18. Some of the criteria of the other six Petals, while addressing sustainability, also relate to health and well-being. I discuss these petals and the criteria that relate to health and well- being below:
Petal: Place
Imperative 2: Urban Agriculture
All projects to dedicate a part of the area to growing food and to provide access to healthy local food through farmers' markets, CSA programs or other local food producers.
WELL, v2 addresses this criterion under Responsible Sourcing, Providing Gardening Space, and Local Food Access.
Fitwell addresses this criterion under Farmers Market, Fruit and Vegetable Garden, Crop Share Drop-Off and in its Healthy Food and Beverage Policy.

Core Imperative 4: Human-Scaled Living
Projects to maintain or increase density to support human-powered lifestyle.
WELL v2 meets this criterion under Design Active Buildings and Communities, Select Sites with Pedestrian-Friendly Streets, Offer Physical Activity Opportunities, Offer Physical Activity Incentives, Select Sites with Access to Mass Transit.
Fitwell addresses this issue in its criteria of Walkability (with 3 variations of distance), Proximity to Transit, Pedestrian Route to Transit, Incentivizing Transit, and Walking Trail.
Projects to be built per human scale as per the neighborhood.
WELL v2 meets this criterion in its part titled Design Active Buildings and Communities, Select Sites with Pedestrian-Friendly Streets, Offer Physical Activity Opportunities, Offer Physical Activity Incentives.
Fitwell addresses this issue in its criteria of Walkability (with 3 variations of distance), Proximity to Transit, Pedestrian Route to Transit, Incentivizing Transit, and Walking Trail.
Projects to provide spaces to gather and connect to the surrounding community.
WELL v2 offers this criterion under its parts titled Promote Community Engagement, Provide Community Space. Fitwell does not meet this criterion.
Projects to provide sufficient weather-protected storage for human-powered vehicles and related facilities like showers, lockers to encourage bikers. WELL v2 meets this criterion under Providing Cycling Infrastructure, Providing Showers, Lockers and Changing Facilities. Fitwell meets this criterion under Bicycle Parking and Active Commuter Showers.
Additionally, Fitwell also undertakes to conduct a Commuter Survey.
Petal: Water

Imperative 6: Net Positive Water
Projects to address grey and black water through on-site treatment and management through reuse, a closed-loop system, or infiltration. WELL v2 addresses this criterion under Implement Safety Plan for Non- Potable Water Capture and Reuse. Fitwel does not have any criterion to address this issue.
Core Imperative 7: Energy + Carbon Reduction
Projects to reduce total net energy consumption and combustion to be limited.
WELL v2 addresses this criterion in its criteria of Carbon Reduction Goal, Carbon Reduction, Carbon Neutral, and Managing Combustion.
Fitwell does not have any criterion to address this issue.
Imperative 8: Net Positive Carbon
Projects to supply one hundred and five percent of their energy needs through on-site renewable energy without the use of combustion.
WELL v2 does not have this criterion.
Fitwell does not have any criterion to address this issue.

Core Imperative 7: Energy + Carbon Reduction
Projects to reduce total net energy consumption and combustion to be limited.
WELL v2 addresses this criterion in its criteria of Carbon Reduction Goal, Carbon Reduction, Carbon Neutral, and Managing Combustion.
Fitwell does not have any criterion to address this issue.
Imperative 8: Net Positive Carbon
Projects to supply one hundred and five percent of their energy needs through on-site renewable energy without the use of combustion.
WELL v2 does not have this criterion. Fitwell does not have any criterion to address this issue.

3. Petal: Materials

A. Imperative 12: Responsible Materials

a. Projects to contain one Declare label product per 200 sq. m. (A Declare label of the International Living Future Institute shows the contents of a product in an easy-to-read color coded format.)

While WELL v2 does not specifically meet this criterion, it contains equivalent requirements in its parts titled Select Products with Disclosed Ingredients, Select Products with Enhanced Ingredients Disclosure, Select Products with Third-Party Verified Ingredients, and Select Materials with enhanced Chemical Restrictions.
Fitwell does not meet this criterion directly. However, it has a Green Purchasing Policy for purchasing cleaning and hygiene products as well as for purchasing paper products.

b. Projects to incorporate one product certified under Living Product Challenge. (Living Product Challenge is claimed to be the world's most advanced product sustainability standard.)

WELL v2 contains equivalent requirements in its parts titled Select Compliant Interior Finishes, Select Compliant Architecture and Interior Products, Select Products with Disclosed Ingredients, Select Products with Enhanced Ingredients Disclosure, Select Products with Third-Party Verified Ingredients, Select Materials with Enhanced Chemical Restrictions, Select Optimized Products
Fitwell does not meet this criterion directly. However, it has a Green Purchasing Policy for purchasing cleaning and hygiene products as well as for purchasing paper products.

B. Imperative 13: Red List

a. Projects to avoid the Red List chemical classes in 90% of the projects' new materials by cost.

WELL v2 addresses this issue under Restrict Asbestos,
Restrict Mercury, Restrict Lead, Select Compliant Interior Furnishings, Select Compliant Architectural and Interior Products, Limit VOCs from Wet-Applied Products, Restrict VOC Emissions from Furniture, Architectural and Interior Products, Select Materials with Enhanced Chemical Restrictions.
Fitwell does not address this issue.

C. Imperative 16: Net Positive Waste

a. Projects to reduce or eliminate production of waste during design, construction and operation, and end of life to integrate waste back into an industrial loop or a natural nutrient loop.

WELL v2 addresses this issue under Implementing a Waste Management Plan. Fitwell does not address this issue.

4. Petal: Equity

A. Core Imperative 17: Universal Access

a. Projects to make all primary transportation, roads and non-building infrastructure accessible to all members of the public.
WELL v2 addresses this issue under Promoting Diversity and Inclusion Fitwell does not address this issue.

b. Projects to provide for access to those with physical disabilities.

WELL v2 addresses this issue under Integrating Universal Design. Fitwell does not address this issue.

B. Core Imperative 18: Inclusion

a. projects to have Just label for at least two project team organizations. (Just label ensures diversity, inclusion, employee health, employee benefits, stewardship and purchasing and supply chain).
While WELL v2 does not require a Just label, it addresses this issue under Promoting Diversity and Inclusion, Facilitating Stakeholder Charette.
Fitwell addresses this issue in its Stakeholder Collaboration Process.

5. Petal: Beauty

A. Core Imperative 20: Education + Inspiration

a. Projects to provide a Living Building Challenge case study, an annual open day for the public, a copy of the Operations and Maintenance Manual, a simple brochure describing the design and environmental features of the project, Install interpretive signage that teaches visitors and occupants about the project, develop and share an educational website about the project, Include one Living Future Accredited Professional on the project team.
WELL v2 addresses this issue under Achieving a WELL AP, Offering WELL Educational Tours.
Fitwell does not address this issue.

ANALYSIS & INFERENCE

As is seen above, the scope of LBC is sustainability and accordingly, most of its imperatives are focused on building design, ecology and the environment. Since WELL v2 and Fitwell are focused on human health, their stipulations are much more detailed in the areas of health and well-being of occupants and the community. Due to its broad scope of sustainability, LBC has limited itself to only some aspects of health and wellbeing, viz. ventilation, air quality, reduction of emission of pollutants and toxins from materials and cleaning chemicals, daylight, and natural views. Other criteria for enabling health and well-being of occupants is met indirectly through the framework's sustainability Imperatives. Seen in comparison with WELL v2 and Fitwell, we see that there are several areas that LBC does not address within and outside of the "Health + Happiness" Imperative.
These are discussed below:

1. Under the WELL v2 framework is the concept of Nutrition which has an equivalent in the sections of Prepared Food Areas and Vending Machines and Snack Bars. LBC does not address this critical area of food and nutrition in its framework. This can be seen as a major omission since food a nutrition are among the most significant contributors to health and well-being.
2. Fitwel and WELL v2 facilitate and design extensively for physical movement and activity. Fitwell has numerous sections dedicated to movement and related infrastructure in its sections of Location, Building Access, Outdoor Spaces, Stairs and more. WELL v2 also addresses movement as a critical concept in its framework and contains 22 parts that facilitate physical activity and movement. However, LBC seeks to reduce the use of fossil fuel vehicles and asks for the creation of a pedestrian environment. While this helps in health and well-being, its aim is not so. It would help if LBC paid specific attention to physical activity and movement in its Health + Happiness Imperative.
3. Another issue that LBC is silent on is noise. WELL v2 has a dedicated concept on Sound under which it seeks to minimize or control sound within a workspace. Fitwell does not specifically address the issue of Sound but provides a quiet room for occupants within a workspace. However, LBC does not address the area of Sound at all.
4. While LBC addresses the criterion of community in its Imperative 17 (Universal Access) and Imperative 18 (Inclusion), it does so in a limited way. It does not reach out to the community the way WELL v2 does in its criteria of Promoting Community
5. Engagement as well as in its numerous other criteria that treat employees as community stakeholders. Fitwell does not address community.
6. Another area that LBC does not address is that of Emergency Preparedness. Fitwel and WELL v2 have several criteria each for emergency preparedness in times of calamities as well as when employees are unwell.
7. WELL v2 has 10 credits for innovations in enhancing health and well-being of occupants. This enables creative interventions from project teams for customized facilitation of criteria to enhance health and well-being of occupants. Both, LBC and Fitwel do not have this criterion.
8. WELL v2 has the critical concept of Mind that addresses mental health. It has 21 parts within it that are aimed at facilitating good mental health of occupants. These parts range from screening to support to education and awareness and more and include addiction services. Both LBC and Fitwel do not have this important consideration.
9. Besides the above, WELL v2 and Fitwel require conducting surveys for measuring occupant responses in a range of areas tat affect health and well-being. LBC does not have such a provision.
10. Additionally, WELL v2 is far more detailed in its requirements than LBC and Fitwel. While Fitwel is also fairly detailed (though lesser than WELL v2), LBC is not as detailed in the area of health and well-being as even Fitwel.
11. Further, WELL v2 uses metrics extensively to set limits and thresholds for its various criteria. LBC and Fitwel do not specific as many metrics to measure their performance. Due to these metrics, WELL v2 is more precise than Fitwel, (Todd, To be WELL or FITWEL, 2022) and, as we can see, than LBC too.
12. However, LBC contains the important Imperative of Beauty + Biophilia which addresses the idea of beauty through nature within a building design and its processes. This is a unique contribution of LBC to health and well-being of occupants and deserves to be included in WELL v2 and Fitwel besides other frameworks.

CONCLUSION

This comparison is done with the primary aims of the various criteria of the three frameworks. Each has a specific objective to meet and while some requirements may overlap or maybe common, there are some specific measured requirements in terms of metrics that may be different. However, as we can see, there are significant differences between the two health and well- being criteria and LBC. In fact, there are differences even between the two health and well- being criteria of WELL v2 and Fitwell.
Based on this study, it can be seen that LBC can elaborate its “Health + Happiness” Imperative, at least in the ways mentioned above to make it more holistic. On the other hand, WELL v2 and Fitwell can include LBC’s unique contribution of Beauty + Biophilia to make their frameworks more complete. As of now, to ensure health and wellbeing of building occupants, the two dedicated frameworks of WELL v2 and Fitwell are more suitable. Additionally, this study also helps contribute toward the United Nations’ 2030 Agenda for Sustainable Development by addressing SDG 3 which relates to Good Health & Well-being by working toward the evolution of a framework for achieving good health and well-being for humanity.

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SUSTAINABILITY FROM CORE TO SHELL-TRADITIONAL SUSTAINABLE ENVELOPE FOR FUTURE

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ABSTRACT: *An envelope to a building is a shield that not only safeguards the building from external impacts, forces, weathering conditions but creates an environment within the building to facilitate better indoor environment conditions. The design principals, ideologies, constructional techniques and building materials need to be integrated in order to create synergy with its occupants and their comfort. However, the problem remains as to what constitutes towards sustainable envelope design that would enhance building thermal conditions and adaptability to the local climate. Therefore, the aim of this research paper is to identify and compare traditional building envelope with local climate of specific region which are significantly sustainable from core to shell. This will be validated by envelope study of various cases that are local and traditional in their architectural inputs. It is expected that , the selected examples would promote the traditional building envelope significance and bring about building sustainability.*

KEYWORDS: Sustainability, Core, shell, traditional, microclimate

INTRODUCTION / BACKGROUND:

Traditional architecture is a subject that provides a window on the lives and traditions of the indigenous people of our world, and in so doing creates a mirror that reflects our own experiences. This in turn ,helps us to understand more clearly where the buildings of in turn, helps us to understand more clearly where the buildings of our contemporary world spring from, and, more importantly, why such buildings so often fail to meet our fundamental human needs. It takes little imagination to appreciate the disastrous long-term effects that, for example, high-density ,high-rise housing has had on the communities and social cohesion of our world's cities. Rationally applied building technology and forms matched the required "function" of the building. Solutions were fixed, immovable, and sold as a modern utopian ideal to the world's aspiring urban classes. However ,if we look at both current and historical vernacular building traditions, there exist opportunities to learn solutions to our housing needs that draw less on the limited resources available to us. The traditional domestic architecture of the dwellings of indigenous communities in the secluded pockets and the rural folks on the countryside forms a class by itself for the nostalgic charm and quintessential qualities. It never disturbs or transgresses the natural ambiance of the locality. It not only harmonizes with it but also complements it by imparting 'humane' touch. These impact more gently on our fragile ecosystems ,offering solutions that engender a profound connection between the builders, environment, the materials used, and the wider community. Vernacular traditions are dynamic and generated through a continuous and dialectic interplay of stasis and change, precedent and creativity, stability and innovation. Accepting this dynamic and adaptive nature of vernacular traditions allows us to expand the scope of the field of vernacular studies by incorporating the emergence of new traditions (Bronner,Payne)and the way in which existing ,traditional ones merge with modern building practices (Vellinga,H.Davis).Furthermore, by accepting the way in which vernacular traditions dynamically respond to the challenges of the present and future ,it is possible to envision more clearly the ways in which the vernacular may contribute to the provision of sustainable future built environments (Lawrence,Meir and Roaf,Marchand). This research would also put light on the unprecedented cultural and environmental challenges of traditional building practices, and how it will be possible to rid the traditional of its thatched 'cottage and mud huts 'image by proving the fact that the many traditional building techniques, vernacular technologies, resources or forms are appropriate and sustainable.

AIM / PURPOSE

To investigate and study different traditional building envelopes that have adopted new environments ,technologies and economic opportunities through which new methodologies for the understanding and optimization of the performance of traditional buildings from core to shell are analysed and discussed.

OBJECTIVES :

1. To understand what is sustainability w.r.t contemporary architectural discourse and traditional building practices.
2. To study the adaptive nature of traditional technologies for future emergencies.
3. To elaborate on the generative concepts in vernacular architecture.
4. To study and identify key performance issues within the building envelope designed with traditional technologies

RESEARCH METHODOLOGY

ARCHITECTURE OF MODERNISM VS MODERN REGIONALISM.

The beginning of the twentieth century, the prevalent paradigm in architecture has been Modernism. Over time, Modernism, with its strong roots, has become diversified and has developed a plurality of its own . Pioneers of minimalist architecture such as Ludwig Mies van der Rohe ,Walter Gropius principles of Modernism initially set out an expression of progress claimed to be valid for any geographical or cultural context. Gradually it became not only a conviction but a lifestyle, and even a political attitude towards the built environment. Minimalist internationalism in time became the most challenged and criticized aspect of architecture Modernism. On other hand the followers of Le Corbusier and his simple and sublime expressions, explained by his affinity for the Mediterranean Explore a valid Modernism for different cultural and specific climate settings. Architects such as Frank Gehry, Zaha Hadid, Peter Eisenman, Wolf Prix,REnzo Piano, Daniel Liebeskind and Santiago Calatrava can be called ‘ new moderns ‘who believe that when the function of the building is underplayed, a huge area opens up for free expression by engaging many means and techniques of contemporary design.

Fig 1 : Showing Core and shell of Bauhaus Museum Dessau,ostkreuz ,Source: Thomas Meyer,2019

While few obeyed Modernism blindly with creative cynicism, the traditionalist ,who in essence hold similar aspirations, have a mission that is more geared to the rural environments and the use of appropriate technologies. Luis Barragan , Geoffrey Bawa, Tadao Ando, Charles Correa, Balkrishna Doshi, Rafael Moneo, Ricardo LeGarrette, Alvar Sisa and Sedad Eldem can be mentioned among the hundreds who are committed to culture - and Climate specific envelope design which has been referred to as ‘modern regionalism’.

Fig 2: Showing Core and shell of Amdavad ni Gufa ,1994 designed by Ar. Balkrishna Doshi

TRADITIONALISM IN ARCHITECTURE BY HASSAN FATHY
'For many years Fathy's projects have been described as Postmodern vernacular, and only recently has he been rediscovered as a master who proposed a different idea of modernity'
Source : The Architectural Review

Known as 'the architect of the poor', Fathy's name rarely appears in histories of architecture of the 20th century. For a long time, his work was associated with the vernacular and confined to the boundaries of critical regionalism, making the Egyptian master a full member of that 'multifaceted family of architects'. Fathy discovered Nubian vernacular architecture and the significance of the vault in Egyptian history during a trip to Aswan, visiting archaeological sites with students in 1941. The reference to Nubia was already clear in his project for the Hamed Said house, built a year later in the Cairene suburb of al-Marg, evolving into a paradigm in his architectural language. This house was also one of Fathy's first attempts to use mud bricks. The idea of building with clay was fostered by the outbreak of the war which had blocked the import of iron and timber. There was a real need to use local materials, which Fathy answered by observing peasants' houses and by developing an in-depth understanding of the use of mud bricks in the construction of catenary vaults and domes.

Fig 3: New Gourna Village by Hassan Fathy,1952.Source : Mark Ryckaert

One of Fathy's most famous projects was New Gourna Village near Luxor, Egypt. Designed and built between 1946 and 1952, the village was conceived as a settlement for people who had been displaced from Old Gourna Village, which stands in the middle of archaeological sites of the Luxor Necropolis. The goal of the experimental village was to use local materials and techniques to relocate the community living near the ancient sites, both to limit damage and looting as well as facilitate tourism. Fathy used earthen building materials throughout the village. Architectural elements common in the old village, such as enclosed courtyards, vaulted ceilings, and perforated walls, were incorporated in the design.

Fig 3: New Gourna Mosque by Hassan Fathy,1952. Source : Ronald Unger

Fathy considered mud brick to be the most appropriate material, for what it symbolically expressed and its resonance with the context. According to Fathy, the use of mud leads to a result which is ‘bound to be natural … most basically of all, in terms of its texture and colour. It’s he same mud, the same colour, as the environment – that’s one aspect of good faith’.

Fig 5: Fathy’s New Baris public buildings, 1967, with museum in foreground and market vaults to rear. Source **:** Viola Bertini

BUILDINGS WITHOUT ARCHITECTS : TRADITIONAL ENVELOPE STUDY FROM THE CORE TO SHELL

Cob House Cob is an earth -base building material comprising subsoil,clay,sand and gravel, which is mixed with straw and water to stiff but malleable mass and used to build the walls of a house and numerous items within it, including shelves,benches,floors and ovens. Such houses and shelters can be found in many parts of Europe, United States, Africa ,Australia as well as New Zealand. The Word cob is an old Devon (place in southwest of England) word for mud wall constituted for a wet climate. Cob is load bearing so cob houses need no wood framework, wall thickness is 2 feet(60 cm) means they are warm in winter and cool in summer. The only disadvantage is that the building process involves various stages which is very labour intensive. Foundation layer involves laying of ‘lift "typically 2 feet(60 cm) high and 2-3 feet(60-90 cm) thick is shaped by hand and trodden down to compress it.Each lift needs several days to dry out before the next is added.it takes good six to nine months span for the thick walls to dry out completely, in order to shrink.

Fig 6: A cob and thatch cottage at Naseby, Northamptonshire(left) and foundation layering on (right).

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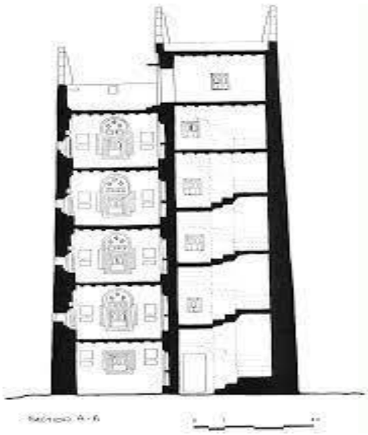
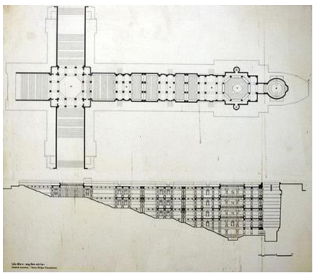


Yemen Tower House are form of building unique to southern Arabia. Where tribal strife was the motivation for developing an effective way of building defensive towers out of local materials as well as ideal solution for housing an extended family considering its vertical approach in adding new stories. Different stories mainly the ground floor are planned for housing animals to the storage of wood ,fruits, grains in rural area whereas in towns it is used for shops and stores. First floor for public reception illuminated by windows that have shutters for ventilation in the bottom hal and coloured glass in the top. Top stories are for private sittings, kitchen adjacent to terrace with high screen walls. The foundations of the tower houses are constructed using stone or earth .upper floors constructed of fired bricks with highly decorated facades.

Fig-7: Cross Section of Yemen tower**, Source**: Salma Samar Damluji



Indian stepped ponds and stepwells are subterranean water reservoirs ,housed in highly decorated linear stone temples ,in which numerous flights of stairs, with columned pavilions on each landing lead many levels downward to a water pool deep below. They provided access to ground water and collected the rainwater from the monsoons and held it through dry months of the year. The four walls of square stepped ponds were composed as it is of a zigzag of stairs, following it step by step to the bathing pool below.

Fig 8: Cross Section of Adalaj stepwell **Source: Dave** Morris

Bata maliba Roundhouse The basic form of the houses a ring of seven earthen twerk, linked together by semi-circular walls to form a seamless protective outer shell. Inside the ring there is another circular thatched tower in the centre ,which is surrounded by an earthen roof terrace supported by wooden framework., which extended to the outer ring.

Fig 9: Batammaliba House clearly displaying house horns, granaries, and soul mounds**.**
Source: University of Pittsburgh.

Considering all these above examples and shelters such as Inuit Igloo built of snow blocks by the inuit people of the far north to prevent the snow shell from melting ,covered with caribou skins to trap a layer of cold air and serve extra insulation. Also houses such as New mexican adobe homes which are energy efficient and use natural materials are the work of unsung and often anonymous builders that combine artistic beauty ,practical form and necessity which defines sustainability to the core.

MODERN VERNACULAR ARCHITECTURE

Bottle Houses are found in numerous countries of the world. Many in the United States are well known tourist attractions. One of the seminal steps in this regard came in 1963 with the Heineken ``World Bottle"(WOBO), an idea inspired by a journey where Alfred Heineken observed beaches littered with bottles in a society that had a shortage of affordable building materials. Hence with architect John Habraken he devised "the brick that holds beer". The WOBO came in 350 mm and 500mm versions as a wall thickness designed to lie horizontally and interlock in a fashion that echoed traditional brick-and- mortar construction.

Fig 10:The most impressive bottle structure built by Buddhist monks from one million bottles in Khun Han district of Sisaket province, Thailand. **Source**: atlasobscura

There are different uses for different types of bottles based on their material characteristics. Plastic is usually used for wall infill and plastered on the exterior, while glass bottles can provide some structure and bring in light. All recycled bottles used in buildings help to reduce the need for new materials and lower the costs.

Fig 11: Construction of wall with bottle in a stack bond **Source**: Suhaila Sahat

INFERENCE: Why bottles? Packaging and plastic bottles are ubiquitous today, making up a large portion of waste and greenhouse gasses around the world. Reuse is better than recycling, and bottles are easy to reuse in building projects. Providing a secondary function for bottles keeps them out of landfill while offering a readily available and economical building material.

Earthships One of the basic principles of Reynold's Earthship Biotecture thinking is that " A sustainable home must take use of indigenous materials, those occurring naturally in the local area .The earth ships gets most of its power from solar panels and a wind rotor. The roof is designed to capture rainwater and snow melt, which are then channeled through silt catches into cistern for drinking and domestic use. The main building blocks of an earth ship are recycled steel belt rubber car tires, which are rammed full of earth and used as " bricks" to form the walls of the house. These bricks and the resulting bearing walls form are virtually indestructible and fireproof.

The earth ship's Internal walls are created using aluminum cans and glass /plastic bottles set in a cement matrix .Both internal and external walls can be shaped to suit the builder's requirements. The basic principles of earth ship construction can be adapted and customized to suit a wide variety of climates and individual living styles and have been built around the world. Earthship structures have also been used in disaster relief.

INFERENCE: Why Earthships? The earth ship is a form of architecture that embraces elements of both the vernacular and technological and points the way towards a sustainable future .It is a vernacular response to an era of mass production and consumerism. It is a Biotecture aimed at creating buildings that are in tune with the natural world.

Fig 12: Discarded tires, bottles, and cans are used to build the walls of an Earthship near Taos,
Source : N.M.Earthship Biotecture

SQUATTER SETTLEMENTS IN DHARAVI AND MANILA

More than nineteen million people live in the rapidly expanding city of Mumbai, and the land on which Dharavi sit is a prime site for redevelopment. The inhabitants of Dharavi live mainly in ramshackle two-story buildings of brick, concrete ,and scrap lumber with metal roofs, all parts of which are slightly askew. Meanwhile, in the Philippines , a five year survey has been made of the architecture of informal settlements in Manila. The dwellings made of discarded materials were there by choice, despite the poor sanitation, lack of basic facilities .Thus the architectural solutions were often surprising in their use of materials and space.

INFERENCE: By far the most numerous vernacular buildings of the modern age are the ad hoc constructions of the millions of urban squatters living in city environments across the developing world.:

FINDINGS : Vernacular Revivals

NUBIAN VAULT BUILDING

The lateral cross section above showing an earthen building employs Nubian vault system. This technique of earth architecture, known as la Volute Nubians makes it possible to build houses with vaulted roofs without having to use wooden shuttering as a support. Roof is waterproofed using locally manufactured plastic sheeting covered within a rendering of enriched mud mortar.

Fig 13: Completed Earthship
Source: Democracy Now (top) and **Source:** Nathaneil Berman (bottom)

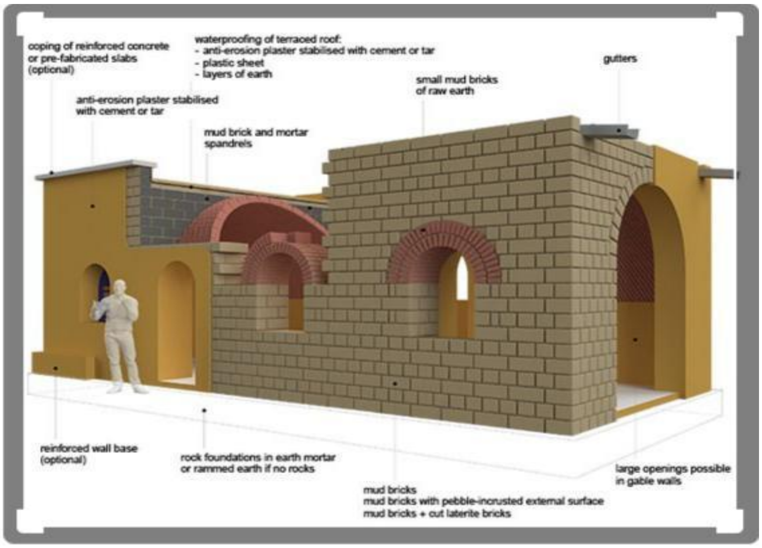


Fig 14: Illustration showing layers of Nubian vault in mud-brick construction

Fig 15: A house made from cob in the Pacific Northwest. (Photo: Gerry Thomasen/CC BY 2.0)

Pacific Northwest Style

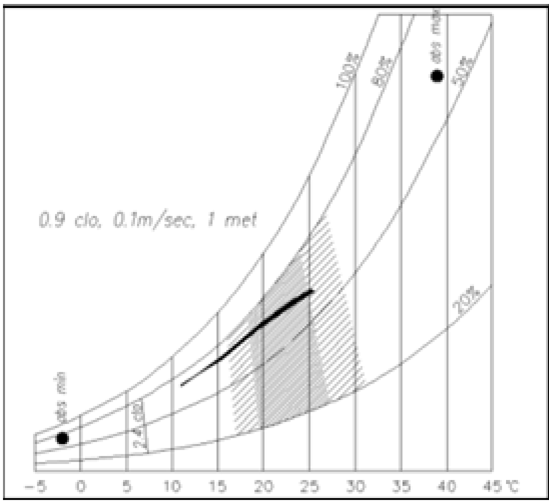
This is an example of Pacific Northwest -style cob house, a form of building that is ideally suited to what is called the 'wet Coast" provided the building has deep overhangs and gutters to protect the earthen walls as well as a high, imperious foundation. Cob absorbs moisture in the air without weakening and releases it again when it bakes in the sun. This form of house offers an attractive low-cost, low-impact, energy efficient alternative to conventional homes.

CONCLUSION: Towards new methodologies for optimization of the traditional building performance. If we are to be able to really understand the extent to which Traditional dwellings are suited to their natural environments , we need clear and systematic research methods to perform. At the threshold of a new century and faced with the potentially devastating impacts of climate change and the end of the fossil fuel age., 'What types of buildings will be more resilient in the face of such challenges. ?''is the frequent question being asked .Vernacular revivals along with generative concepts of open courtyard been one of the earliest protective shelters of man in dry, semi -arid conditions. like the generative concept of the cave .Similarly a generative concepts closed courtyard, the anthropomorphic analogy as a generative concept , the hearth as a generative concept could enhance performance of traditional building in the desired environment.

Discussing climatically responsive design from core to shell and its environmental performance by examining few cases:

CASE 1: SANTORINI ARCHITECTURE : THE FOUR ELEMENTS OF NATURE

Earth (Building Materials): Despite the widespread perception about the Greek islands, Santorini climate is rather cool during several months, when comfort conditions can be improved by the intense solar radiation -but also worsened by the forceful winds. A key feature of old masonry buildings in Santorini is their resistance to earthquakes: Aseismic rules shaped the overall geometry of the building, as well as of many details in plan and elevation, like thick side walls and thin vaults, buttresses and tendons, narrow openings and rigid corners. Santorini is one of the few places in Europe with troglodytes even today: the special properties of the ground, coupled with the necessity of materials saving, led locals to excavate vaulted caves into the soft but coherent top layers of the volcanic ash, that are widely used as dwellings, stables, wineries, etc. Their front was enclosed by masonry walls, frequently supporting the veranda of the next house up. The deep caves are typically divided in 2-3 rooms by partitions similar to the front elevations; the front room was for daytime use, with a bedroom and a storage room at the back. These are the best structures to withstand earthquakes, with the additional benefit of acting as free heating and cooling mechanisms due to the large thermal mass of earth.



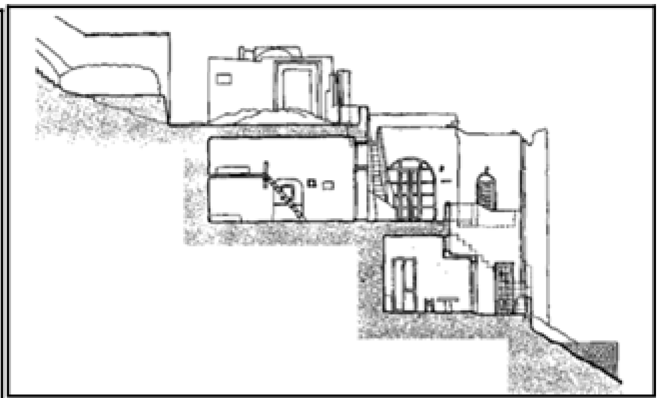


Diagram1(left) & Diagram2(right) : Excavated and built dwellings were stacked on the steep ground in a 3D layout.

Fire: Solar radiation is quite intense in Santorini, especially in summer when clouds disappear . more than two months. Discomfort is intensified by the blinding glare and the heat emitted from the warmed-up mass even after sunset. Pergolas and canopies required costly timber; they should also be rigid enough to withstand the forceful winds, thus becoming even more costly. Furthermore, water scarcity and the strong winds prohibit.

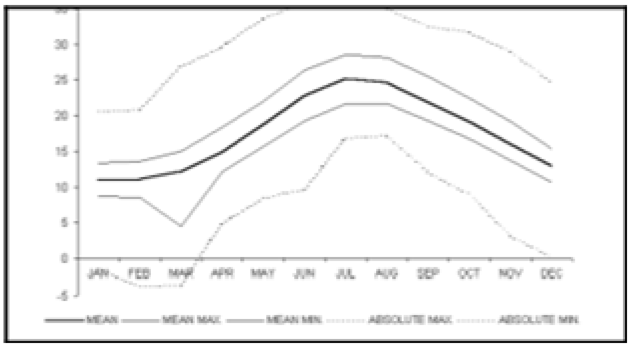
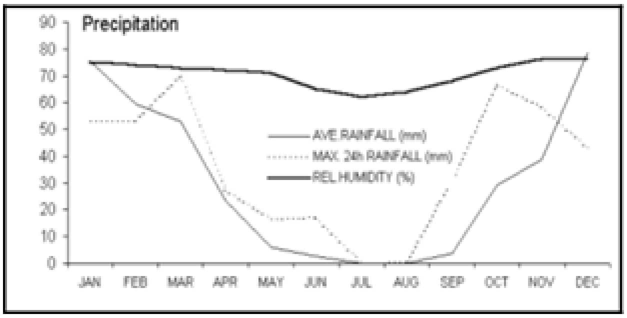


Diagram3(above) : Mean ambient temperature is above 20 degree for 4 months only.

The growth of climbers. For those reasons, solar protection in outdoor spaces was offered only by the shade of adjacent buildings or free-standing walls, the same ones that were used for wind protection too. It is interesting to note that in several cases today a layer of thermal insulation is added on the cave walls, thus canceling the heat absorption process. Winter is rather chilly in Santorini, humid and windy. Due to the large heat capacity of the earth that dampens down diurnal and seasonal temperature fluctuations, a satisfactory level of thermal comfort can be achieved in the excavated dwellings during most of the winter, reducing the need for extra heating that is required mainly to lessen discomfort caused by humidity. Water: Annual rainfall seldom exceeds 370mm in Santorini, and the volcanic earth hardly holds underground water reserves. Consequently, plants survive mainly due to air moisture in summer. As said, the meagre vegetation offers limited firewood supplies and makes structural timber an exotic luxury. In earlier eras rainwater collection was the only source to harvest water. The typical dwelling had one or more underground cisterns where rainwater was collected from roofs and terraces via elaborate routes. Air (Wind): Santorini is totally exposed to the frequent winds that sweep the Aegean Sea, a fact that local plants know too well. It is only the cliffs around Caldera and small valleys that offer some protection, unless they face the incoming air stream when discomfort is intensified by the sand-blast effect caused by turbulence. Wind protection is of prime importance for outdoor living, as shown by many courtyards with raised walls or lowered floors where view has been sacrificed for sheltering. Air (Ventilation): Ventilation and daylight can be provided into the deep excavated caves only through their façade. The typical clerestory above the door lets the warm air to escape, bringing also daylight to the maximum depth possible. That is supplemented in some cases by vertical ducts through the ground above that admit air and light into the dark and unventilated rooms.



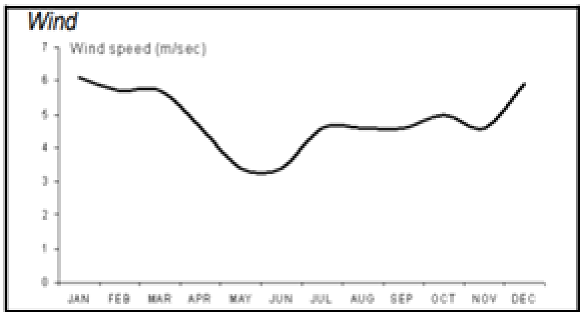
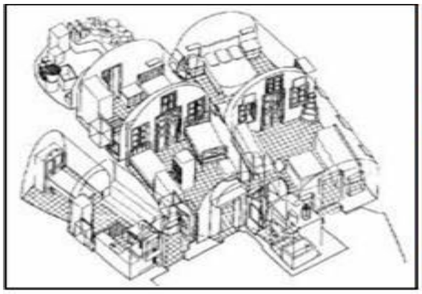


Diagram4 (left)& 5 (right) : Relative humidity remains high all year round; rainfall is rare during the summer 5 months. Santorini is a windy place all year long



	Fire	Water	Air	Earth
layout	• dense fabric for mutual shading		• dense fabric for mutual wind protection	• stepped back due to topography
building types				• excavated • masonry vaults
layout features	• yards for shade	• terraces for rainwater collection	• yards for wind protection	• narrow & deep spaces
materials	• Theran soil for mortar • pumice for insulation	• no water? no timber!	• robustness needed, to withstand wind	• soil easy to dig • large variety of stones • difficult transport
walls	• heat capacity dampens temperature swings		• wind protection • plastered to avoid decay	• earthquake • horizontal vault forces
roofs	• insulated with pumice	• no timber? vaults! • rainwater collection	• heavy to avoid uplift	• covered with pumice
windows	• small size reduces heat transfer	• arched lintels	• shutters behind glazing for wind protection	• small size to avoid wall weakening
forms	• compact to minimise fabric heat flow	• curved structures with compression materials only • rainwater channelling affects geometry	• aerodynamic shapes & details reduce wind effects	• compact to save materials • aseismic rules dictate geometry • embedded rubble & rocks to reduce transport
heating	• minimal direct gain	• no fuel for heating, just for cooking • moisture lessens indoor comfort	• wind may reduce comfort	• thermal mass augments indoor air temperature in early winter
cooling	• high reflectivity reduces solar load • warm mass emits heat	• no timber for shading • no climbers for shading • moisture enhances indoor comfort	• wind may improve comfort • strong winds damage shading devices	• thermal mass absorbs heat improving indoor comfort
ventilation	• clerestories expel warm air	• dampness & mould due to limited ventilation	• clerestories & air ducts enhance air movement	• limited in caves
daylight	• small openings sufficient for summer daylight • clerestories admit daylight more deeply			• limited in caves
watering		• rainwater collection • plants surviving on moisture		• no water reserves in volcanic ground

Diagram6 : Excavated houses are often separated into 2 or 3 rooms with narrow facades on a common yard.
Fig 16: A whitewashed terraces and A mélange of roofs, walls, terraces and stairs.
Table 1 (above): Relation between the four elements and features of Santorini architecture

INFERENCES

The locals adapted their notion of comfort and other needs to the local setting and merged the effects of the four elements into an honest, minimalist architectural idiom, thus offering a brilliant example of vernacular environmental sustainability. In order to contemplate the fifth element as the spirit and ingenuity of the locals that have created and sustained life out of the other four.

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ECO FRIENDLY BUILDING MATERIALS AND CONSTRUCTION TECHNIQUES USED FOR CONSTRUCTION OF SUSTAINABLE BUILDINGS.

ECO FRIENDLY MATERIALS FOR SUSTAINABLE BUILDINGS CONSTRUCTION.

Ar. Akshay Joshi, Ar. Muktai Gaikwad, and Ar. Arsheen Palkar

ABSTRACT*:* *The purpose of this study was to investigate the properties, advantages and application of eco-friendly building materials and construction techniques, which are available in India. The study found that, eco- friendly building materials are efficient, strong, and durable and it has grate environmental advantages, eco-friendly construction techniques are helpful to reduce the carbon footprints of the building. This study provides evidence that the eco-friendly building materials and construction techniques plays a major role in reducing the carbon footprint of the buildings. This study, attempts to focus on eco – friendly materials while considering their accessibility, affordability, and usability with the appropriate use of construction techniques.*

KEYWORDS : Construction techniques, sustainable building, efficient construction, eco – friendly materials.

INTRODUCTION

Eco – friendly building materials does not harm the environment, in form of production use or disposal and can easily be recycled. It is necessary to reduce our energy consumption and choose wise construction materials and techniques in reference to Building materials like cement, steel, bricks, etc. produces large amount of greenhouse gases & CO2. Therefore, it is necessary to use energy efficient material & techniques that helps to save energy. The above research paper gives a significant information about eco – friendly materials & construction techniques that are locally available and helps maintaining healthy environment. Natural resource availability is declining, and prices are steadily rising because of overexploitation. Utilizing non-toxic and unusual materials can help decrease CO2 emissions and reliance on natural resources. Living intentionally is what it means to be eco-friendly. The goal is to prevent interactions from harming the ecosystem. Eco-friendly technologies use abundant alternative resources for sustainable construction, consuming less non – renewable resources needed by traditional methods. In India, numerous research institutions, producers, and entrepreneurs have created a variety of technologies and materials that are useful in the building of homes. The building industry has responded by adopting eco-friendly building materials to lower the environmental cost of creating and utilizing structures. The building industry moves toward more sustainable construction by choosing eco – friendly materials & techniques during all phases of construction. More environment friendly building materials must be chosen for use in construction. Receiving sustainable building components is an excellent strategy to cope with achieving this goal. Eco – friendly materials –Academics initially suggested the term "Eco-Friendly construction materials" during the inaugural International Conference on Materials Science. In 1992, the international academic community defined eco-friendly materials as those that have the least detrimental effects on both the environment and people throughout the world during their manufacture, application, and post-use phases. The following definition of green building materials by China is as follows: advanced science and technology, minimal or no use of natural resources, extensive use of solid waste in industry and agriculture, pollution-free, low-level radioactive elements, and recyclable construction materials. As can be seen from the definition of the above- mentioned Eco – friendly materials, the focus of the researchers is primarily on the manufacturing process, technology, emissions, recycling, and health benefits. Benefits of using Eco – Friendly Materials –

1) According to reputable studies on several EFM now widely used in India, they often have the following advantages when compared to standard construction materials:
2) Reduce energy consumption: To achieve the goal of reducing water and land resource consumption, use waste slag and domestic waste as raw materials for production, or use renewable environmental protection materials, and use more advanced production technologies to increase energy efficiency, resulting in energy savings and emission reductions in the manufacturing process, as well as green environmental protection.
3) Sustainability: Because qualified materials can be reused and recycled several times, they reduce energy consumption and pollution emissions associated with repetitive material fabrication or replication. Health and safety: Unlike traditional building materials, green building materials are not harmful to the environment.
4) Good material characteristics: Most EFMs are strong, waterproof, and lightweight, which helps lower material handling costs and raise building quality.

AIM

The aim of this study was to gain the understanding of different eco-friendly materials and construction techniques, which will have low impact on environment.

OBJECTIVES

To study the minimal impact of the eco - friendly construction materials.
To study the properties and application of eco-friendly building materials in construction.
To analyze the advantages of eco-friendly materials.
To analyze different construction techniques that are less harmful to environment and can help reducing the carbon footprint of the buildings.

RESEARCH METHODOLOGY

In this research paper, qualitative research method is been used to understand the different eco-friendly materials and construction technologies by a systematic literature review of the data available on internet and secondary data from published research papers, blogs, and academic journals. The basic information, properties are investigated through literature study and online media. eco-friendly materials available in India. Rice Husk Ash Concrete-India produces approximately 20 million tones of rice, and 24 million tones rice husk is extracted every year, rice husk is usually used as combustible material for preparation of paddies and approximately. million tones of rice husk ash is created as a by-product of this burning process. It has a similar chemical composition as many of the organic fibers, a general compounds of rice husk ash are as follows :Cellulose ($C5H10O5$), Lignin ($C7H10O3$), Hemicellulose, $SiO2$, Holocellulose
These compounds may differ depending on the source of rice and the burning process. The silicate is one primary compound of rice husk ash, which gives it a pozzolanic reactivity capacity. He common composition of rice husk ash is given in **table no 1.**

SI No	Components	Percentage
1	Silicon Dioxide	86.94
2	Aluminium oxide	0.2
3	Iron oxide	0.1
4	Calcium oxide	0.3-2.25
5	Magnesium oxide	0.2-0.6
6	Sodium oxide	0.1-0.8
7	Potassium oxide	2.15-2.30

Adding rice husk ash in concrete makes it an eco-friendly supplementary Cementous material; following are the properties of rice husk ash in concrete: Heat of hydration is reduced by adding rice husk ash into concrete, which helps in drying and shrinkage and makes it more durable. The reduction in permeability of concrete which help in penetration of chloride irons thus avoiding th e disintegration of concrete structure. Makes the structure chloride and sulphate attack resistant.
Application of rice husk ash concrete:

1. Waterproofing
2. Used as admixture in concrete to avoid chemical penetration.
3. High performance concrete.
4. Insulator.
5. Industrial flooring.
6. Swimming pools.
7. Green concrete

ADVANTAGES

1. Addition of rice husk ash in concrete makes it an eco-friendly building material,
2. The heat of hydration is reduced makes the drying process faster.
3. Rice husk ash give good compressive strength to the concrete
4. Because of its high silica content, it is a superior pozzolanic admixture.
5. It offers good protection against Sulphur attacks.
6. It has better shrinkage characteristics.

COB

Cob is a composition produced by mixing natural materials such as sub-soil, sand, Fried Straws and coconut fibers in appropriate proportions while adding water to bind then together effectively. The final mix of cob, which is ready to construct, is called as “cob bricks/loaves. It is one of the most environmentally friendly and naturally processed material used for construction Practices. It can be processed by manual. techniques or machine automated technique. The ratio of these materials to be added are usually extracted by analyzing in the depth properties of sub soil and sand procured from site.
Mixing Methods: Manual / Traditional Method :

One way to make a mixing pit is just to dig an inclined saucer shaped depression in the ground. To mix a cob in the pit, combine clay, soil and then segregate the organic waste and add turmeric water in the pit draped with a tarpaulin sheet, mix and stamp vigorously until all the Pumps are dissolved. The General ratio of soil and sand is 4:1, may vary depending on the varies geographical location. In a pit most of the mixing happens by sloshing about your feet, which is fun and easy on using a tarp lines pit by pulling back on each corner of the pit in turn to move unmixed material into the middle, one must make sure the clay and sand are thoroughly mixed before adding Straws and coconut court. Machine Automated Method : A bulldozer can make enormous batches quickly. Soil, sand and water are mixed by moving the bucket in the pit upside down in order to get an appropriate pre-mix. Initial steps in this method are like the traditional method, varying only the ratio I.e., 4:1, 8:2, 12:3, 16:4…In Mechanized approach to cob, an initial mix is DEPRIVED of Straws, as Straws undergone breakage with heavy machine mixing and hence, they are added later in the Manual mixing, but one can add coconut fibers. Properties of Cob: Fireproof material, Resistant to seismic activity. Good thermal and acoustic insulation. Low-cost material.

APPLICATION OF COB:

1. Wall construction.
2. Arches
3. Foundation
4. To construct monolithic structure.

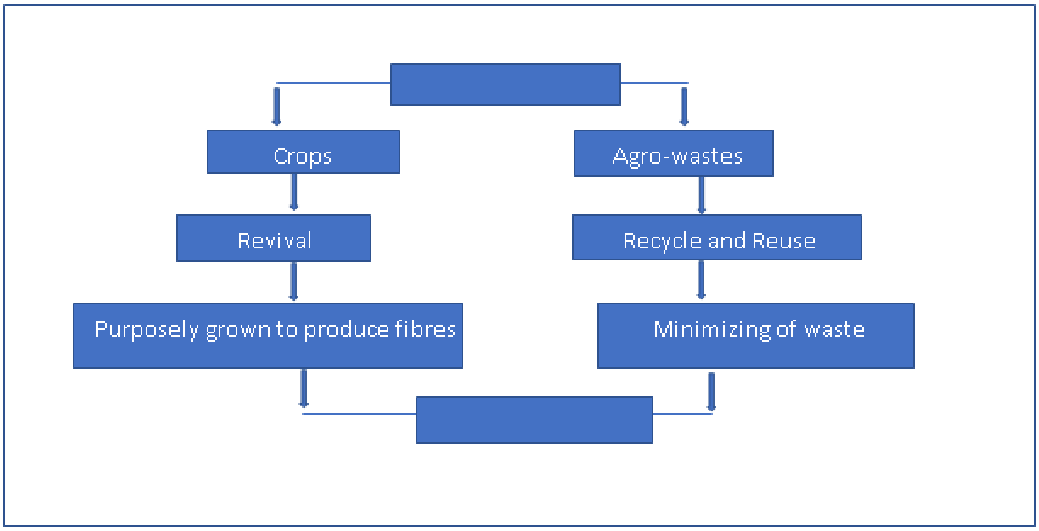
ADVANTAGES

1. It is the most sustainable of a building material
2. It has almost zero embodied energy
3. It is a breathable material.
4. No chemical or additives used in the preparation.
5. It is recyclable

BIO-COMPOSITE MATERIALS

Bio-composites or referring to practices or policies that do not negatively affect the environment composites, are the future generations of sustainable construction materials They’re made up of an association of environmental factors – usually plant fibers argue open resins and binders – and are used to manufacture roofing sheets, fences, fireproof doors, and many more other building components. Bio-composites materials help remove non-sustainable waste, reduce natural resources habit, and cut Fossil-fuel consumption. Many biography-composites use reused materials or fast-growing plant fibers. In turn, they are recyclable or are designed to swiftly decompose. Bio-composites usually use natural binding. agents, lowering the need for petrochemicals or different fossil-fuel products. Even more fuel is saved in the conveyance of lightweight, locally derived bio-composites. Like other sustainable building materials, bio-composites still help construction workers and homeowners earn Leadership in Energy and Environmental Design certification, the authorization for green building and construction. Bio-composite materials are classified in two types, Structural and Non-structural bio-composite materials (R.M. Rowell, 1995). Structural composite materials, which carries, load e.g., walls, roofing etc. Non-structural bio-composite materials which does not have role in carrying load of the structure e.g. furniture, doors, windows etc.

DEVELOPMENT OF BIO-COMPOSITES FROM RENEWABLE RESOURCES



APPLICATION – BIO COMPOSITE ROOFING - Bamboo is one of the best sustainable material, it can be pressed, and resins can be added to make lightweight, strong roofing panels. Bio composite landscaping materials .India produces abundant amount of wheat straws that can be used with recycled plastic from waste bottles to make fens for gardens or outdoor areas. Bio composite Doors By using bio-composite technology wheat hulls into a fire rated doors, for interior purpose light and low-density doors are available in market. Bio-composite Concrete Common example of bio composite concrete is a combination of natural lime and hemp. This hemp-lime concrete can be recycled as fertilizer later. Advantages –Lightweight Lower manufacturing cost. Sustainable alternative. Reduces the carbon footprint Recycled Rubber According to Indian rubber statistics 2012-2013, in India around 110-112 million tyres are scrapped and goes to the landfills. Most of this waste is consumed as a fuel in power plants or any other domestic use but this is not a sustainable way as it accelerates air pollution. This waste rubber can be used in civil works as fine aggregate, as a binding agent in bricks and pavers or as railway ballast effectively and it will solve the waste disposal issue in a sustainable manner.

Application – Flooring, Roofing tiles, Driveways, Furniture, Walls

Advantages-

1. Resolves the Landfills issue
2. Reduces pollution
3. Boots local economy
4. Relives Environmental pressure

BAMBOO

Bamboo is considering as most eco-friendly and sustainable material as it grows faster and can be harvested quickly. Bamboo is also grown locally in India that makes it more eco-friendly as the transportation is reduced so the carbon footprint. Bamboo is being used from several generation because of its durability and easy availability. It has high compressive and tensile strength; it is flexible in nature that makes it most suitable material in construction industry.

Application –

Bamboo as a reinforcement, Walls Furniture, Landscape materials, Compressed bamboo sheets for paneling Flooring, Décor. Doors and windows

ADVANTAGES

1. It has great tensile strength
2. It is lightweight
3. Fire resistance
4. Compressive strength
5. Very low carbon footprint

ECO-FRIENDLY CONSTRUCTION TECHNOLOGY

Passive Solar Buildings
Concept of passive solar building is that all the components of the building such as roofs, walls, windows, floor etc. are designed in such way that they can collect and store the solar energy, this stored energy is then used in winter for warmth and to reject the heat during summer season.
The building converts the solar energy into useful energy without any mechanical system. Principals of passive solar buildings
The sun path should be studied properly
The location of thermal mass should be properly placed to absorb the energy and to release it later in the evening time.
Direct sun can be restricted by placing shading devices. Proper insulation enables warmth in winter and coolness in summer.
Passive design in one of the best way to make building more sustainable, the building is designed in a way that the orientation of the building designed to capture the maximum day light through the day to avoid the use of artificial lighting, which results in saving electricity and reduces the carbon footprint of the building.

Green Roof technology

Roof is exposed to the sun throughout the day, and it is the main reason of solar gain in the building. Green roof technology is a technique to create contained green spaces on the rooftops of buildings. Green roof technology may differ roof to roof; a general green roof is where the roof is covered with a vegetation and because of that, we can reduce the solar gain and ultimately the need of mechanical way to cool down the interior spaces.

Rainwater harvesting

Rainwater harvesting is a technology to collect, convey and store the rainwaters from roofs, catchment areas. The collected rainwater either directly go the ground water recharge wells or can be stored in rainwater tank.
The collected water is relatively easy to treat and reuse and does not require much resources and money.
Rainwater can be harvested in several easy ways:

Water butt

In this type of a system, rainwater is collected directly in containers or buckets and later used in landscaping purpose or any other domestic purpose; it is the easiest way to harvest the rainwater.
Gravity systems Rainwater is collected in a tank, which are located on lower heights and bellow the catchment area, the water directly stored in the tanks by using gravity.

In-Ground Storage

Water is stored in an underground storage tanks, that keeps the water safe from evaporation and doesn't get freeze in cold climates.

Recharge wells

In this type of systems, the rainwater is directly goes to the recharge wells without any purification, as the aim is to recharge the ground water table. This process helps to maintain the ground water level and helpful in agriculture for better yield. Rainwater harvesting is the most important technology that any building should have, considering the current scarcity of water, it is the best way to reduce the pressure on the natural water resources.

CONCLUSION:

Eco- friendly building materials and construction techniques have great potential to replace the conventional practices, which can be helpful to reduce the carbon footprints of the buildings as well as can reduce the pressure on the natural resources. By eliminating health risks, the use of green building materials may not only improve construction quality and production efficiency, but also meet the demands of sustainable development. As a result, the government ought to promote its utilization and breathe new life into the construction sector.

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AUTOMATIC DYNAMIC FAÇADE OF PNEUMATIC DAYLIGHTCOMPLAINT MICRO-ACTUATORS FOR CONTROLLING DIRECT AND INDIRECT

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ABSTRACT*: The sun changes direction continuously which makes traditional fixed facades and apertures efficient only for short period of time. Currently available dynamic façade has many moving parts. As the number of moving parts increases linearly, number of failure points and chances of failure increases exponentially resulting in very high maintenance and low reliability. Also, such moving parts require energy which makes the façade less efficient and unreliable. This creates the need for a building envelope solution which is dynamic, energy efficient and has no moving parts. Pneumatic compliant micro-actuators create movement with help of controlled air pressure which requires very low energy to operate and as there are no moving parts, this technique becomes highly reliable and requires low to none maintenance (no bearings, no oiling, no friction, etc.). In layman's term, basically, it is a flexible sheet of certain material which changes shape and size as per requirement and inputs. Research methodologies used in this paper focuses on operating principles of pneumatic complaint micro-actuators, overview of automation model, building performance analysis regarding daylight before and after the installation of façade. Also included are various simulation driven results and reports as proof of concept.*

KEYWORDS: Pneumatic complaint micro-actuators, Adaptive facade, Model and analysis of Dynamic facade, Responsive complaint facade, Sustainable responsive façade

INTRODUCTION / BACKGROUND

Actuator is a device which aids to create the movement (rotational and linear). In traditional dynamic façade, the actuators used contains many moving hard mechanical parts and assemblies where an electric motor is the primary source of motion. As there are many moving parts, there is a high chance of failure. Due to friction loses, energy requirements for such systems are high and manufacturing cost also out of the budget of many people. Also, current generation of dynamic façade is either controlled manually or with the help of timers. These techniques are not adaptive and thus, less efficient. A compliant mechanism is a mechanism without any joints. In simple words, compliant machines are machines that bend. As there are no moving parts (moving part is an assembly with more than one joint and more than two elements), failure rate of compliant machines is very low. Pneumatic actuator is a device which creates motion with the help of pressurized air. As it isn't dependent on electricity, it requires very low energy to operate and stays functional even after leaks. A dynamic façade made with pneumatic complaint micro actuators is reliable, efficient, maintenance free, easy to install and cost effective.

AIM / PURPOSE

When we discuss about façade, images of beautifully designed exteriors come to mind. Façades are frequently connected with a building's aesthetics without much thought given to their practical or utilitarian use. When the performance of the structure is examined, it is discovered that façades play a significant role in the building envelope and significantly increase heat intake from solar gain. A well-designed façade system can raise a building's overall performance by increasing energy efficiency and occupant comfort. Through climate analysis, building orientation and sun path analysis, day-lighting analysis, material selection processes, etc., it can be implemented into a variety of façade design principles. If the glazing and shading features of a façade are taken advantage of during design creation, overall energy efficiency would inevitably increase, producing excellent performance. The goal of occupant comfort and productivity must not be sacrificed, finally.

RESEARCH METHODOLOGY

WHAT ARE ADAPTIVE FACADES?

Modern adaptive facade solutions include everything from dynamic glass (with variable g-value) and sun shading devices to solar integration and noise- and self-cleaning exterior materials. The development of new building envelopes that are also energy self-sufficient by producing their own electricity, for example through integrated solar cells, must be a long-term objective of façade makers and developers. Adaptive facades can adjust, among other things, to variations in the ambient temperature and solar radiation (sun shading and glare protection). They simultaneously permit a maximum intake of natural light. Such intelligent facades are integrated with the building control system to reach an ideal.

REQUIREMENTS FOR ADAPTIVE FACADES

Adaptive solar shading to reduce thermal loads
- Dynamic glare shielding that adjusts to the strength of the sun's rays
- Enough daylight to properly brighten the space
- Directing light to interior spaces using light control systems
- Energy production, namely using sunshine in the winter.
- Power generation (energy self-sufficiency, building-integrated PV)
-Ventilation functionality (automated if possible)

WHAT ARE PNEUMATIC ACTUATORS

Pneumatic actuators, also known as pneumatic cylinders, are extremely dependable and secure motion control tools that transform force into rotary or linear motion. These devices are frequently used in industrial settings, particularly potentially risky industrial conditions, where the repetitive opening and closing of valves is necessary. This includes the process and chemical industries where the direct movement and transfer of fluids occurs.

HOW THE PNEUMATIC ACTUATOR WORKING PRINCIPAL WORKS

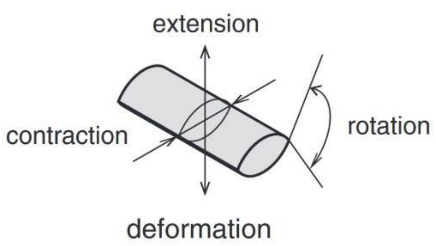
The process of how pneumatic actuators work is known as the working principle of pneumatic actuators. There are two types of pneumatic actuators: Operated by diaphragm and piston. Pneumatic actuators efficiently use compressed air to generate drive energy. Instrument air builds up a force or pressure acting on a diaphragm or piston. This moves the valve actuator into position on the valve stem, resulting in mechanical movement. The use of air in this movement has two factors. It is easy to compress and absorb and is safer than other gases. For this reason, and because the conversion of compressed air into kinetic energy can be very well controlled, pneumatic actuators are very popular devices in industrial production environments. The process of how pneumatic actuators work is known as the working principle of pneumatic actuators. There are two types of pneumatic actuators: Operated by diaphragm and piston. Pneumatic actuators efficiently use compressed air to generate drive energy. Instrument air builds up a force or pressure acting on a diaphragm or piston. This moves the valve actuator into position on the valve stem, resulting in mechanical movement. The use of air in this movement has two factors. It is easy to compress and absorb and is safer than other gases. For this reason, and because the conversion of compressed air into kinetic energy can be very well controlled, pneumatic actuators are very popular devices in industrial production environments.

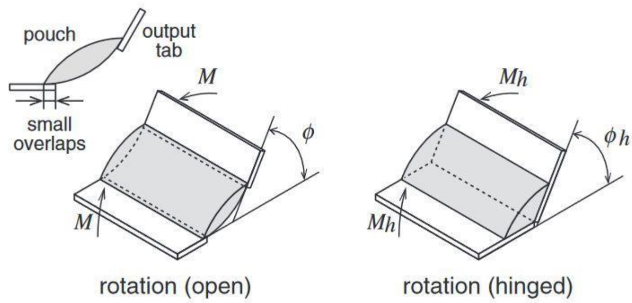
WORKING OF MICRO ACTUATOR

A micro actuator is a tiny servomechanism that supplies and transmits a precise amount of energy for the operation of a system or another mechanism. A micro actuator must adhere to the same requirements as a normal actuator, such as quick switching, extensive travel, high precision, low power consumption, etc. The sizes of these actuators range from millimeters to micrometers, but once they are packaged, they can be made to the full size in centimeters. The purpose of a micro actuator is to create mechanical motion in fluids or solids by converting one type of energy (such as thermal, electromagnetic, or electrical energy) into another energy (such as the kinetic energy (K.E) of movable components).

FINDINGS/ ANALYSIS AND INFERENCE

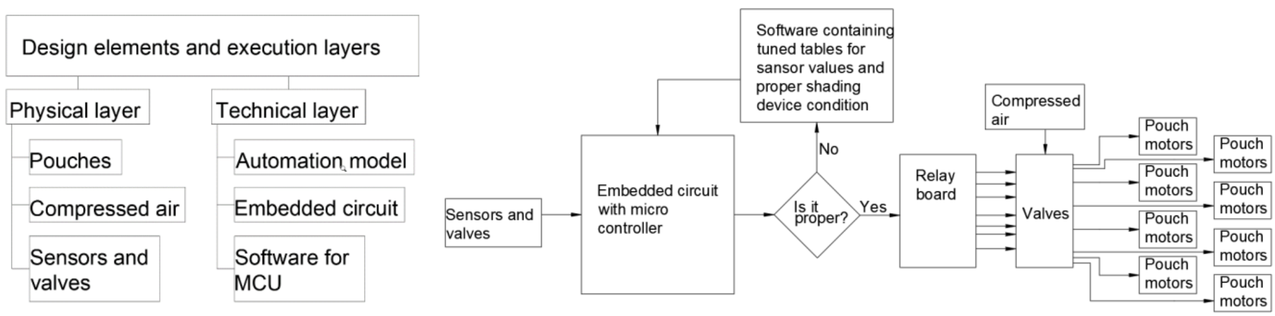
Pouch motors The pouch motor is an innovative concept being heavily used in soft robotics. As name suggests, a pouch motor is made with one or more inflatable pouches which can expand, and contract based on fluid pressure. This expansion and contraction process creates the motion. In the context of this paper, the fluid being used is air. A bag motor converts mechanical work in a fluid. B. Air, water, and oil in deformation of inflatable surfaces bag. Changes in length and curvature are used here Linear (translational) bag motor and angular (rotational) bag motor. Includes rigid exit tabs Attached to the edge of the pouch to provide mechanical strength. As shown in the figure, the pouch can expand and contract which can create linear and rotational motion. The range of motion of a pouch is limited by the physical size as well as construction of the pouch. To tackle these limitations, we can connect and arrange multiple pouches in multiple ways.





WORKING PRINCIPLE OF THE WHOLE SYSTEM

As shown in the chart below, whole mechanism is divided in 1) Physical layer which contains Pouch, Compressed air, Sensors and valves and 2) Technical layer which focuses on automation model, required circuitry (hardware) and software to run the hardware.

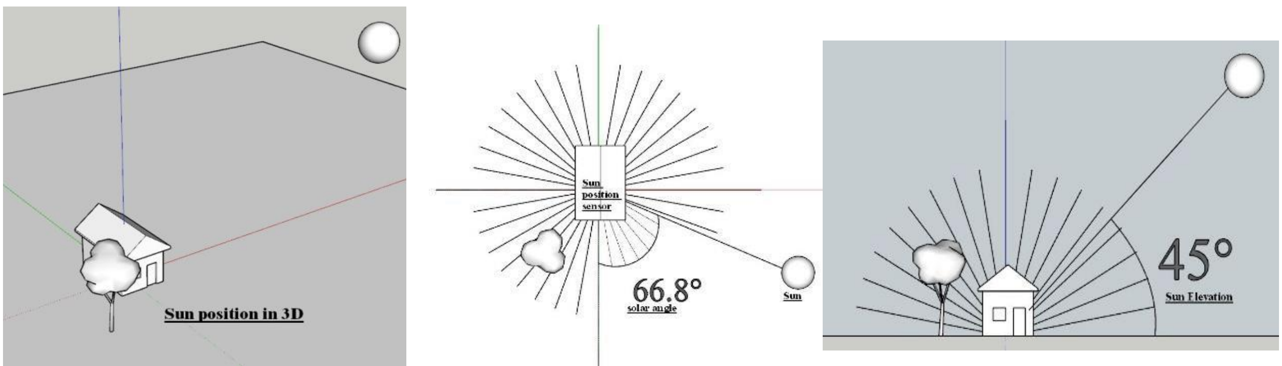


elevation Angle		10	20	30	40	50	60	70	80	90
10	100,100		90,100	80,100	70,100	60,100	50,100	40,100	30,100	20,100
20	100,95	90,95	80,95	70,95	60,95	50,95	40,95	30,95	20,95	
30	100,90	90,90	80,90	70,90	60,90	50,90	40,90	30,90	20,90	
40	100,85	90,85	80,85	70,85	60,85	50,85	40,85	30,85	20,85	
50	100,80	90,80	80,80	70,80	60,80	50,80	40,80	30,80	20,80	
N 60	100,75	90,75	80,75	70,75	60,75	50,75	40,75	30,75	20,75	
70	100,70	90,70	80,70	70,70	60,70	50,70	40,70	30,70	20,70	
P 80	100,65	90,65	80,65	70,65	60,65	50,65	40,65	30,65	20,65	
90	100,60	90,60	80,60	70,60	60,60	50,60	40,60	30,60	20,60	
U 100	100,55	90,55	80,55	70,55	60,55	50,55	40,55	30,55	20,55	
110 T	100,50	90,50	80,50	70,50	60,50	50,50	40,50	30,50	20,50	
120	100,45	90,45	80,45	70,45	60,45	50,45	40,45	30,45	20,45	
130	100,40	90,40	80,40	70,40	60,40	50,40	40,40	30,40	20,40	
140	100,35	90,35	80,35	70,35	60,35	50,35	40,35	30,35	20,35	
150	100,30	90,30	80,30	70,30	60,30	50,30	40,30	30,30	20,30	
160	100,25	90,25	80,25	70,25	60,25	50,25	40,25	30,25	20,25	
170	100,20	90,20	80,20	70,20	60,20	50,20	40,20	30,20	20,20	
180	100,15	90,15	80,15	70,15	60,15	50,15	40,15	30,15	20,15	

The chart provided here demonstrates the working of whole system. Sensors monitor sun angle and provide that information to the computer (read: embedded circuit/MCU/hardware). If the values are not in sync with current state of shading devices, the software then reads a table with all possible sensor inputs and their appropriate outputs. The proper output is then sent to relay board, which controls multiple valves controlling the air pressure in pouches. Multiple pouches need to be grouped so; one valve can control state of multiple pouches. In the given chart, rows indicate difference in sun elevation and columns indicate difference in sun angle. This data, acquired by the sensors, can tell us about precise sun position. And by knowing actual sun position, the software then can refer the table to provide proper output.

SUN TRACKING

STS works as a relative pyranometer. Under cloudy conditions, real-time information on relative irradiance and sun orientation can be provided to the tracking control unit to optimize the aiming accuracy of the tracking system. A wide viewing angle allows STS to operate as a closed-loop tracking system. It can also be used beneficially in hybrid tracking control systems that implement both closed-loop and ephemeris-based tracking strategies. Sun tracking is done by LDR based solar position sensor, the sensor outputs two values, one for sun angle and other for sun elevation.



1) Sun position shown in 3D , **2)** Sun angle with respect to sensor **(output 1), 3)** sun elevation **(output 2)** Sensor output is given as input for computer which, after carefully analyzing the table, outputs proper values for the actuators.

VALVES

Two way or three-way solenoid valves can be used for controlling the air flow direction in pouch motors. A solenoid valve is an electromechanical valve. Solenoid valves differ in the characteristics of the electrical current they use, the strength of the magnetic field they produce, the mechanism they use to regulate the fluid, and the type and characteristics of the fluid they control. Mechanisms range from piston-type linear actuation actuators to slewing armatures and toggle-type actuators. Valves can use a two-port design to regulate flow, or a three or more port design to switch flow between ports. Multiple solenoid valves can be placed together in one manifold.

NORMALLY OPEN (NO) 3-WAY SOLENOID VALVE

A normally open 3-way solenoid valve has three pipe connections. Lumen port, body port, stop port. It has two openings. Either the body orifice or the locking orifice is always open. This allows for two flow paths. When power is turned off, the piston rises, sealing the stop orifice and opening the body orifice, allowing flow from the body orifice through the valve to the lumen orifice. When the coil is energized, the piston descends, sealing the body orifice and opening the stop orifice, allowing flow from the lumen orifice through the valve to the stop orifice.

NORMALLY CLOSE (NC) 3 WAY SOLENOID VALVE

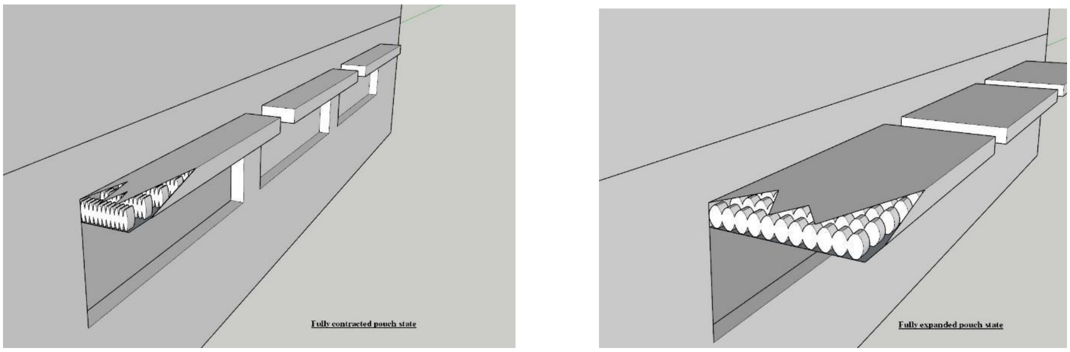
A normally closed 3-way solenoid valve has three pipe connections. Lumen port, body port, stop port. It has two openings. Either the body orifice or the locking orifice is always open. This allows for two flow paths. When power is off, the piston is down, sealing the body orifice and opening the stop orifice, allowing flow from the lumen orifice through the valve to the stop orifice. When the coil is energized, the piston rises, sealing the stop orifice and opening the body orifice, allowing flow from the body orifice through the body of the valve to the stop orifice.

DIRECTIONAL 3-WAY VALVES

A 3-way solenoid valve has three pipe connections. Lumen port, body port, stop port. It has two openings. It has body openings and barrier openings, one of which is always open. This allows for two flow paths. Energizing the valve raises or lowers the piston. Raising the piston seals the check orifice and opens the body orifice, directing flow through the body of the valve. As the piston descends, it seals the orifice in the body and opens the stop orifice, directing flow through that orifice.

DYNAMIC SHADING DEVICES

Once we get the motion creating devices up and running, the shading devices we can use are just limited by our imagination**.** Some examples of dynamic shading devices which can be used with pneumatic compliant micro actuators are elaborated below:



The images above shows translational actuation achieved by pouch motors

These seven studies of dynamic shading systems is performed by theoretical approach. In Similar cases, pneumatic compliant micro-actuators can be used.

PERFORMANCE OF DYNAMIC SHADING SYSTEMS

Performance of dynamic shading systems
Control strategies
No. Study Location Climate System Design criteria Control schemes Algorithm/Set point
Simulation-based studies (theoretical approaches) Controlling algorithm
1 Tzempelikos and Athienitis (2007) Canada/ Montreal Humid continental Roller shade Energy (lighting/cooling) Feed- forward The shade opens when solar radiation is < 20 w/m2
2 Nielsen et al. (2011) Denmark Temperate Blinds Daylight Energy (lighting cooling and heating) Feedback The blinds are lowered when indoor air temperature is over 24° or the risk of glare exceeds
3 Yun et al. (2014) South Korea/ Seoul Humid subtropical Blinds Daylight Glare Energy (lighting/cooling) Feedback The slats are adjusted at 0°, 15° and 30° when illuminance level is (3klx indoors 10, 20 and 40k 1x outdoor). respectively
4 Bunning and Crawford (2016) Australia/ Melbourne- Brisbane Maritime Humid subtropical Blinds Energy (lighting, cooling, heating and ventilation) Feed- forward The blinds are adjusted based on hourly sky condition and annualsolar angles
5 Skarning et al. (2017) Italy /Rome- Copenhagen Warm/cold temperate Roller shade Daylight Thermal Energy (heating loads) Feed- forward The shade closes whena certain value of 18 C outdoor air temperature and 300 w/m2 solar irradiation exceeds
6 Konstantoglou et al., (2013) Greece Mediterranean Louvre Energy (lighting, cooling and heating) View Feedback The slats are adjusted at angles (0°-90°) with a step of 10° to ensure WPI of 500 lx, glare index DGI<22 and visual connection to the exterior
7 Kim et al (2015) UAE/Abu Dhabi Arid Origami Energy (cooling loads) Feed- forward Incidence sun angle 0°- 90 of a given surface drives three states: closed, partially and fully open

The study found that some methods were generally poorly presented Interpretation on automation and control issues. For this reason, Dynamic system performance is classified and verified using: Two approaches: (a) simulation-based research conducted independently or in parallel; Empirical verification without applying manipulation mechanisms (b) an experimental study to test responsiveness System with control algorithm. geometric complexity are distinguished accordingly. Templelike and Atheneites tested a dynamic roller shade on an office space in Canada against lighting and cooling energy using simulation. The device is driven by incident solar radiation, where it opens at < 20 W/m2. This strategy, along with dimming light control, can reduce 50% of annual cooling energy compared with a non-shaded window whilst increasing lighting demand. Hammad and Abu-Hijleh tested the impact of dynamic louvres on lighting and HVAC energy of an office space in Abu Dhabi. The control aims to ensure minimum energy consumption incorporated with a light dimming strategy that considers the occupancy parameter. Several slat angles were modelled and tested in IES simulation program. Although a slight preference over static louvres was observed in most cases, the effective model achieved the maximum energy reduction of around 28%–34% amongst other scenarios.

CONCLUSIONS

The evaluation of Pneumatic compliant micro actuators based dynamic shading device could be summarized based on following parameters -

A. Reliability performance -High reliability can be achieved with the help of compressed air-based pouch motors and by eliminating moving parts. Even if there is a leak, it still functions .

B. Cost performance- It would help in reducing the running cost as well as maintenance cost. The initial installation cost will be higher than traditional dynamic facades.

C. Efficiency performance- Automation with proper feedback loop and proper reference table helps in keeping the shading device functional at full efficiency.

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WEATHERING; PATINA, AND OTHER MEANS. REVEALING MATERIAL'S EXTERNAL CLIMATE ADAPTATION PROCESSES

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ABSTRACT: *Materials used in building facade assembly are materials that have been man-processed into specific elements. All materials start as crude material, raw and sourced from our earth. A process of production demands crude material to change state - in wood for example - it is felled. Chopped down, killed and reprocessed under specific controlled processes. We assume control of all building materials through rigorous quality control specifications and regulations to ensure materials perform under specific constraints. Yet facade materials confront an external environment that is not controlled, and are susceptible to heat, to rain, to snow, to wind, to UV. All live forces undetermined, and of which materials naturally act and react through weathering, patination, discoloring promoting natural chemical reactions such as rusting. The purpose of the paper is to present recent research that explores the after-life of specific material types and how understanding of materials' natural processes of transformation when exposed to the external climate can inform initial design decisions. The research follows iterative prototyping processes where knowledge has been accumulated via explorations of specific material performances, from laboratory to construction mock-ups focusing on the architectural qualities embedded in control of production techniques and facilitating longer term patinas of material surfaces to extend the aesthetic beyond common judgements. Experiments are therefore focused on how the inherent material qualities drive a design brief towards specific investigations to explore aesthetics induced through production and patinas obtained over time while exposed to external climate conditions.*

KEYWORDS : Patina, Climate, Material Performances

INTRODUCTION AND BACKGROUND TO BUILDING FACADES

A building's facade operates, both aesthetically and functional, on many different levels. As a functional part of a building, it serves as a climatic barrier and protects an inner environment from external weather conditions. It provides a robustness to protect a building throughout its lifespan. It is usually constructed as a waterproof membrane to ensure water does not penetrate and destroy the structure and internal materials. It guides rainwater away, allowing water to fall on a facade, but channels water safely away via guttering and piping. It is the first line of protection - and usually the only line of protection, to ensure a building doesn't deteriorate substantially when exposed to unreliable external weather conditions. Aesthetically, a facade provides identity to a building. It communicates, for example, a corporate identity and provides evidence for what the building is used for. A factory's facade is normally different in its character than a facade of a one family home for example. Or an office. A facade communicates to the outside wealth, power, dominance - the status of the occupants in the society it finds itself in. Or a facade may consciously NOT communicate and act as a veil whereby it is difficult to get an insight into what a building contains. In Venturi, Scott Brown and lienor's book Learning from Las Vegas1, they write about the decorated shed as buildings with facades used as veils with applied symbols can also communicate the opposite2, namely accentuate the value of what is behind and modulate a facade so that it goes beyond form-based design application, to symbol based meanings. Facades therefore become signs, rather than a functional layer for weather protection alone.

"The sign is more important than the architecture. This is reflected in the proprietor's budget. The sign at the front is a vulgar extravaganza, the building at the back, a modest necessity. The architecture is what is cheap. Sometimes the building is the sign: The duck store in the shape of a duck, called "The Long Island Duckling," is a sculptural symbol and architectural shelter. Contradiction between outside and inside was common in architecture before the Modern movement, particularly in urban and monumental architecture. Baroque domes were symbols as well as spatial constructions, and they are bigger in scale and higher outside than inside in order to dominate their urban setting and communicate their symbolic message.
Western stores did the same thing: They were bigger and taller than the interiors they fronted to communicate the store's importance and to enhance the quality and unity of the street. But false fronts are of the order and scale of Main Street. From the desert town on the highway in the west of today, we can learn new and vivid lessons about an impure architecture of communication. The little low buildings, gray-brown like the desert, separate and recede from the street that is now the highway, their fronts disengaged and turned perpendicular to the highway as big high signs. If you take the signs away, there is no place. The desert town is intensified communication along the highway."3

As the authors write, contradiction between outside and inside is common in architecture. Often through choice, as described in Learning from Las Vegas, there are corporate driving ambitions. But there are also contradictions between outside and inside through a necessity of navigating between internal and external environmental setups. There are many driving factors that stimulate the way a facade is both designed, and how it performs. An external facade needs to navigate through changing weather conditions as a minimal requirement and establish durability throughout a building's lifespan. The symbolic value of messaging corporate identities needs to come secondary to responding to climate. Responding to climate variations over substantial time. As Kirsten Harries, Professor of Philosophy at Yale University, writes, " Architecture is not only about domesticating space', 'It is also a deep defense against the terror of time."4 As a facade is continually exposed to the natural environment, materials that make up the facade will inevitably weather, meaning their appearance and performance will change over time. The aesthetic consequences of material change through weathering, today in new buildings, is often not substantially considered. The changing effects of material and a building's facade, and through tenuous observations of newly constructed buildings in local neighborhoods, it is evident weathering is not adversely considered as a conscious and a positive design tool. Far from it. Buildings stand out with facade coverings more conscious of symbolic values rather than barometers of time, meaning an architecture of today that is preferred as timeless, and therefore artificially removed from the reality of time. John Ruskin (1819-1900) in his book, The Seven Lamps of Architecture, writes that "The greatest glory of a building is not in its stone, or in its gold. Its glory is in its Age (...) it is in that golden stain of time, that we are to look for the real light, and color, and preciousness of architecture."5 Juhani Pallasmaa also focuses on how materials can trace time and offers a critique of modern architecture's neglect in embracing the passage of time for other architectural ambitions. "Matter records time, whereas shape, particularly geometric form, emphasizes space and the world of ideas. Geometry and form speak of permanence, whereas materials – through the very laws of nature – trace the passing of time. Modernity has been obsessed with novelty and a perfectionist formal language that does not register this. As deterioration, erosion and entropy are the unavoidable fate of all material constructions, the ideal of perfect and unchanging form is bound to be a momentary illusion, and eventually a false ideal."6

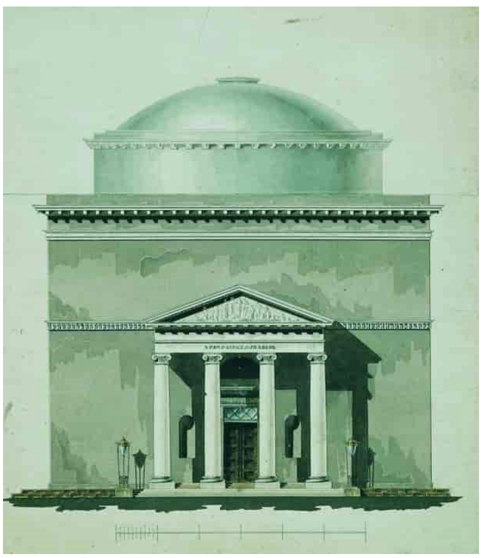

Fig 1: Christiansburg Slot. C.F. Hansen. Kunstakademiets Bibliotic. Kunstakademiet

Christian Frederik Hansen (C. F. Hansen (1756-1845)) was a Danish classicist architect who was appointed as a royal court architect as well as a professor and director of the Academy of Arts in Copenhagen, Denmark. He is considered one of the most important architects in Danish history and was very prominent in Copenhagen in the early 19th century. His best-known works today are Domhuset, and Vor Frue Kirke in Copenhagen. Today these buildings are characterized by their marked weathering of the pink external rendering that gives an appearance of two building navigating well under years of changing weather conditions. At inception of course, the buildings did not appear as they do today. They have weathered and patinated. C F Hansen was an avid painter and he produced watercolor renderings of his buildings that seem to anticipate the buildings' weathering and patination. In Albert Algren-Petersen Ph.D. 'Patina. Architecture's motive and informant'7, he describes C F Hansen's approach to how a building's facade can accommodate possible patina through his drawing methods, and how these inform the buildings design development. " The large production of watercolor drawings he left behind testifies to an architect who was also a persistent and thorough draftsman. In several projects, numerous of C.F. Hansen's facade studies are made of the same facade with small adjustments and changes from drawing to drawing. They are done in line and with light watercolor or wash, as a drawing method to add color to the facade surfaces of the line drawing and a hint of materiality and texture as well as shading.

However, it is also clear that C.F. Hansen also deals with the facade's possible ability to patina with his drawing method. Using the drawing method for the facade drawings, Hansen gives the impression of an architectural surface that is not newly constructed but has been attempted to be projected with traces of the patina of time. Adjustments to the facade, where cornice bands are moved, the processing of materials is adjusted, or where the relief processing of the facade is changed, also changes the watercolor work's hints of patina. It means something for the structure when the smooth plastered facade is divided into squares. Not only for the pattern, but also for the facade's ability to patina. Such a study can be seen, for example, in the facade studies for an unbuilt carriage gate for a detention center. Here he shows how the processing of the plastered facade is important for its(presumed) patina.

It is not possible to say with certainty whether C.F. Hansen used the drawing method, where the building's patina was tried to be shown in the project drawing, as a carefully conceived and conscious design tool. In any case, I have not come across written sources that can neither confirm nor deny that hypothesis…….. I will pursue the hypothesis that C.F. Hansen worked with patina as an architectural informant in his drawings of not yet constructed buildings, ………. where a present awareness of patina in the drawing led to decisions about weathering such as material selection, surface treatments and processing as well as building details."8

Although there is no conclusive evidence so far available, it is fair to assume C F Hansen used his knowledge and experience of how material changes through time as an architectural design informant that provoked design decisions and material choices. Public buildings at the time were predominantly constructed from stone, lime mortar and fired clay, with wood used for internal construction cladding and furniture. Today however timber is a well-resourced material for building in Scandinavia in particular, due to its availability and a pursuit for better sustainable building materials. Timber weathers in very different ways to stone and clay and is a result of a combination of light, moisture, heat, causing both physical and chemical changes to the appearance of the wood. A relatively rapid photochemical degradation of the surface occurs as a result of exposure to ultraviolet light. Wood begins to take on a brown tone, which then changes to grey. During this process, the UV rays damage the polymer bonds within the wood substrate (cellulose, hemicelluloses, and lignin). As a result, exposed wood in a Scandinavian environment can weather to a soft, silver-grey color. This color change is due to the degraded lignin being washed out of the wood by moisture. The fibers that remain on the wood surface are high in cellulose content, grey in color, and are more resistant to leaching and UV degradation.9 The resultant weathered appearance of wood is highly regarded and often compared to sealskin in both its appearance and texture. It is also relatively resilient to decay, providing the wood is allowed to dry after wet periods. More significantly however, patina and discoloring of wood over time communicates just that - that time has been embedded in the architecture (facade) and it is this that is well appreciated - the understanding that architecture becomes part of a wider ecosystem whereby the thresholds between nature and manmade become less defined. Time being a keeper of this phenomena.

Fig 2: Rådhusets Entrance Gate. Kattesundet.Tegning © Kunstakademiet

ANALYSIS AND INFERENCES

In building construction and its performance, today the industry amounts to up to 40% of CO2 emissions globally10. In urgent pursuits from the building industry to establish better environmentally conscious building practice there is now a focus on thinking of new constructions in a more circular manner, and investment into more bio-based material types. Biobased materials are a natural part of our environment, or biosphere. They typically have a low embodied carbon footprint and as they are organic, they tend to absorb carbon as they grow11. Significantly, they lock carbon sourced from our environment during their lifespan. When however, they are harvested for, for example building components, this carbon can be released. Limestone processed into cement being a typical example. Processing of raw material for building use therefore requires careful study and consideration to avoid negative impacts. The projectorary therefore is to think of material sourcing and application that promotes building materials that are NOT processed and 'artificialized', but as natural as possible, to be an embedded part of the biosphere. Materials used today in building assembly are primarily materials that have been man-processed into specific elements. All materials start as crude material, raw and sourced from our earth. A process of production demands crude material to change state. This change of state is energy consuming, and often releases CO2 absorbed throughout the material's 'life'. We assume control of building materials through rigorous quality control specifications and regulations to ensure materials perform under specific constraints. Yet with facade materials for example, the material must confront an external environment that is not controlled, and is susceptible to heat, to rain, to snow, to wind, to ultraviolet deterioration. All live forces as such, that are undetermined, and of which materials naturally act and react through weathering, patination, discoloring, and promoting natural chemical reactions such as rusting for example.

The development of a building practice thinking of new constructions in a more circular manner, and investment into more bio-based material types that are a natural part of our environment, or biosphere, gives designers opportunities to engage in how materials perform, change and patinate when exposed to external environments, and how an understanding of materials' natural processes of transformation when exposed to the external climate can inform initial design decisions. Facades for buildings should be considered not only shields from uncontrolled environmental conditions, but to be designed to navigate, contribute, enhance and mend our local and global environment. The North Atlantic island of Bermuda has no fresh-water springs, rivers or lakes. It is therefore entirely dependent upon capturing rainwater and desalination plants.12 Each house is required to collect rainwater from roofs and provide water storage equivalent to 8 gallons for every square foot of livable space. The roofs themselves are constructed from limestone and painted every two years or so with a lime wash. Many houses also have lime-washed facades, resulting in a strong architectural expression often compared to wedding cakes. The use of limestone as the principal material that receives rainwater for collection however is not about an aesthetic but has more practical reasons. In Bermuda, the architectural facades offer a way of 'cleansing' the rainwater for drinking. Firstly, the white color is credited for reflecting rather than absorbing ultraviolet light. This means UV light helps to sanitize the water. The lime-based mortar also has an antibacterial quality helping to keep the rainwater clean. Rainwater has an acidic content due to, for example, acid-rain as a result of industrial pollution. Lime however is an alkaline, and so when mixed with the water can contribute to neutralize the acidic levels of rainwater thereby reducing negative pollution for drinking and further detrimental consequences for plant life as rainwater enters the earth.

The Bermuda lime example describes how a community has found practical solutions through necessity and how the careful application of external material choices can contribute positively to our environment that goes beyond pure aesthetics. It promotes a mindset whereby facades are seen as navigating with our external environment so that they negotiate with external environmental conditions to not only provide shelter, but to respond in a manner that assists in repairing the detrimental damage done by mankind to our ecosystem. A kind of ecological engineering practice using external material whereby sustainable ecosystems become part of design development and implementation to establish synergies of new and existing needs of human society with its natural environment. But designing for mutual benefit. "Ecological engineering uses ecology and engineering to predict, design, construct or restore, and manage ecosystems that integrate "human society with its natural environment for the benefit of both".14 Significantly however is the need for humankind to attempt to repair our ecosystem. New building practice and using designs of building fabrics, for example facades, can facilitate this.

Fig 3: Bermuda Roofs. Photo Samantha Clark https://blogs.lt.vt.edu/samclark95/2013/11/17/bermudas-architecture/

"Ecological engineering, defined as the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both, has developed over the last 30 years, and rapidly over the last 10 years.

Its goals include the restoration of ecosystems that have been substantially disturbed by human activities and the development of new sustainable ecosystems that have both human and ecological values."15. The prospect of development of new sustainable ecosystems that have both human and ecological values in facade and building design is tantalizing, as the role of a buildings envelope goes beyond aesthetics and climatic protection, to establishing habitat for systems that contribute positively to our changing environment rather than resource consuming that produces a negative carbon footprint. This approach promotes thinking of facades as places for colonization, that facades can be designed and constructed from building material that can be colonized by living organisms, known as bio receptivity. The term, bio receptivity, first introduced by Olivier Gillette in 1995, describes the ability of a building material to be colonized by living organisms.

"… the term 'bio receptivity' as the aptitude of a material (or any other inanimate object) to be colonized by material (or any other inanimate object) to be colonized by one or several groups of living organisms without necessarily undergoing any biodeterioration. The word 'colonize' is important since it indicates that conditions for harboring, development and multiplication have to be met and excludes the ability of a material to receive living organisms in a transient and fortuitous manner. It implies that there is an ecological relationship between the material and the colonizing organisms."16. As a specific example, the Department of Construction Engineering, Universität Politècnica de Catalunya, UPC, studies have been carried out in incorporating living organisms, such as photosynthetic organisms, on building envelopes to stimulate the development of patinas of biological origin on the surface of building materials.

"At UPC (Barcelona, Spain), we have developed a multi-layered concrete panel for the development of green facades. This patented material is composed of four layers (Manzo et al., 2013). The first layer consists of conventional concrete and is responsible for the structural function of the panel. The main function of the second layer is to protect the first layer from ingress of water and noxious substances. Furthermore, it acts as a bond layer between the inner and outer layer. The function of the third layer is to stimulate the development of the biological patina. It represents an anchorage site for airborne microorganisms and a niche for microbial growth. Finally, the fourth and last layer is a discontinuous one in order to allow different designs of the surface. Exit of water is then redirected to the areas without this fourth layer, promoting better local conditions for colonizing organisms." Research applications into bio receptivity assumes building material (principal facades) to be receptacle to colonization, that material has a porosity to colonizing from airborne microorganisms but is dependent upon airborne living organisms to attach themselves to a facade material for example. The most recent examples of material research and testing that I have carried out takes a more proactive stance in the sense that organic substance is embedded into material components to operate as a substrate and nutrient to and for organic growth. This work is an extension to previous research into recovered plastics as potential building material.17 "…the outer skin of buildings are seen as a climatic barrier protecting the inner layers of moisture and temperature variations, like a skin protecting the building within. Traditionally (Denmark), the preferred material has been bricked as clay can be locally sourced. Due to advancements in building demands – higher constructions, sustainable agendas, internal comfort, especially natural daylight – other materials are being adopted, normally using a dry assembly technique and promoting prefabrication. Panels. Our research development was to begin tests into using recovered plastic as a potential cladding, with a focus on the statement of intent,....... i.e., plastic to be understood as a species – that the composition of the material in question and its inherent DNA, metaphorically speaking, is a means to achieving a high level of architectural design articulation and detail."18

Fig 4: Recovered Plastic facade. Photo. © Chris Thurlbourne

Fig 5 : Plastic growth with sawdust. Photo © Chris Thurlbourne

Plastic is probably one of the principal materials that is a long way from being termed organic. It is non-organic, and one of the materials principal challenges is that it does not biodegrade at a fast rate, if at all. It therefore is either burnt or ends in landfill. In Denmark however, infrastructure has been set in place to recycle as much plastic as possible giving scope for establishing new uses for recovered plastic.19 This material has had a previous life, and is available for a new, after-life. In my research I suggest it can also be a host for new life - to be receptive to colonizing living organisms, in particular organic plant species that will attract and promote wildlife such as insects that in turn attracts birdlife. The examples tested use organic substance embedded into recovered plastic material components to operate as a substrate and nutrient to and for further organic growth. As recovered plastic is cleaned and shredded before becoming available for heating and remolding, it creates an ideal opportunity to mix the material with other materials - organic materials that provide a substrate for plant growth. Shredded plastic is granular and can be readily mixed with additional materials. After sourcing domestic plastic waste products, I shredded the plastic in a customized hand built shredding machine. This created rough shavings that I then mixed with sawdust as the first experiment. The mixture was placed in a metal form and put in a low heat oven for a couple of hours. Once the plastic was soft the form was put under pressure whilst cooling, thereby compacting the material composite, and containing the plastic ensuring it did not distort whilst cooling. The low temperature during firing also ensured the sawdust did not ignite, and the nutrients not burnt away. Examples have been left outside for some weeks (months), and it is clear colonization occurred relatively quickly due principally to the sawdust's ability to absorb moisture. The plastic on the other hand, as an oil-based material is resilient to moisture and does not root. The next exploration was following the same recipe but using seaweed as the nutrient. Seaweed is being introduced into buildings as a building material. Eelgrass, a type of sea bound grass, has been developed as a raw material source for paneling. A Danish company, Søuld20 has developed different types of paneling and have established themselves as experts in the field to convert the material into CO_2-storing building materials that combine a high degree of acoustic performance with quality aesthetics.

"Working together with local farmers, municipalities and ecologists, Søuld has optimized eelgrass collection based on environmental protection and the preservation of natural eelgrass meadows. The CO_2-binding sea plant is found washed ashore along Denmark's coastline as an abundant, renewable and overlooked local resource. The plant absorbs significant amounts of CO_2 while growing in the sea and therefore serves as a carbon sink when used in construction."21 I sourced dried seaweed as it is more manageable for my process. Seaweed, when wet, can however regrow and when my experiments were placed outside the seaweed did in fact begin to expand putting pressure on the reformed plastic.

Another experiment is with horse manure. This is often used as fertilizer in agriculture so is well known for its ability to provide a source of nutrients to plants. This, to date, has not had sufficient time outside to test the potential for colonization, but although all these experiments are at an early stage, it is clear with the results so far there are potentials in the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both. Both through sustainable, eco engineering as a framework, but also to develop a new aesthetic for building facade systems that embraces our ecosystem in new, exciting ways.

Fig 6 : Plastic with Seaweed.
Photo © Chris Thurlbourne

CONCLUSION

Another experiment is with horse manure. This is often used as fertilizer in agriculture so is well known for its ability to provide a source of nutrients to plants. This, to date, has not had sufficient time outside to test the potential for colonization, but although all these experiments are at an early stage, it is clear with the results so far there are potentials in the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both. Both through sustainable, eco engineering as a framework, but also to develop a new aesthetic for building facade systems that embraces our ecosystem in new, exciting ways.

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BIO- SOLAR ROOFTOPS FOR SUSTAINABLE BUILDINGS: A REVIEW OF BENEFITS AND LIMITATIONS

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ABSTRACT: *A green or sustainable building is one that fulfils the functional requirements of its users without any or minimum harm to environment because of its design and characteristics. As per the world green building council, green buildings may save energy up to 30 - 40%. Energy demand is growing across many countries in the world, dealing with the energy problem is one of the challenges humanities confront in the twenty-first century. While energy consumption is expected to rise in all end-use demand sectors, the buildings sector is expected to grow rapidly with an average annual growth rate of 1.6 per cent globally. Renewable energy is often seen as a cornerstone in our move towards a more sustainable future. Bio roof integrated with solar panels is not only good for thermal performance of buildings but also produce clean energy. This paper presents an overview of the role of PV green roofs (bio-solar rooftops) as part of sustainable buildings and their advantages worldwide. Study also tries to assess the challenges and opportunities for Bio-solar roof tops in Indian climatic conditions.*

KEYWORDS: Sustainable buildings, green terraces, Renewable energy, Energy efficiency, Bio-solar rooftops, Energy demand

INTRODUCTION

Commencement of the twenty-first century marked the beginning of the construction industry. Now, everyone is constructing modern structures using the most advanced materials and techniques. The majority of these structures use energy inefficiently, generate substantial amounts of waste during their construction and operation, and release substantial amounts of pollutants and greenhouse gases. Green buildings aim to use land and energy efficiently, preserve water and other resources, enhance indoor and outdoor air quality, and increase the use of recycled and renewable materials, in contrast to conventional buildings. (Jahanfar et al., 2019)

The Office of the Federal Environmental Executive presents a helpful working definition of what makes a green building, despite the concept's ongoing evolution. This organization defines this term as the practice of

1. increasing the efficiency with which buildings and their sites use energy, water, and materials, and
2. reducing building impacts on human health and the environment, through better siting, design, construction, operation, maintenance, and removal—the entire building life cycle.

Environmental Protection Agency (EPA) definition of green building: The discipline of developing structures and employing techniques that are ecologically responsible and resource-efficient across a building's entire lifecycle, from site selection to design, construction, operation, maintenance, renovation, and deconstruction (Awadh, 2017). This method expands and complements the traditional building design considerations of economy, usefulness, durability, and comfort. Green building is also characterized as a 'high performance' or 'sustainable' building. Both definitions include life cycle assessment (LCA). LCA is the research and evaluation of a product's environmental, economic, and social implications. In the context of green buildings, life cycle assessment (LCA) considers a material's embodied energy, the solid waste generated in its extraction, use, and disposal, the air and water pollution associated with it, and its contribution to global warming (Energy, 2001).

THE MOST IMPORTANT ELEMENT: THE EFFICIENT USE OF ENERGY

It is difficult to establish that a building is truly green if it does not use energy efficiently, despite the fact that it may have many green features. In reality, due to the ambiguity of the label "green building," some individuals prefer the term "high performance building." A high-performance building is one whose energy efficiency and environmental performance are significantly superior to industry standards. Although green buildings use less energy than traditional buildings on average, energy efficiency remains elusive. In fact, there is a growing controversy as to whether buildings that attain a certain level of LEED certification utilise energy more efficiently than standard buildings (Kaewpraek et al., 2021). There are several techniques to improve the energy efficiency of a building, like installing automatic light switches and insulating the walls. Local and state energy codes can and frequently do mandate energy efficiency, requiring new and substantially modified buildings to meet with increasingly strict energy efficiency criteria. If a building is not energy-efficient, it cannot be considered environmentally friendly.

THE REALITY OF THE BUILT ENVIRONMENT: EXISTING BUILDINGS AS A PROBLEM

Although green buildings represent the next generation of buildings, the vast majority of structures are not green, and these structures will continue to be utilized for many years. Retrofitting is the traditional method for improving the energy efficiency of existing structures, which can involve anything from installing more energy-efficient fixtures to boosting a building's insulation. The U.S. Green Building Council has a rating standard for existing structures called LEED-EBOM (EBOM stands for "operation and maintenance of existing buildings") (Energy, 2001). Existing building greening receives less attention than new green building construction, yet it is unquestionably more significant for lowering the global environmental effect of buildings. Conventional Building Effects that Green Buildings Aim to Correct The environmental implications of structures are immense. Conventional buildings require substantial amounts of energy, land, water, and raw materials to develop and operate. They are responsible for significant greenhouse gas (GHG) and other damaging air pollution emissions. In addition, they generate substantial volumes of construction and demolition (C&D) waste and have severe effects on plants and animals. An examination of these difficulties reveals the scope of the issue. Using Energy in Buildings Globally, buildings utilize enormous amounts of energy. According to the United Nations Environment Programme, 30–40 percent of all primary energy produced globally is consumed by buildings. According to a 2018 report by the International Energy Agency, existing buildings account for more than 40 percent of the world's total primary energy consumption and 24 percent of worldwide CO2 emissions. (Gremmel Pacher et al., 2021; Lakshmanan et al., 2017).

ENERGY CONSUMPTION AND ENERGY EFFICIENCY

The building's heating, ventilation, and air conditioning (HVAC) system is major energy consumer. A building's heating and cooling energy consumption can be reduced if the HVAC system is designed and built correctly. A heating, ventilation, and air conditioning (HVAC) system consists of a heater, air conditioner, and fan, and operates at a partial load virtually always. The HVAC system is designed to conserve energy by monitoring airflow and maintaining a relatively consistent indoor temperature. A properly built HVAC distribution system will limit the quantity of airflow (and consequently energy) required to heat and cool a building. Additionally, allowing building occupants to individually adjust heating and cooling in their living and working spaces is an excellent method for reducing energy consumption. (Ali et al., 2018; Schindler et al., 2018). Approximately one-quarter to one-third of the energy in a typical business building is consumed by electric lighting. Effective and efficient lighting minimizes the size of a building's air-conditioning plant by reducing the amount of energy needed for lighting, which generates heat. Building information modelling (BIM) allows design and construction teams to develop and test the building's running systems, such as electricity and hot water, in a single computer model. Building Information Modelling (BIM) can facilitate quantitative energy analysis by integrating complex systems and enabling more precise analysis for more efficient energy consumption.

Fortunately, there are numerous ways to increase the energy efficiency of a structure such as weather-stripping, maintaining entry door closers, and installing storm windows as a low-cost alternative to replacements. In addition, adding insulating materials to new and existing frame buildings is a proven and very inexpensive approach to increase the heating and cooling energy efficiency of a building. New advances in insulation can minimize the amount of energy required to manufacture insulation and make it recyclable or biodegradable. (Dimond & Webb, 2017)

METHODOLOGY

This literature review provides a critical critique of current research into PV-green roofs, and this part discusses the search methods used to conduct this systematic review of the literature. A thorough and broad analysis of the literature can provide important information about the fundamentals of PV-green roof applications in sustainable building design and point to future research directions. The key steps for collecting literature were as follows…

1. Preliminary search – Identify paper based on keywords.
2. Content selection method – Select papers on the basis of topic and abstract.
3. Screening and final selection of papers after the reviewing the content.

The primary purpose of this investigation is to supply exhaustive details on the PV-green roof. This review also covers the problems that need to be considered prior to the implementation of PV-green roofs on a big scale and includes those discussions in its scope. In conclusion, the research suggests the potential pathways for adopting green energy through the interaction of various renewable energy practices on the scale of buildings in order to increase power output from green roofs and provide ecological and stormwater management benefits. This is accomplished in order to fulfil the goals of the study.

BIO- SOLAR ROOFTOPS: INTEGRATION OF SOLAR PV PANELS ON GREEN ROOFS

Green roofs, one of the primary pillars of sustainable architecture and urban green infrastructure, can meet the need for safeguarding and integrating dense urban environments. Another use of the lower metabolism strategy is the progressive substitution of fossil fuels with renewable energy. At the building scale, photovoltaic panels, micro wind turbines, and solar thermal can be used to generate energy and warm water, respectively. In terms of metabolic equilibrium, cities can produce energy while also providing habitats to restore natural cycles and ecosystem services. Despite the fact that the cooling effect of vegetation and substrate on optimizing panel performance has been demonstrated, the combination of the two systems on rooftops has not yet been used systemically. (Shafique et al., 2020)

Fig. 1: Bio- Solar Rooftop
Source: https://www.architectmagazine.com/technology/rooftop-systems-integration_o

In fact, one of the most important characteristics of green roofs is their capacity to provide many benefits on the same area, frequently at the same time. These include the improvement of the energetic and acoustic behavior of buildings; the reduction and amelioration of storm water runoff; pollution abatement and carbon sequestration; the regulation of the local microclimate and the reduction of the urban heat island effect, particularly when combined with ground-level vegetation; the provision of recreational space; the provision of habitats for wild flora and fauna; and the implementation of the urban ecological network. Indirect economic advantages include the protection of the waterproof membrane beneath the substrate, so extending its lifespan, and the increase in property value.

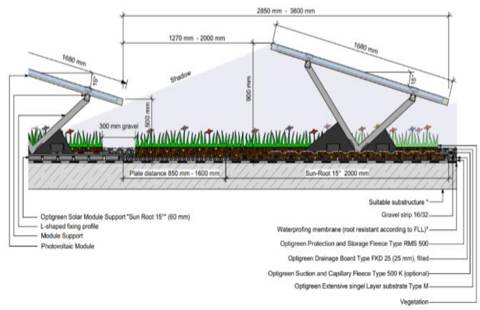

Fig. 2: Section of Bio-Solar Rooftop
Source: https://www.spaceacademy.net.au/spacelab/notes/solpanel

Solar panels capture clean, renewable energy in the form of sunshine and convert it into electricity that can then be utilized to power electrical loads. Vegetation increases the efficiency of solar and photovoltaic panels as a result of its cooling impact and reduced accumulation of particulate matter. A similar improvement might be realized in highly reflecting roofs (white or cool roof) with factory albedo values between 0.70 and 0.85. However, the albedo of installed roofs will diminish over time due to dust deposition and the development of fungi and algae. Therefore, the membrane has a shorter lifespan and higher energy consumption over its life cycle than if it were protected by a green roof. In addition, initiatives to use cool roofs as a global strategy to combat global warming are deemed insignificant.

The integration of green roofs and solar PV panels, also known as Green Roofs Integrated Photovoltaic Systems, is a win-win solution that brings the benefits of greened surfaces to otherwise sterile and unusable roof tops while increasing the PV efficiency. On the other hand, the shade provided by the panels reduces evaporation rates and drought stress, contributing to the diversity of plant and insect species (Arenandan et al., 2022; Elibol et al., 2017; Li & Yeung, 2014).

The cooling effect of green roofs is not primarily attributable to their albedo, but rather to the loss of latent heat through evapotranspiration. Therefore, plant selection is critical, with the Leaf Area Index (LAI) of the vegetation being the most influential factor. LAI is the leaf area per unit of ground area covered by the projected area of the crown, and it influences:

how vegetation reflects incident solar energy and the ability to contrast wind speed and turbulence. Increased LAI keeps the air damp. Similarly, the substrate's depth, moisture content, and density all have a vital influence (Cook & Larsen, 2021).

LIMITATIONS OF BIO-SOLAR ROOFTOPS

The primary technical challenges associated with the implementation of PV green roofs as efficient practices for maximizing the power output of PV systems are outlined in the following paragraphs:

1. The PV-green roof is an efficient way for maximizing the power output of the PV system. Additionally, it provides a variety of social benefits as well as economic benefits, including the decrease of CO_2 emissions, the improvement of ecological and air quality, and the enhancement of social interaction in urban areas through the provision of green spaces. On the other hand, its widespread implementation is still hampered by the fact that people in developing nations (such as Pakistan, Bangladesh, India, and Sri Lanka, amongst others) do not have enough information about the advantages it offers. (Karakaya & Sriwannawit, 2015; Olowu et al., 2018).
2. The overall cost of the system is another potential obstacle that could prevent the installation of a photovoltaic green roof. Low-income nations are unable to afford the substantial initial investment required for the PV-green roof. Therefore, further research needs to be done to develop materials that are more cost-effective for PV-green roofs, to lower the cost of production, and to determine the possible commercial applications for the PV-green roof. (Alshayeb & Chang, 2018)
3. A significant obstacle in many parts of the world is the absence of legislation and regulations governing the use of photovoltaic green roofs. (Kaewpraek et al., 2021)
4. The geographical and architectural features of the locations are also important factors that have the potential to become a barrier to adoption. For instance, in metropolitan settings, the most significant barrier is the insufficient availability of suitable installation space for photovoltaic green roofs. For optimal performance, the photovoltaic green roof needs to be exposed directly to the sun.

FUTURE DIRECTIONS

By studying the PV-green roof, which is one of the most important roles in enhancing sustainability all over the world, this study makes a significant contribution to the research field of sustainable energy generation. The focus of this study is on the enormous benefits that the system can achieve in urban settings. This study makes it possible for researchers from a variety of fields to have a conversation about the overall benefits and problems of PV-green roofs. Despite the benefits of the PV-green roof that were discovered as a result of earlier research, its widespread use is still hampered by several hurdles. These obstacles need to be solved in order to improve the PV-green roof's global application. Some of the most significant obstacles are connected to the financial implications of the components of the material that are used in the production of PV-green roofs. (Barreca, 2016; Cook & Larsen, 2021). If future study considers the carbon sequestration benefits of green roofs, photovoltaic green roofs may become more commonplace in the not-too-distant future. This is since vegetation on green roofs and soil have a greater capacity to absorb and store carbon in urban settings (Gremmel Pacher et al., 2021). In view of these potential future possibilities, additional research into certain variables is required in order to make the PV-green roof safer and more environmentally friendly. For instance, there is a significant demand for additional experimental investigations to determine the materials that are both environmentally benign and ideal for use in photovoltaic green roofs in a variety of climate zones. This is because most of the research on PV-green roofs has been conducted in parts of the EU, which have climate and geographical characteristics that are extremely different from nations in Asia, such as China, Japan, Korea, Pakistan, and so on. This will result in a reduction in the additional costs for maintaining the green roof, such as the cost of fertilizers or irrigation. In addition, the expenses of maintaining PV systems, such as replacing PV system batteries or performing PV system regulatory monitoring, need to be factored into any future analyses (Chemisana & Lamnatou, 2014; Lakshmanan et al., 2017; Tibermacine & Zemmouri, 2017).

CONCLUSION

PV-green roofs, or the integration of a PV system and a green roof, is a novel and effective green practice for increasing the power output of a PV system. This study extensively analyzed the advantages of the PV-green roof system and the aspects that contribute to its performance over a prolonged period. This study provided a summary of the significant elements pertinent to the PV system, such as the position of the PV system above the green roof and the varieties of plants on the green roof. This report also identifies the significant obstacles that must be overcome to increase the future deployment of the PV-green roof. In the future, it will be necessary to conduct a large-scale experimental investigation during different seasons in order to provide a clear image of the PV-green roof's benefits. This research establishes a clear picture for the future development of a PV-green roof by highlighting the most significant components. Recent studies demonstrate that the scientific examination of the PV-green roof system is an emerging subject in sustainability. The research on PV-green roofs is anticipated to give academics and politicians with a greater knowledge of its global benefits and ramifications. More collaboration and interdisciplinary work is required to improve the PV-green roof's effectiveness.

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BUILDING ENVELOPE: SUSTAINABLE BUILDING ENVELOPE

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ABSTRACT: *Contemporary architecture, today, is highly influenced by shallow gimmickry in the name of 'Modern'. Due to the growing concern of global warming, there is an immediate need for understanding our responsibilities towards living in harmony with nature and how we can smartly adapt traditional as well as contemporary design elements to protect our structures from the prevailing vulnerable climatic conditions of wind, solar, humidity, temperature, etc. Many dimensions have been attributed to 'Sustainable design, and one of them is 'Building envelopes. Many buildings even today are built with their focus only on their façade treatment, ignoring the comfort level of the users and how it contributes to our carbon footprint. The research in this study is based on the analytical understanding of previously built sustainable designs in tropical climates (India). This paper is the study of an envelope design that prove aesthetically contemporary as well as sustainable. The purpose of this study is to look at the envelope design of a built structure which can contribute to keeping the internal environment comfortable and energy efficient. The paper will advance with the example of the already-built structure in tropical zones where its design parameters will be studied and explained to understand how it has helped to keep the internal environment comfortable with passive design strategies and has helped reduce energy consumption. Through analysis, this paper aims at explaining how we can plan envelope designs in an articulate and coherent way with passive techniques to make them more sustainable and energy efficient.*

KEYWORDS: Building envelope, thermal comfort, energy consumption, ventilation, Energy Efficient

INTRODUCTION/BACKGROUND

The concept of sustainability started when it was introduced by Brundtland Commission in 1987. Since then, every country is trying to play certain roles to globally make some difference by adopting various ways to contribute towards it. Every other day we find articles in the paper or hear some news on the internet about Global warming. With the kind of development seen around the world and the growing demands of mankind, we have started adopting new technologies and inventions which we think can increase our comfort. Although, every place invents or discovers new architectural practices, considering their needs and what fits their climatic conditions. But some practices try to follow aesthetically best designs to give a contemporary modern look. They fulfil aesthetic design protocols, but at times, at the cost of internal atmospheric comfort.

When we talk about the comfort of the internal surroundings of a structure, the most important features which affect these conditions are walls, windows, and roofs. These form the outer periphery of any building or structure, together we call it a building envelope. A sustainable building envelope is understood as a tough outer shell to the structure which takes care of the inner environment and protects it from the outer harsh conditions of climate by using creative sustainable facade elements. It not only helps in the energy efficiency of the building but also gives it a contemporary look. With the kind of modern innovations and different innovative and attractive elements being used for façade beautification, the comfort level of the inner environment and subsequently, the energy consumption is greatly affected creating a negative impact on the performance of the building.

To keep the inner environment sustainable and energy efficient the building envelope plays a major role. The facade design majorly decides upon the effects of Air, wind, sunlight, pressure, noise, etc. on the internal atmosphere of the building. With the growing numbers of global temperatures due to Global warming, it has become necessary for Architects to give mankind a safe, comfortable, and yet contemporary design for today's living.

Decades ago, the most practiced design was vernacular Architecture. Based on the climatic conditions, angle of the sun, wind direction, etc. the facades of the buildings or any structure used to be designed as per the material and skill available locally.

India has different climatic zones, and being a tropical country, has witnessed climate-based architectural practices in respective zones. Simultaneously, there was a tremendous Architectural boom all around the world with new concepts of designs and the use of new materials, leading to different types of building technologies. They were invented and discovered based on individual climate requirements, but being aesthetically glamorous were getting used even in tropical countries. Slowly, even the tropical countries started adopting new technologies and design practices which, certainly changed the skyline of the horizon. But unknowingly, the comfort levels inside the buildings got affected due to increased thermal levels. Roughly 90% of the buildings under construction today are in a contemporary style that pays little attention to a region's climate. Over the years, the users realized that the quality of internal comfort is compromised due to the increase in thermal levels inside the structure and consequently increasing the energy consumption to make the internal environment better. The impact of this is largely increasing the carbon footprint on the earth and consequently the increase in global temperature.

There are practices that still largely concentrate on sustainable methods and yet give a contemporary façade look. This study will show how by using passive methods and simple design elements, façade treatments can give a contemporary look as well as can successfully reduce energy consumption to give a comfortable internal environment in the structure.

AIM/PURPOSE

We can plan Envelope designs in an articulate and coherent way with passive techniques to make them more sustainable and energy efficient.

RESEARCH METHODOLOGY

To begin with, we will discuss how the different passive design elements on the facades play a significant role in providing a comfort zone inside the structure. Then we will discuss where they are used in the built project opted for the case study and how this technique has proved very useful in performing energy savings and giving a healthy internal environment.

CEPT, University in Ahmedabad has constructed an 'NZEB' (Net-Zero Energy Building) 'Living Laboratory' on its campus, which was taken up by 'CARBSE' (Centre of Advanced Research in Building Science and Energy) for its creation of building envelope design and testing its envelope components for energy simulation performance. They conducted thorough research on the various components, materials, and design strategies for the envelope design to get close to a net-zero energy building.

A thorough analysis was done on the climate of Ahmedabad and the site where it was going to be constructed. A pre-design analysis was done in tot suitable design solutions for massing, the orientation of the building, day-lighting and artificial lighting, natural ventilation, thermal comfort, HVAC, and renewable energy systems. And after a thorough study of various design strategies, a final design was executed on site which again was subjected to various continuous monitoring to assure the results expected at the design stage.

We now discuss the passive envelope design elements for how it works and then we will check for its application with the example of CEPT Living Laboratory at Ahmedabad.

CLIMATE TYPE

Ahmedabad has a hot semi-arid climate (Köppen climate classification BSh). There are three main seasons: summer, monsoon, and winter. Aside from the monsoon season, the climate is dry. The weather is hot through the months of March to June - the average summer maximum is 45°C (113°F), and the average minimum is 23°C (73°F). From November to February, the average maximum temperature is 30°C (85°F), the average minimum is 15°C (59°F), and the climate is extremely dry. Cold northerly winds are responsible for a mild chill in January. The southwest monsoon brings a humid climate from mid-June to mid-September. The average annual rainfall is about 76.0 cm (36.7 inches), but infrequent heavy torrential rains cause the river to flood, fulfil highest temperature recorded is 47°C (116.6°F) and the lowest is 5°C (41°F).[1]

PASSIVE DESIGN STRATEGY (WINDOWS AND FENESTRATIONS)

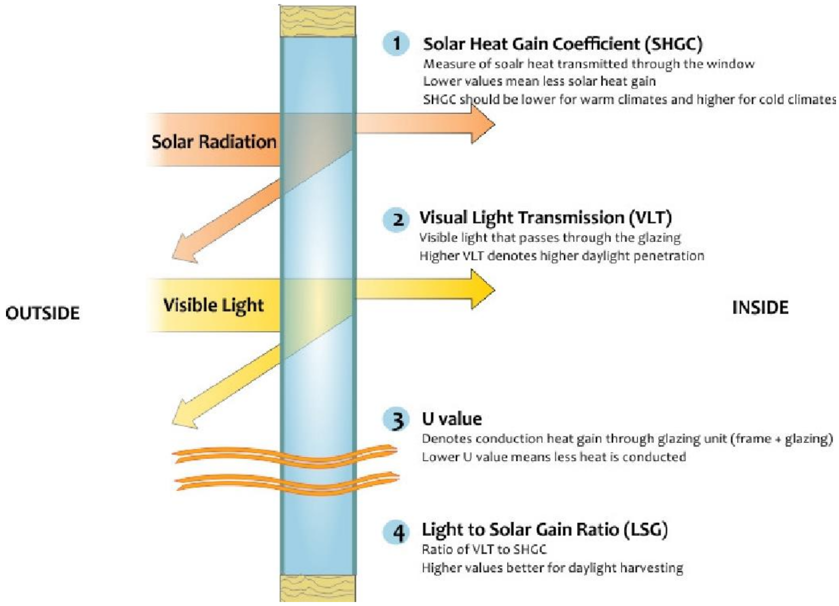

Fig. 1: Working of an Ideal Window detail.

Fig. 2: Double glazed window at CEPT Laboratory.

When we talk about envelopes, the major factors that affect the inner environment are heat gain and ventilation. And this heat gain and ventilation mainly depend on the orientation, sizing, and glazing of the windows or the fenestrations provided on the facades. India, being a tropical country, is located in such a way that the solar radiation intensity is minimum on the northern walls, followed by the southern walls, where the east and west walls receive the most throughout the year. The U-value of the glazing and Solar Heat Gain Coefficient (SHGC) should be lowered in hot climate regions and vice-versa in cold regions. This helps in maintaining a comfortable inner temperature and helps in reducing energy consumption.

In climates with significant air conditioning loads, specify windows, with low SHGC values (< 0.40). In general, high (>30%) Glass Visible Transmittance is desired, especially for day lighting applications.

PASSIVE STRATEGY AT CEPT LIVING LABORATORY

The building is oriented with a long side on an east-west axis, with no windows on the eastern and western walls to avoid the solar radiant heat and also to optimize day lighting. Most of the windows face South and North to reduce glare and maximize daylight. Windows on the south have deep projections to provide proper shading. The window-to-wall ratio on the south façade is 10% and on the North façade is 90%. Windows that are provided on the North-south walls have a uPVC frame with an insulated double-glazed unit (DGU) having Low-E glass. Visual light transmittance (VLT) of the windows is 39% with a solar heat gain coefficient of 0.29% (SHGC) and U-value of 1.7W/m2k.2.

PASSIVE DESIGN STRATEGY (THERMAL MASS)

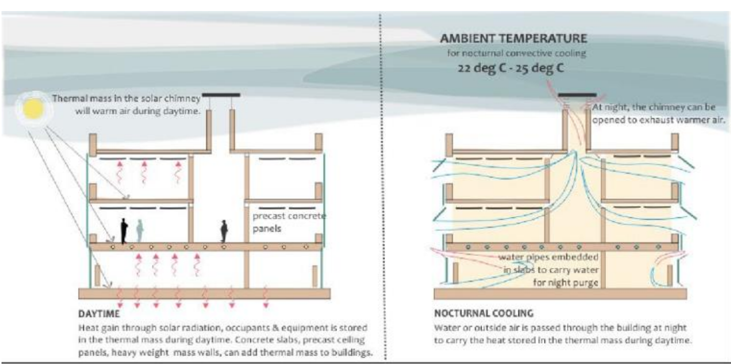

Fig. 3: How Thermal mass helps control inner temperatures.

Thermal mass plays a major role in achieving thermal comfort for the occupants, providing the required delay. Every material used for construction has a certain capacity to hold the heat for a certain amount of time, which when used appropriately helps control the inner temperatures. Different building materials can be used in combinations to achieve perfect and required thermal conditions for optimum energy savings.

The mass and density of building materials majorly affect the heat storage capacity inside the structure. High-density materials like stones, bricks, and concrete have high thermal mass whereas low-density materials like wood, and plastic have low thermal mass. Based on the requirement, its efficacy purely depends on where it is placed with respect to direct solar radiation.

Denser the material, the better it stores and releases heat. Such denser materials are very effective in places with large Diurnal temperatures range. Appropriate mass and color with low reflectivity have to be considered for better results. Dark, matte, or textured finish helps in absorbing and re-radiating heat, than light, smooth and reflective surfaces. Heavy thermal mass delays the ingress of heat, and when used with passive strategies and proper natural ventilation, can keep the building cool during the day even if it is hot outside.

Thermal insulation within the wall-make also helps in reducing the temperatures inside the building. There are a variety of insulation materials available such as fiberglass, mineral wool, rock wool, expanded or extruded polystyrene, cellulose, urethane or phenolic foam boards, and cotton. Depending upon the R-value of the insulation, appropriate material is used to achieve the required thermal comfort.

Also, care must be taken that providing insulation more than 100mm thick does not provide much benefit in terms of energy savings. The ideal thickness of insulation should be 25mm to gain maximum energy savings.

3.1 WALL SUPER STRUCTURE
u - VALUE (W/m^2)=0.42
R - VALUE (m^2 .K/W)=2.38

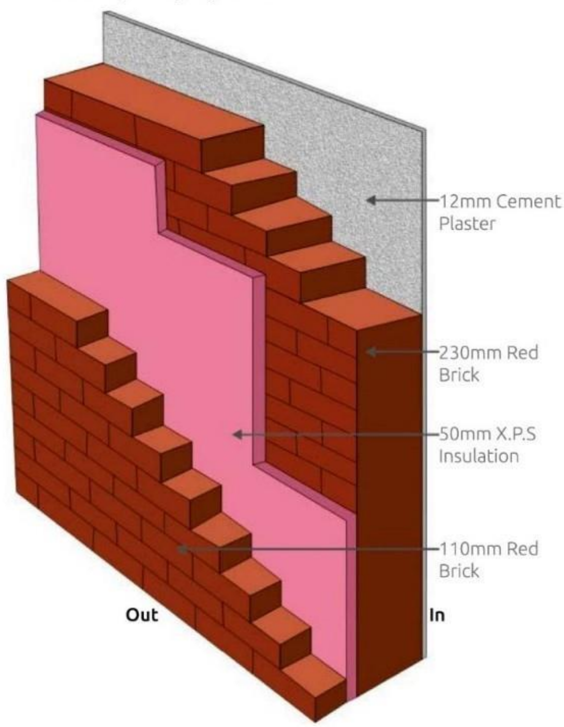

Fig. 4: General wall make at CEPT Laboratory

3.2 WALL BASEMENT
u - VALUE (W/m^2)=2.01
R - VALUE (m^2 .K/W)=0.50

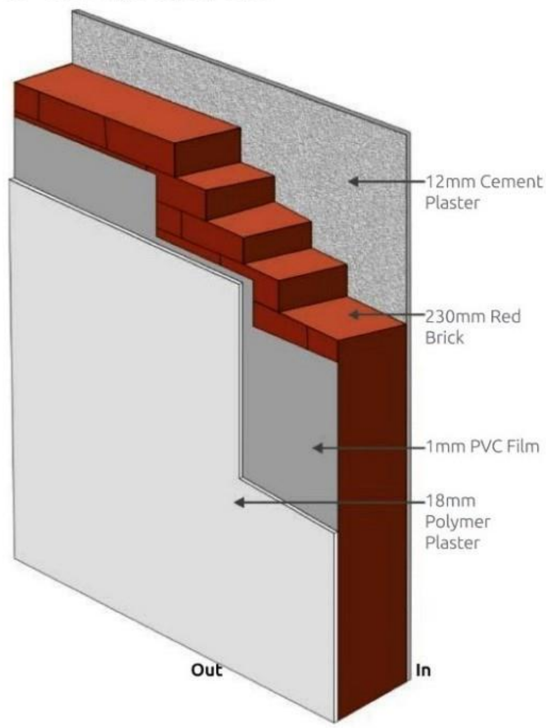

Fig. 5: Basement Wall make at CEPT Laboratory

PASSIVE STRATEGY AT CEPT LIVING LABORATORY

The ideal wall-make of the building should have been insulation on the outside and high thermal mass inside. But it did not align with the other buildings on the campus, so an additional brick layer was added on the external surface of the insulation. The outermost layer is made of a 110mm thick exposed brick wall followed by a 50mm thick XPS insulation layer and a 230mm thick cement-plastered brick masonry wall inside with a U-value of 0.42W/m2k. This helped in increasing the thermal mass of the building which helped operate in mixed mode during the day and night-time ventilation.3

PASSIVE DESIGN STRATEGY (ROOF)

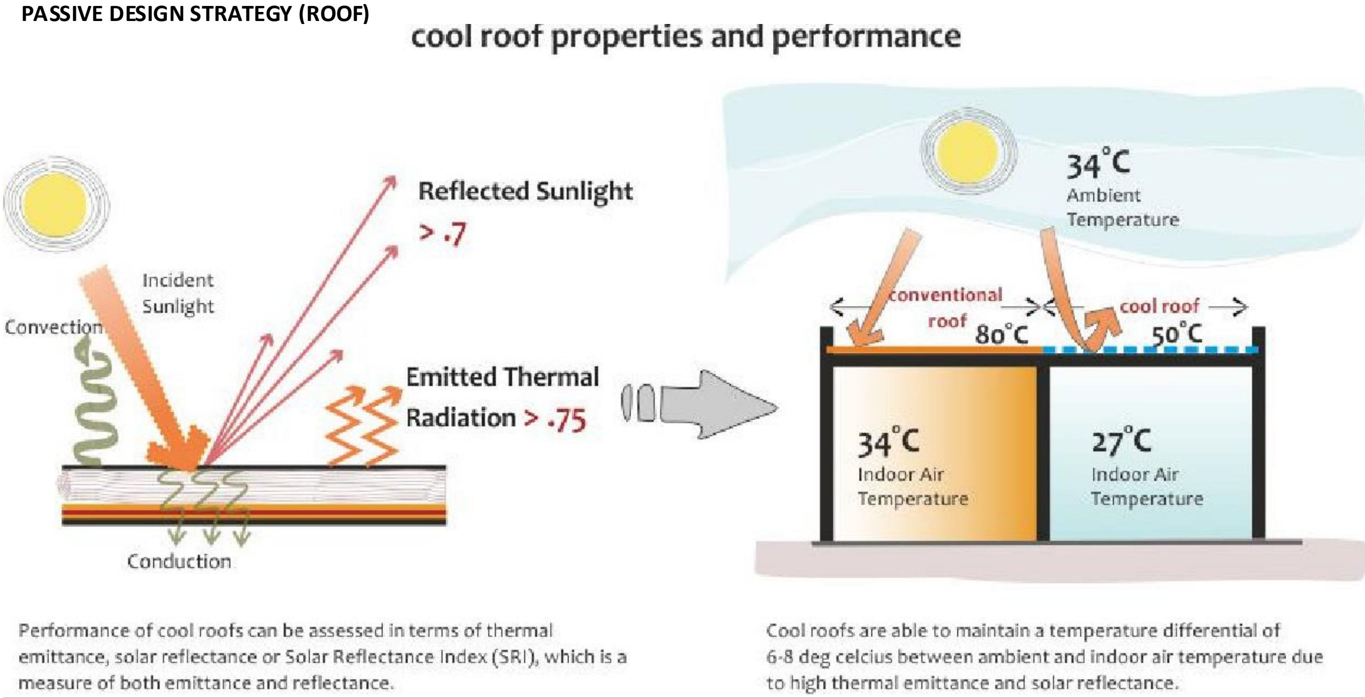

Fig. 6: How cool roofs help in maintaining inner temperatures

Just as we use light-coloured clothes to keep ourselves away from heat, roofs can be finished with solar reflective surfaces to keep the inner temperatures cool. Cool roofs provide maximum energy savings in hot climates.

Cool roof materials include the use of well-graded broken pieces 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 or simply finished with broken white glazed tiles. cool roof materials include the use of well-graded broken pieces 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 or simply finished with broken white glazed tiles.

Slate and tile products are available with solar-reflective surfaces that offer a wide range of cool colours. Concrete and clay tiles may be obtained in white, increasing the solar reflectance to about 70per cent (compared to the 20-30per cent range for red tile).

Additional measures like roof insulation, vegetative roofs, and solar panels can be used to inhibit the flow of heat from the roof to the conditioned space within a building.

Roof insulation reduces large heat gains through the roofs. Insulating roofs can reduce cooling loads by 5% to 8% and can lead up to a 10% reduction in annual energy use. Also, care must be taken that providing insulation more than 100mm thick does not provide much benefit in terms of energy savings. The ideal thickness of insulation should be 25mm to gain maximum energy savings.

PASSIVE STRATEGY AT CEPT LIVING LABORATORY

1.1 ROOF ASSEMBLY
u - VALUE (W/m²)=0.38
R - VALUE (m² .K/W)=2.654

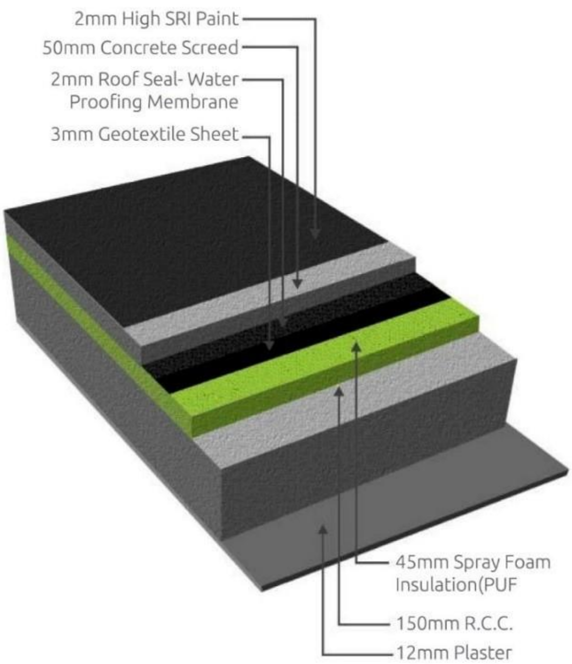

Fig. 7: Roof specifications of CEPT Laboratory

2.1 FLOOR- First Floor
u - VALUE (W/m²)=0.55
R - VALUE (m² .K/W)=1.82

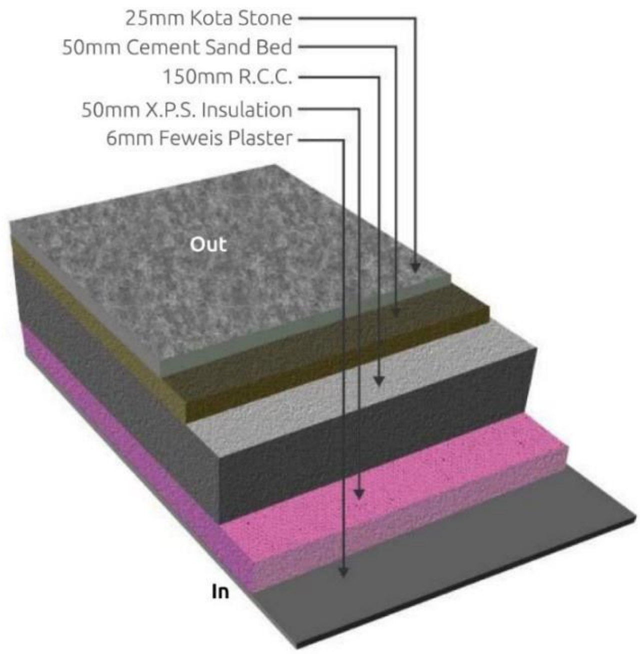

Fig. 8: Floor Slab at CEPT Laboratory

The roof of the structure is made of 150mm RCC with PENETRON waterproofing and a 45mm spray foam (PUF) insulation, geotextile sheet, 50mm concrete screed and high SRI (value 103) paint on the top (U = 0.38 W/m2K). It has inverted beams with 50mm XPS exterior insulation and a 50mm concrete screed painted with high SRI paint. The U-value of the rooftop is U= 0.38 W/m2K.

In addition to the above roof make, the roof is used for Radiant cooling system as the primary cooling system. False ceiling panels made of expanded graphite with anisotropic thermal character have been used for radiant cooling. The radiant ceiling panels are lightweight and contain expanded natural graphite materials with embedded water pipes designed for 15˚C supply and 20˚C return water temperatures. The ceiling radiant panels were selected instead of slab-integrated radiant panels to decouple system and building costs as well as to provide an opportunity to modify radiant panel design, layout, and research operation. The Solar photovoltaic cells provided on the roof not only generate electricity but also provide shade to the roof surface with a ventilated gap of 450mm between them.4

PASSIVE DESIGN STRATEGY (VENTILATION)
Fresh air is always the best solution for thermal comfort inside a structure. It not only comforts the occupants inside the structure but also largely reduces energy consumption, thus affecting air conditioning loads.

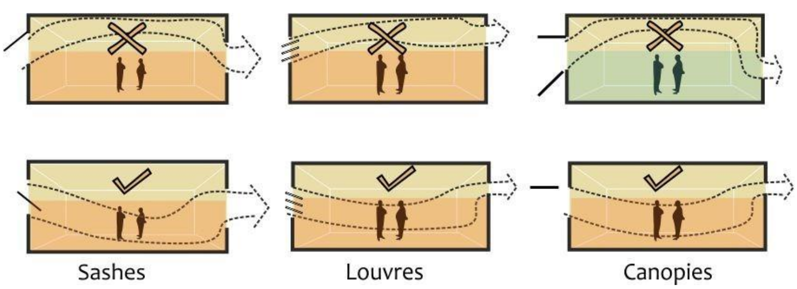

Fig. 9: Do's and Don'ts for the placement of windows while designing.

For better natural ventilation, the windows should be placed in opposite pressure zones. The building should be oriented 0 to 30 degrees to the prevailing wind direction, with the longer façade facing the wind direction. Maximum air movement is achieved by keeping the sill height at 85% of the critical height.

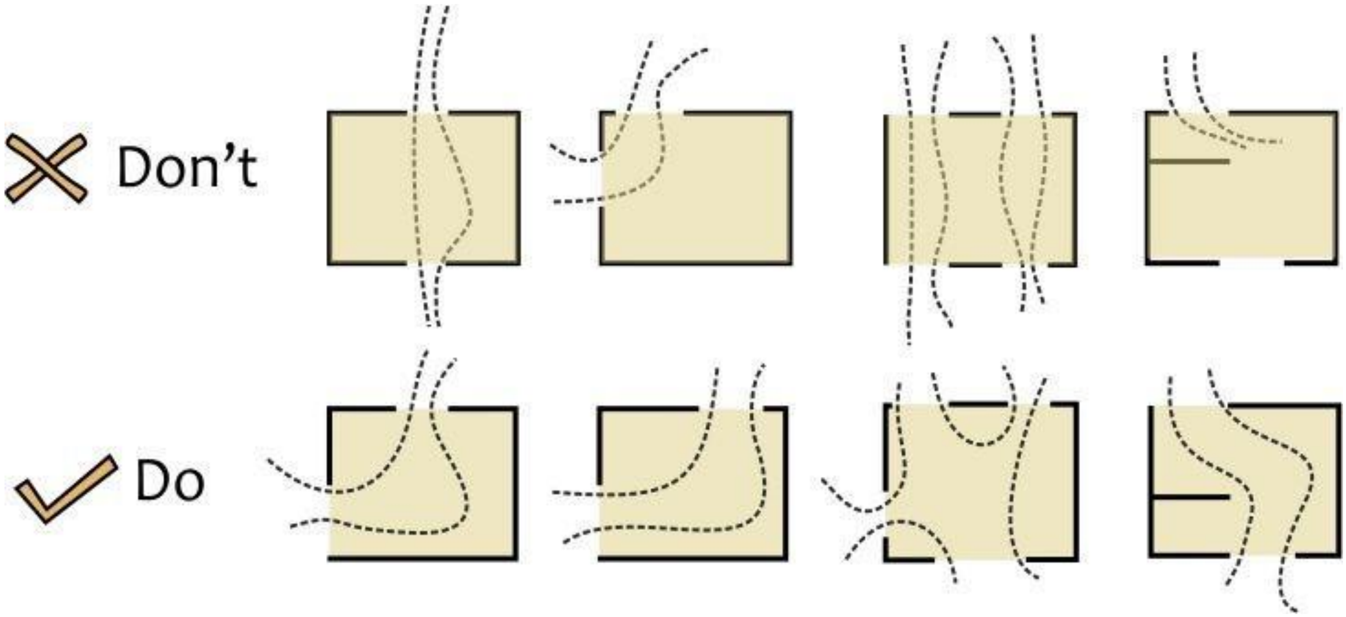

Fig. 10: Best possible alignment of the windows for better air circulation

- Windows should be scattered than aligned to cover the maximum area.
- Window-Wall-Ratio (WWR) should not be more than 60%
- In hot and dry regions, the windows should generally be kept closed during the day to minimize solar heat gains to interior spaces. For regions experiencing high diurnal temperature differences (of the order of 12°C to 15°C cooler at night), Interior spaces should be opened to night-time ventilation.
- In warm humid regions, openings should be designed to capture wind as ventilation is the key comfort defining criteria throughout the day.
- In cold regions, the openings should be kept shut with controlled ventilation.

PASSIVE DESIGN STRATEGY (HVAC)

The design of a building, the climatic zone and the operational parameters govern the energy requirements for comfort conditions. Reducing heating/cooling loads with passive design strategies and enhancing the efficiency of HVAC systems are the compulsory steps which are part of any energy efficiency policy for a building. Apart from selecting an energy-efficient system, it is equally important to select the appropriate size, make and system which helps achieve the desired results.

RADIANT COOLING SYSTEMS

In radiant cooling systems, the guiding principle is heat/cold transfer through radiation. In this system, the heat or cold transfer happens through the floors, ceilings, or walls which in turn are heated or cooled using embedded coils. Ideally, for heat transfer the coils are embedded in the floors and for cooling they are embedded in ceilings. Radiant cooling systems are generally installed in areas which have high latent loads and changes of air leakage from humid areas are high since the improper instalment of such systems can lead to condensation on building structural members.

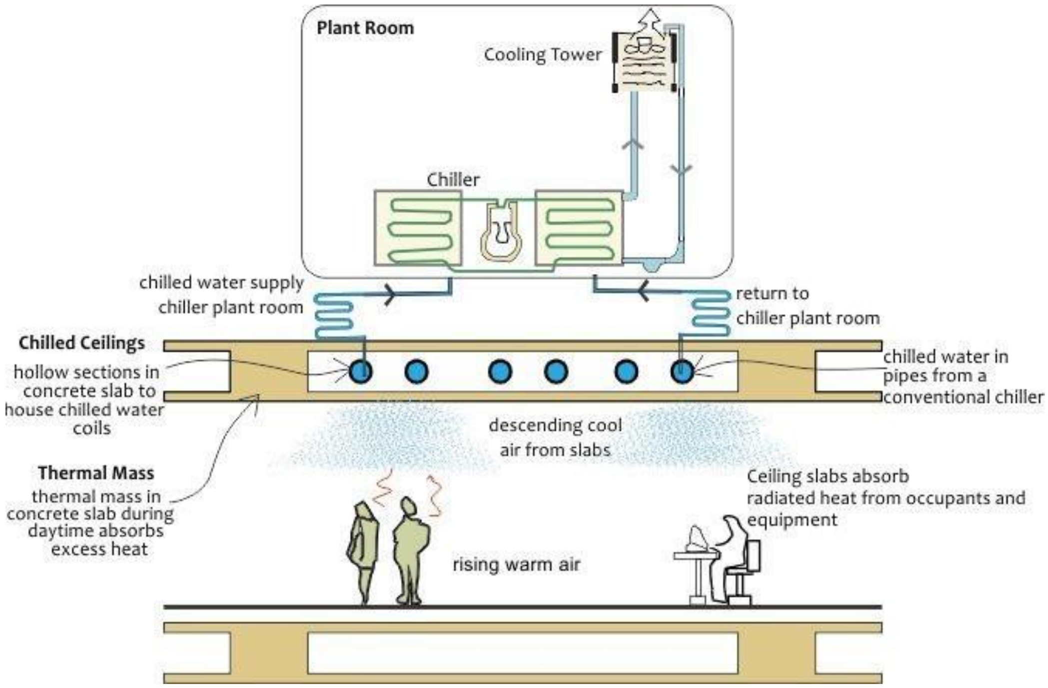

Fig. 11: Working of chilled ceilings slabs.

There are two types of Radiant cooling systems available:

1. **Chilled slabs-** These systems generally deliver cooling through building structures, mostly slabs, these are also generally called thermally activated building systems.
2. **Ceiling panels-** In these systems, specialized panels are used for cooling. Ceiling panels offer faster control and flexibility. Radiant cooling systems consist of coils embedded within the structure. These coils carry chilled water generated either through conventional electric chiller systems or low-energy chilled water generation systems like absorbent chillers, and desiccant chillers. Chilled water in the coils cools down the slab or panels which in turn act as heat sinks for sensible heat loads of internal spaces.

PASSIVE STRATEGY AT CEPT LIVING LABORATORY

The building is designed with a 3:1 building aspect ratio (length-to-width ratio) with a longer East-West axis. Window-to-wall ratios (WWR) optimized at 26.

South facing 30° inclined roof with 450mm high operable clerestories at two levels provide an opportunity for daylighting in addition to creating a stack effect.

Double-glazed high-efficiency operable windows have been installed near the occupants for the opportunity of direct ventilation and effective control measures. The windows are placed on opposite walls to facilitate cross-ventilation.

The stack effect strategy is being adapted with windows on the south wall and the clerestory windows at the top of the chimney on the northern wall. This helps throw the hot air outside the building through the stack effect and makes it comfortable for the occupants inside the building, eventually saving energy.

Radiant cooling is the primary cooling system. False ceiling panels made of expanded graphite with anisotropic thermal character have been used for radiant cooling. Two types of panels with pipes have been used, one type has Poly-Ethelyne Crosslink (PEX) pipes, and the other has copper pipes embedded within an expanded graphite panel. These panels carry supply and return water at temperatures of 16°C and 20°C respectively. The demand-controlled fresh air supply in the space is provided by staging fresh and exhaust fans. Natural ventilation coupled with Radiant cooling systems has helped in achieving great results in terms of energy efficiency.
Natural ventilation coupled with Radiant cooling systems has helped in achieving great results in terms of energy efficiency.5

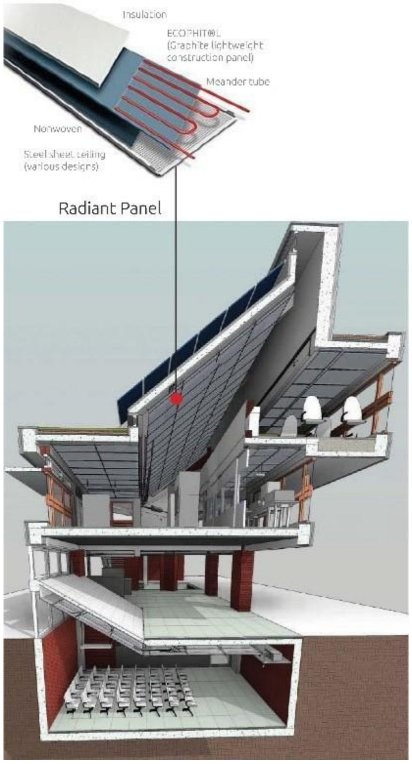

Fig. 12: Radiant ceiling panels used in CEPT Laboratory

FINDINGS/ANALYSIS & INFERENCE[6]

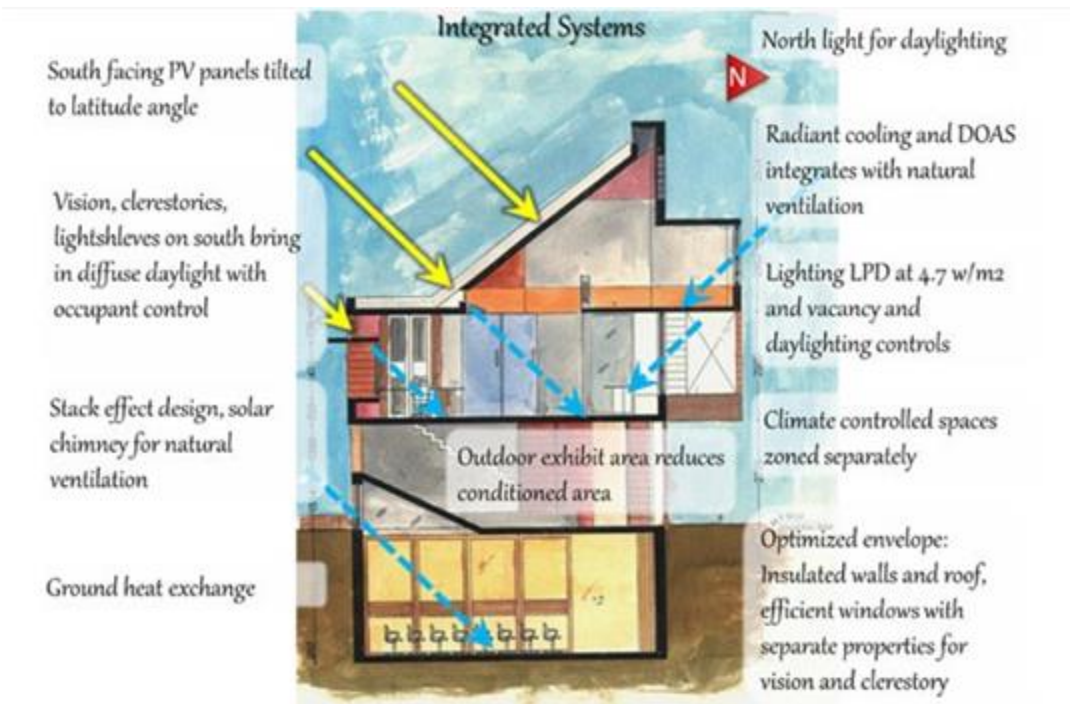

Fig. 13: The complete passive integrated system at CEPT Laboratory

After the building was designed in 2017, it was continuously monitored for its performance using a sophisticated and flexible control system called the Building Management system (BMS). The controls in this building incorporates an array of high-level accuracy sensors for research monitoring a well sophisticated and flexible control system allows us to conduct various research experiments on building energy efficiency.

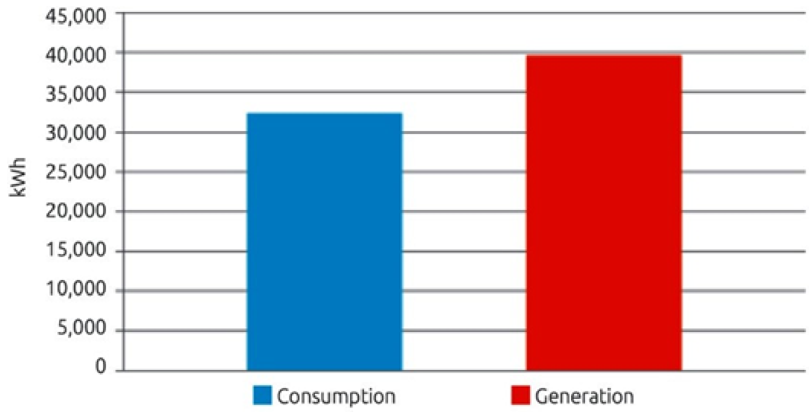

Fig. 14: Actual energy consumption vs. generation through PV panels for year 2016 (Vaidya & Ghatti, 2017)

Air conditioning and envelop monitoring systems have in-built controllers with networking capabilities (Ethernet port) and are integrated with the building management system. Envelope, energy, and environment systems have been specified with built-in controllers to integrate with the building management systems.

All plug loads in the structure are monitored using Smart Power Strips, which provide information for device IDs, usage time, and electricity consumed for each piece of equipment on the desk. Smart Power Strips are connected to a centralized server through Wi-Fi, which stores the data for every minute. Smart strips record a detailed understanding of usage pattern for various types of connected devices and also provide a load profile for the entire building to help develop strategies for plug load management. Electricity generated by solar panels and energy used in the building operations and research experiments is measured and monitored by using Smart energy meters1 connected with BMS. There are 48 sensors in the building used to measure dry bulb temperature, relative humidity, surface temperature and globe temperature which are connected with data nodes.

Outdoor weather data is equally important to analyze the performance of the building. So, A GSM / GPRS- based Automatic Weather Station (AWS) has been installed inside the CEPT campus.

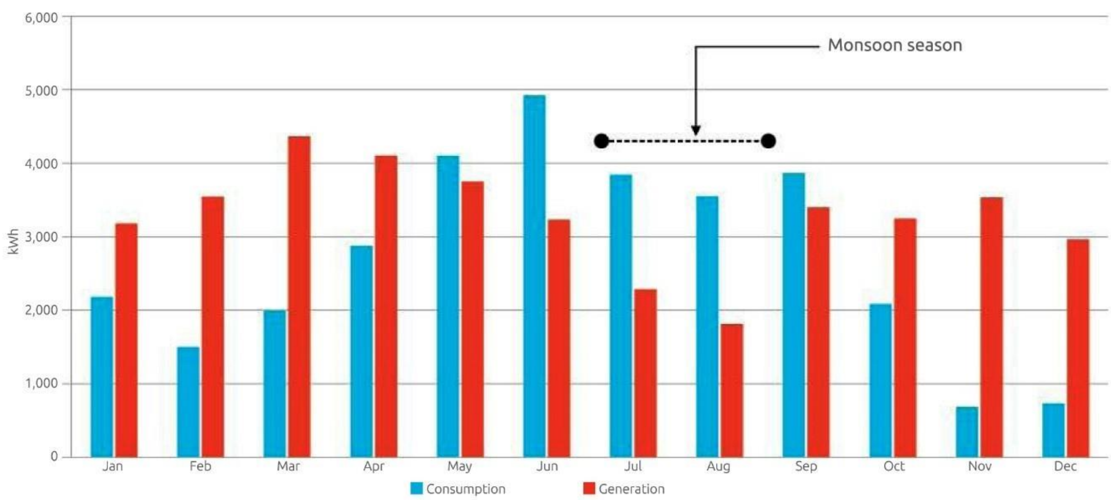

Fig. 15: Monthly Energy consumption and generation statistics in the year 2016 (Vaidya and Ghatti, 2017)

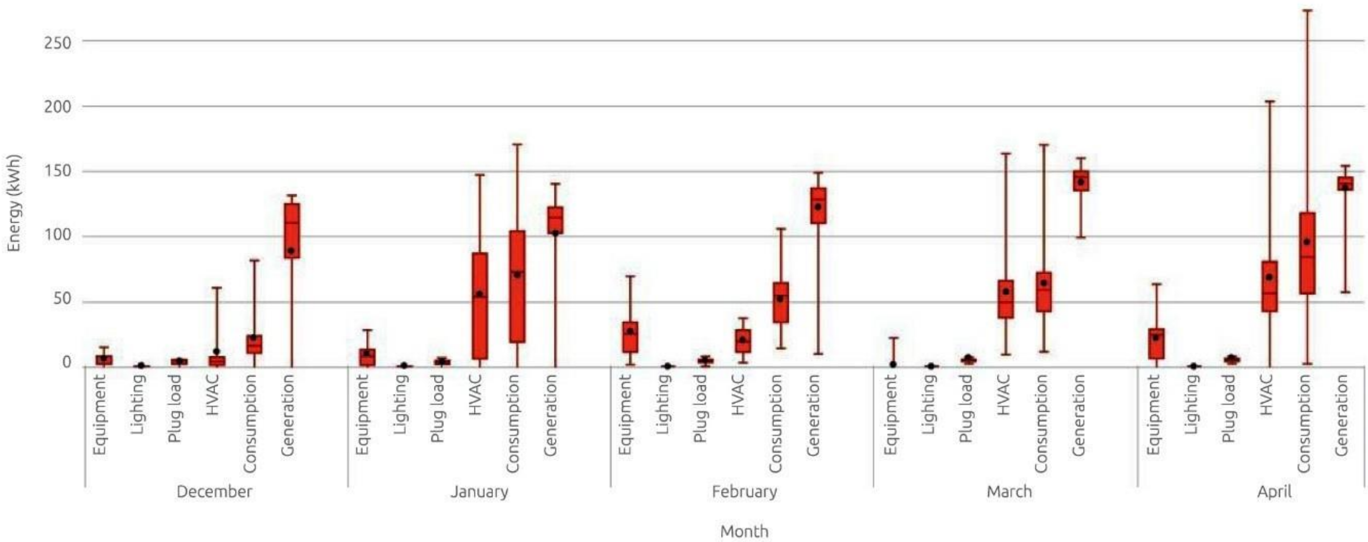

Fig. 16: Whisker plot of NZEB Energy consumption and generation pattern (Dec 2015-Apr 2016)(Behera, Rawal, & Shukla, 2016)

As depicted in Figure 14 to Figure 16, the annual solar power generation exceeds the energy consumed by the building and its systems.

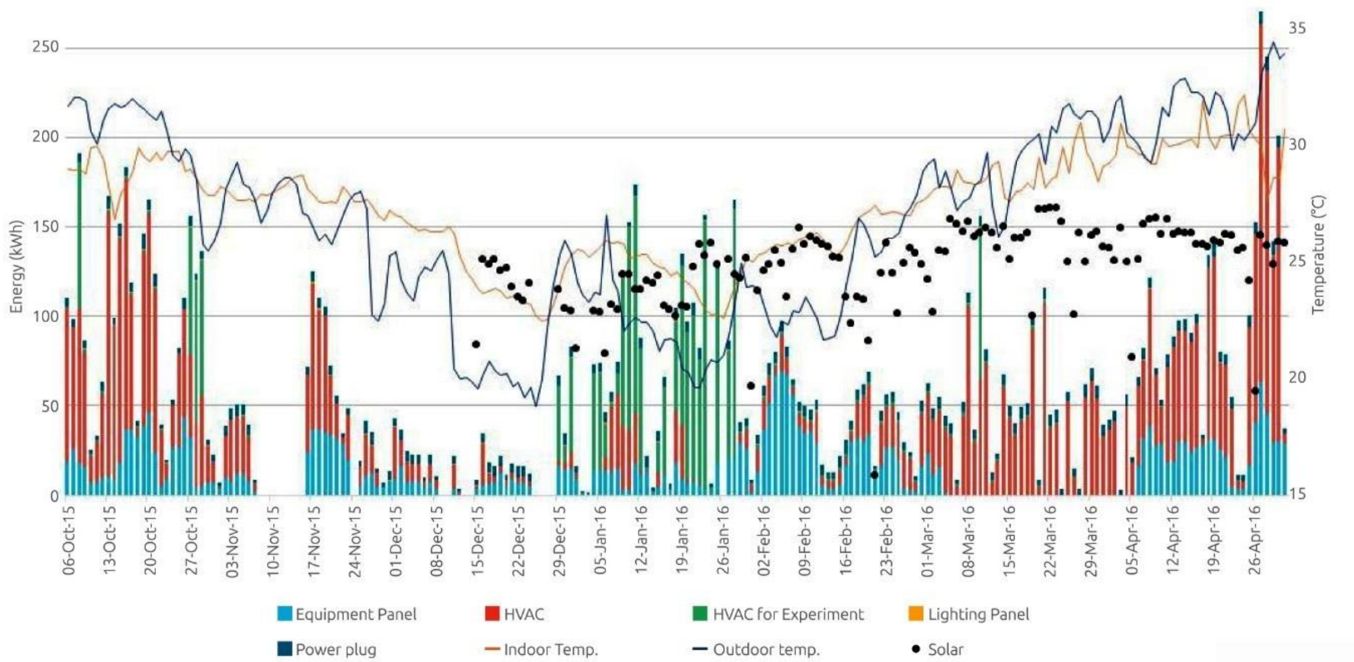

Fig. 17: NZEB energy vs environment plot

Energy consumption

The energy consumption and environmental parameters variation from October 2015 to April 2016, is shown in Figure 17 along with solar energy generation data. Here, indoor environment parameters have also been taken into consideration. Both outdoor and indoor temperatures that are considered for analysis are weighted average temperatures on daily basis. (Behera, Rawal, & Shukla, 2016)

1. The following things have been derived from the study made by CARBSE from the graph in Figure 17:
2. During winter (Nov 2015 – Feb 2016), the HVAC panel consumption is minimum.
3. As the outdoor temperature increases, HVAC energy consumption increases proportionately.
4. It can be observed that solar generation is considerably higher than total building energy consumption, most of the time.
5. Lighting load energy consumption is always negligible to other load energy consumption. This demonstrates the ability of the structure to perform well in terms of natural lighting.
6. HVAC consumes 50%, equipment consumes 38% and power plug consumes 12% of the total energy consumption.
7. At the end of April 2016, the HVAC energy consumption was a bit high as the radiant panel of the building had started on an experimental basis.
8. The period when data is missing indicates holidays. (Behera, Rawal, & Shukla, 2016)

BUILDING ENVELOPE

The building envelope of the structure is monitored by measuring surface temperature using HOBO data nodes. Following are some graphs plotted using year-long data (Sep 2016 – Aug 2017) of envelope surface temperatures of the structure:

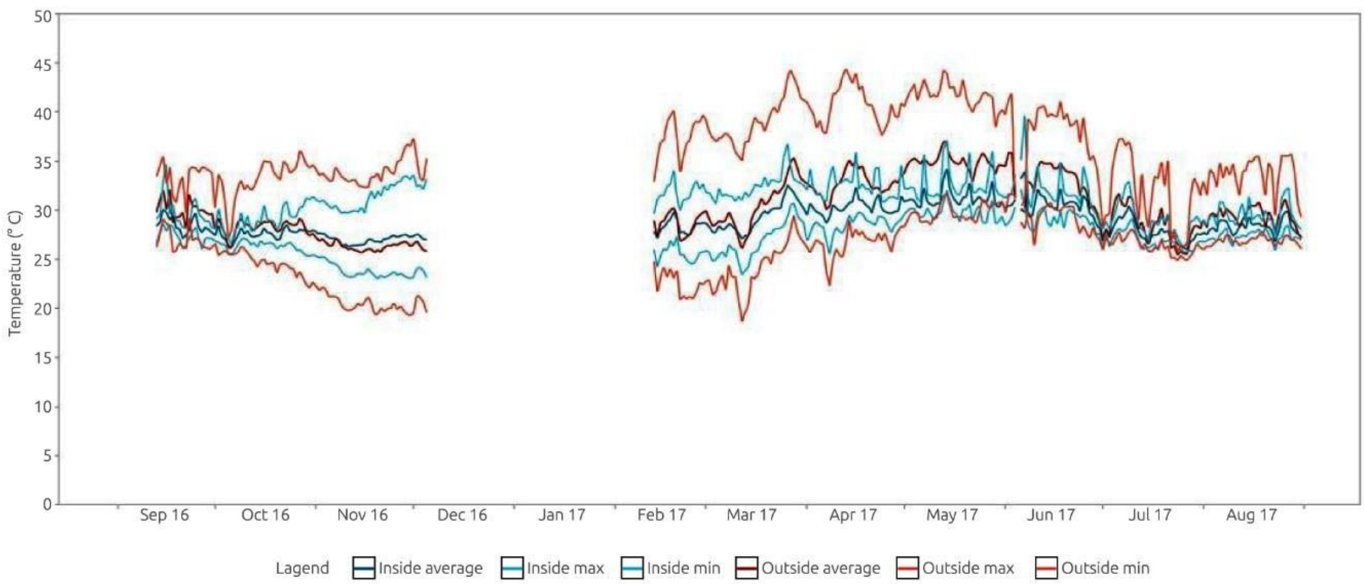

Fig. 18: Surface temperature (indoor and outdoor) near the admin desk on the first floor

Near Admin desk (First floor): The graph shown in Figure 18 represents the variation in average, maximum and minimum values of inside and outside surface temperatures measured near the admin desk on the first floor over the specified year. The wall in consideration faces the south direction. It can be seen that the indoor temperature range is significantly lower as compared to the outdoor temperature range during the hot summer months of April to June. During the monsoon and winter seasons, the temperatures remain close to each other.

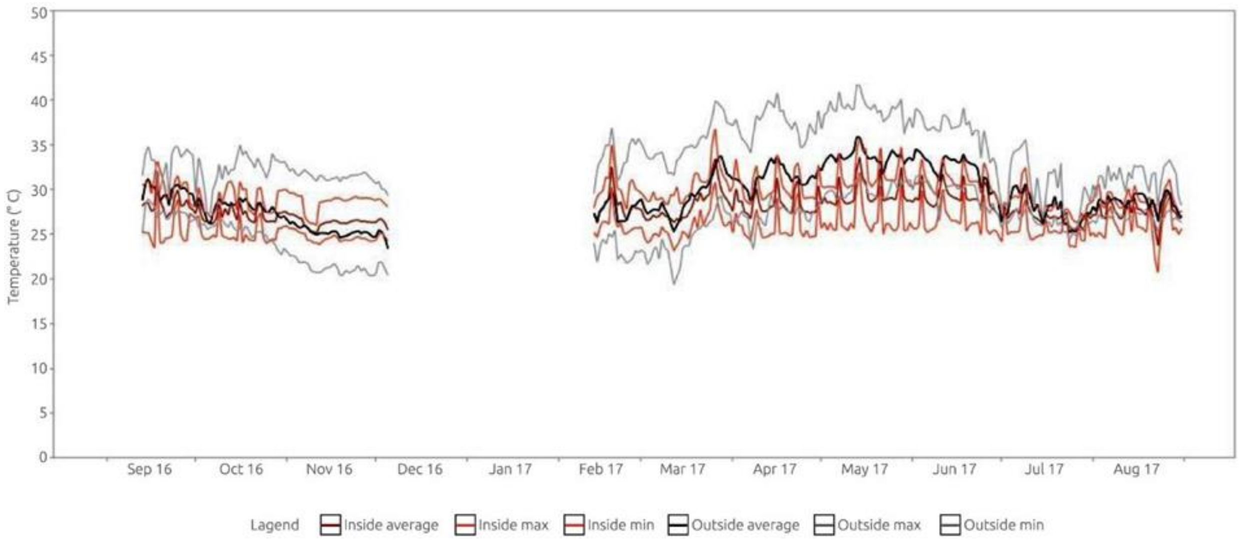

Fig. 19: Surface temperature (indoor and outdoor) inside the equipment chamber on the first floor

Equipment Chamber (First floor): The graph shown in Figure 19 represents the variation in average, maximum and minimum values of inside and outside surface temperatures measured inside the equipment chamber on the first floor. The wall in consideration faces the north direction. The typical weekly consumption profile shows that the indoor temperature range is significantly less compared to the outdoor temperature range specifically during the hot summer months. During other months, the temperatures remain very close to each other.

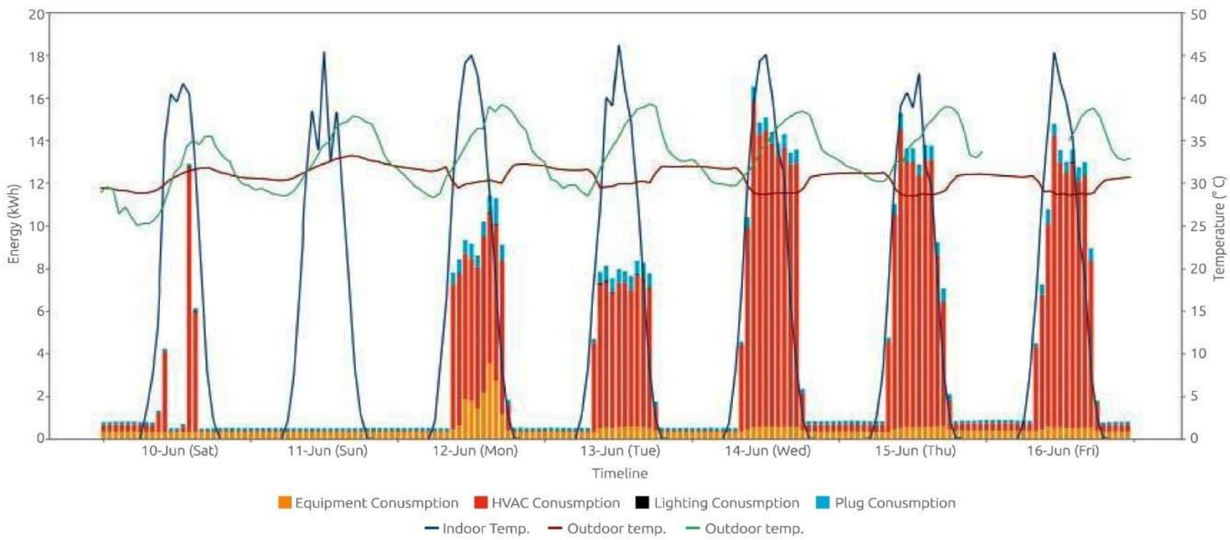

Fig. 20: Hourly total energy generation and consumption profile with outdoor and average indoor temperature for a week before summer typical week

The graph shown in Figure 20 represents total energy generation and consumption with outdoor and average indoor temperature on an hourly basis for a week before summer typical week (10th June 2017 to 16th June 2017).

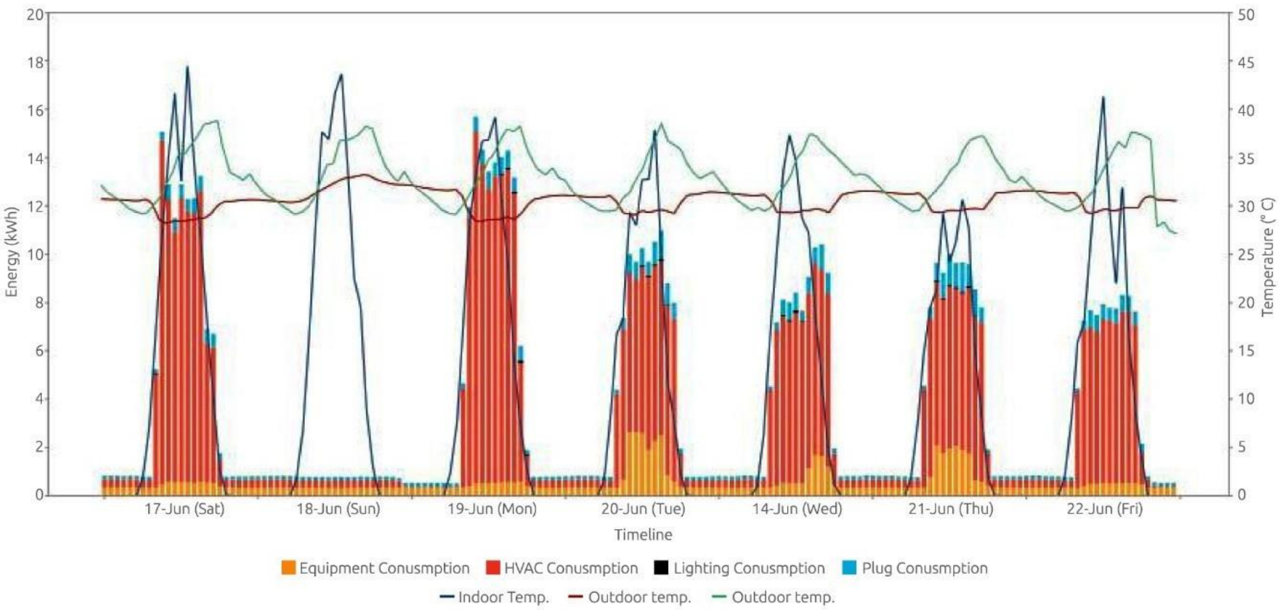

Fig. 21: Hourly total energy generation and consumption profile with outdoor and average indoor temperature for summer typical week

The graph shown in Figure 21 represents total energy generation and consumption with outdoor and average indoor temperature on an hourly basis for the summer typical week (17th June to 23rd June 2017).

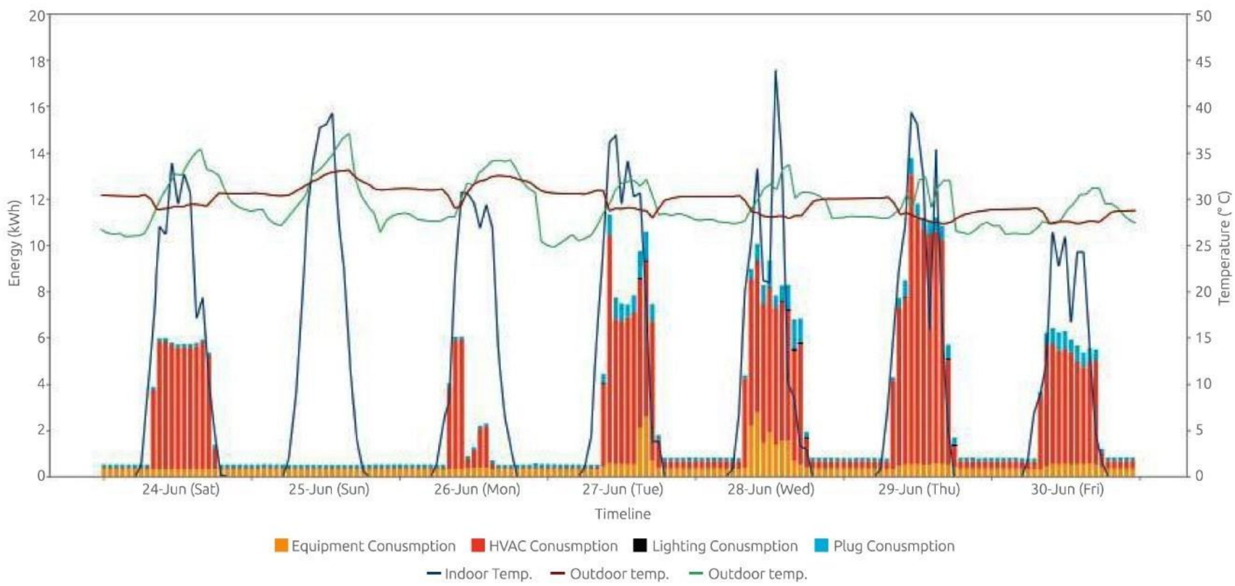

Fig. 22: Hourly total energy generation and consumption profile with outdoor and indoor temperature for a week after summer typical week

The graph shown in Figure 22 represents total energy generation and consumption with outdoor and average indoor temperature on an hourly basis for a week after summer typical week (24th June 2017 to 30th June 2017).

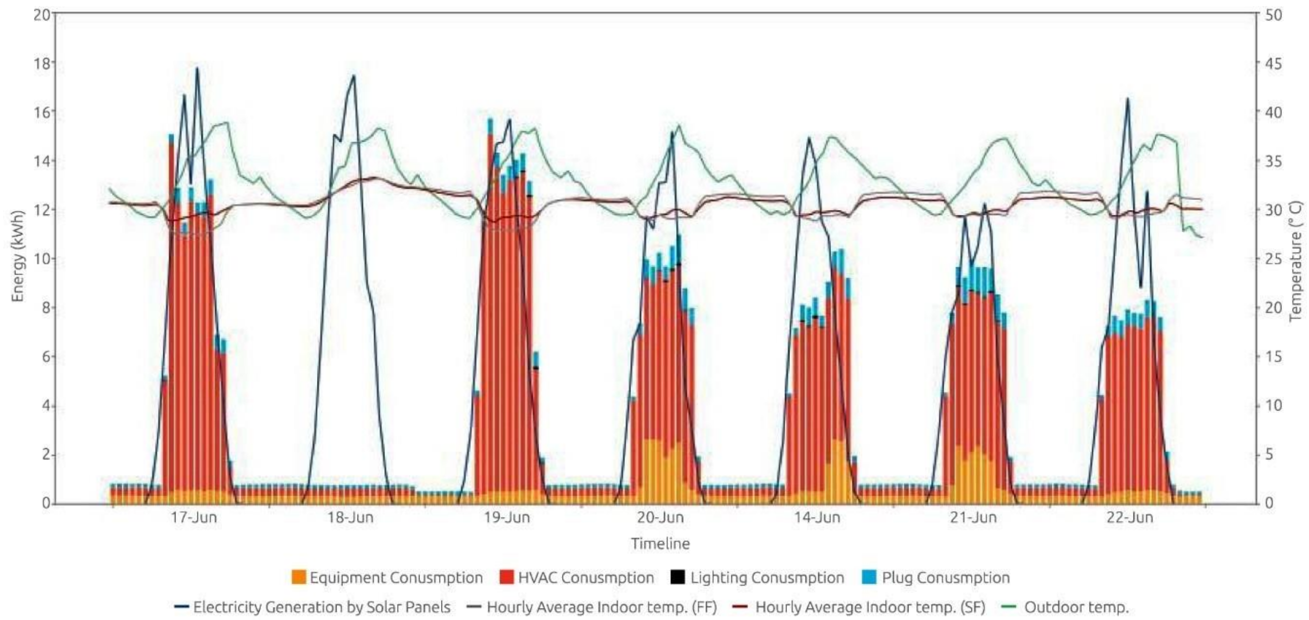

Fig. 23: Hourly total energy generation and consumption profile with outdoor temperature and floor-wise average indoor temperature for summer typical week

The graph shown in Figure 23 represents total energy generation and consumption with indoor and outdoor temperature on an hourly basis for the summer typical week (17th June 2017 to 23rd June 2017) for the first (FF) and second (SF) floors.

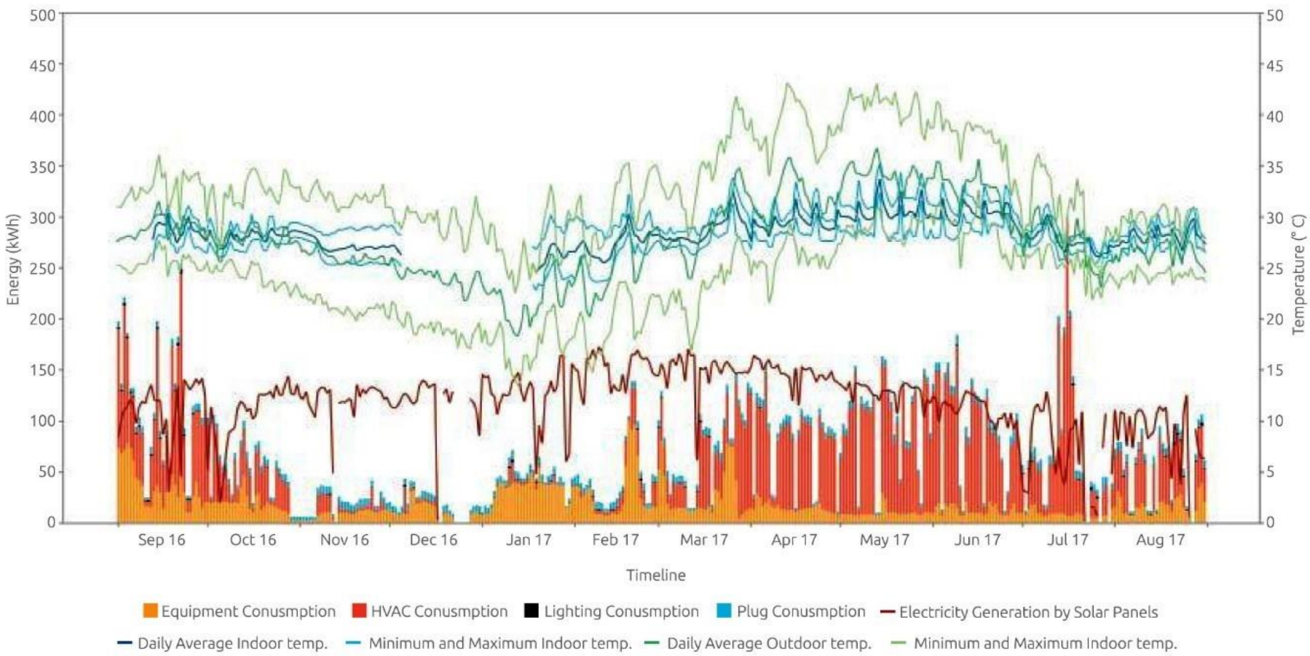

Fig. 24: Daily total energy generation and consumption with indoor and outdoor temperature for the year 2016-2017

The graph shown in Figure 24 represents total energy generation and consumption with indoor and outdoor temperatures on daily basis for the year (1st September 2016 to 31st August 2017).

OPERATION HOURS AND OCCUPANCY PATTERNS

The building operates from 08:30 hours to 18:30 hours every day except on holidays. The operating hours are out of a total of 8760 annual hours for various systems. The building was occupied for 2730 hours considering 10 working hours a day and eliminating 92 holidays in one year. On an average, the place is occupied by 20 users on a working day.

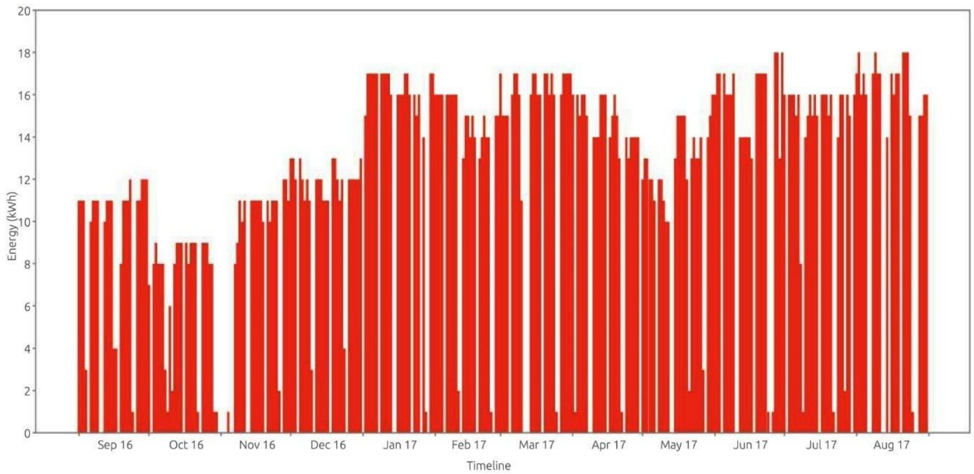

Fig. 25: Annual Occupancy Pattern

The graph shown in Figure 25 represents the occupancy pattern – the total number of occupants present in NZEB for the period from 01 September 2016 to 31 August 2017.

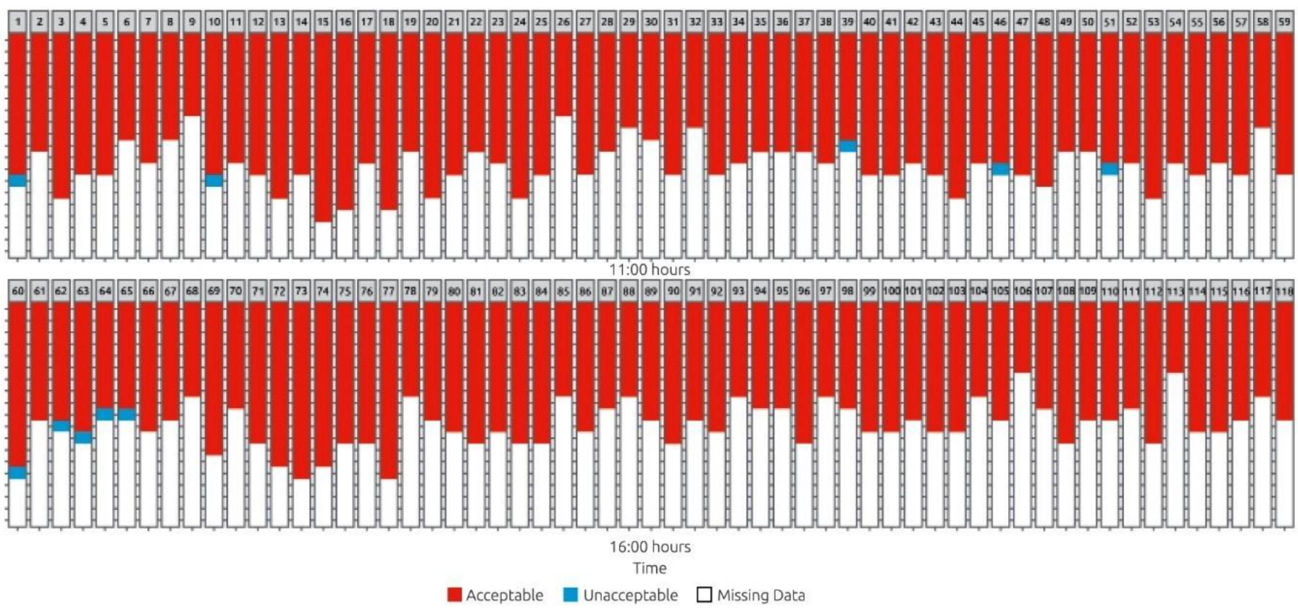

Fig. 26: Acceptance of thermal environment by building occupants

ACCEPTANCE OF THERMAL ENVIRONMENT

The graph shown in Figure 26 represents the acceptance of the thermal environment by the occupants. Each bar in the first row represents the acceptance level of the occupants at 11:00 hours on Mondays and Thursdays alternatively. There were a few instances when some occupants were feeling warm or cool and fewer when they felt very hot or very cold. The second row records their responses at 16:00 hours. It can be seen that the majority of occupants are satisfied with the thermal environment inside NZEB.

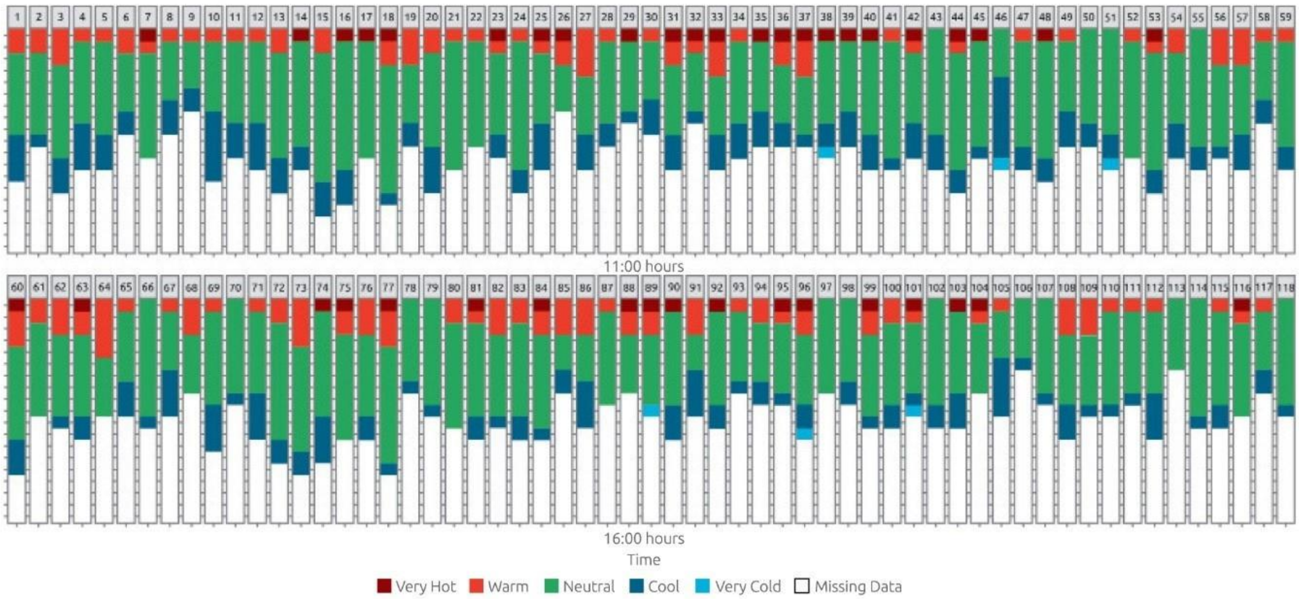

Fig. 27: Thermal sensation of building occupants

THERMAL SENSATION

The graph shown in Figure 27 represents the thermal sensation felt by the occupants. The majority of the occupants voted that they were feeling neutral during the time of the survey. There were some instances when the occupants were feeling warm or cool and a few when they were feeling very hot or cold.

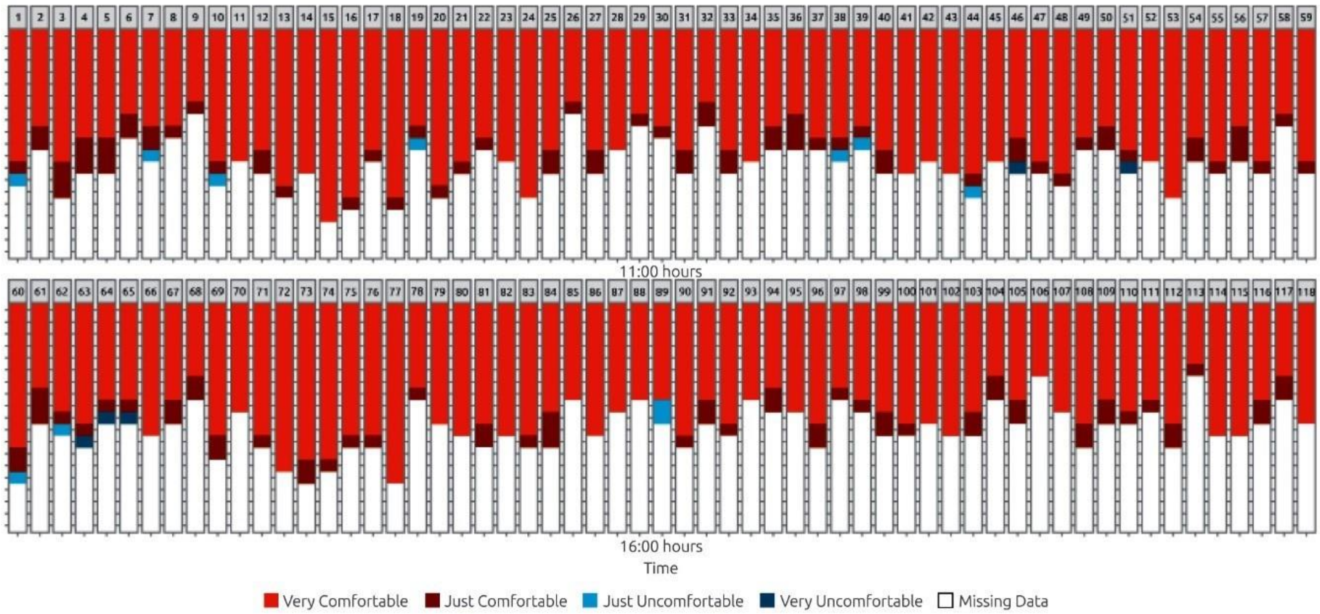

Fig. 28: Comfort Vote by building occupants

COMFORT VOTE

The graph shown in Figure 28 represents the thermal comfort felt by the occupants. The majority of the occupants voted that they were feeling very comfortable during the time of the survey. There were a few instances when some occupants were feeling less comfortable and fewer when they felt uncomfortable.

ENERGY PERFORMANCE INDEX

The energy performance Index is defined as the total energy consumption used in a building divided by the gross floor area in square meters. The whole building EPI for the Living Laboratory is 78.4 kWh/m2. Break-up given below:
Building HVAC EPI- 45.3 kWh/m2 (Energy consumption by air conditioning equipment to maintain indoor space temperature and indoor air quality)

1. Ambient Lighting EPI – 0.3 kWh/m2(energy consumption by artificial ambient lighting devices)
2. Plug loads EPI – 4.5 kWh/m2(energy consumption by computers, personalized fans, and task lights)
3. Research Equipment EPI – 28.4 kWh/m2. (Energy consumption by research instruments such as envelope characterization devices)

CONCLUSION

The results of the analysis done at the CEPT Living Laboratory have largely convinced us about the outcome of the passive design strategies being successfully implemented. They assure us that we can design contemporary facades with passive strategies to overcome the comfort issues arising inside a structure and at the same time can prove energy efficient. It's evident that for every climate type the strategies differ, but with proper climate analysis, it is possible to arrive at appropriate design strategies to fulfil our comfort needs efficiently.

1. The orientation of the building highly helps the circulation of air inside the building based on the flow of air in that area.
2. The size of the opening and the placement of windows play a major role in circulating the air inside the structure.
3. A well-designed roof with passive techniques can drastically bring down internal temperature.
4. Doubly glazed windows and wall make of a structure helps making the interiors comfortable and energy-efficient, even with the kind of finish we want.
5. To increase the energy-efficiency of the building, additional measures like solar roofs can bring down the running costs of the building.

Thus, we can plan envelope designs in an articulate and coherent way with passive techniques to make them more sustainable and energy efficient.

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Figure 13: https://carbse.org/net-zero-energy-building/report, pg. 20

Figure 14: https://carbse.org/net-zero-energy-building/report, pg.40

Figure 15: https://carbse.org/net-zero-energy-building/report, pg.41

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Figure 25: https://carbse.org/net-zero-energy-building/report, pg.46

Figure 26: https://carbse.org/net-zero-energy-building/report, pg.47

Figure 27: https://carbse.org/net-zero-energy-building/report, pg.47

Figure 28: https://carbse.org/net-zero-energy-building/report, pg. 48

SUSTAINABLE BUILDING ENVELOPE

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ABSTRACT: *A sustainable facade is an important concept in today's architecture and will be even more so in the future. The main motive of this research is to study the importance of sustainable facade materials in sustainable building with respect to its benefits, maintenance, and climatic response. Facades have a very deep impact on the minds of the viewers as well as the end users of particular building, and it adds a unique personality, character to it. Buildings are considered to be the largest users of energy. This consumption of energy can be reduced by a sustainable approach towards facade design and material selection for the same. The paper is aimed at examining the role of sustainable building facade material in building design by investigating the impacts of sustainable facade design on building using sustainable materials and to focuses on the deepening of technology of building facade elements, and how the building facade can control the thermal comfort as part of the indoor environment in a building that carries sustainability architecture. The secondary data is collected using references from various research papers, articles about sustainable facade and some internet sites and analytical studies are done. It was found that the principles of passive design on building envelope have a great influence on the comfort level in the building. The goal to be achieved in sustainable design is to minimize the use of the design that takes much energy to address the issue of energy crisis lately. With the focus on the proposal of vocational training institute (at Shirur, Pune) this is the final year Architectural Design Project to be submitted at the final exam in May 2023 the author supports architectural elements and designs based on this research.*

KEYWORDS: Sustainable facade materials, thermal comfort, energy saving, sustainable design

INTRODUCTION/BACKGROUND

The buildings we find today are expected to achieve both energy efficient and environmental-friendly design. A building envelope is the totality of (building) elements made up of components which separate the indoor environment of the building from the outdoor environment (Oral, 2003). It is the key factor that determines the quality and controls the indoor conditions irrespective of transient outdoor conditions. The building envelope provides protection against unwanted external environment influences from climate condition such as heat, radiation, wind, rain, noise, pollution, etc. It has vital role in reducing energy consumption for heating, cooling, and lighting. It refers to an enclosure of a built environment, which comprises of walls, fenestration, roof, foundation, thermal insulation, thermal mass, external shading devices etc. make up this important part of any building. (Suresh B. Sadineni ∗, 2011). Design features of an envelope strongly affect the visual and thermal comfort of the occupants, as well as energy consumption in the building. Emergence of a building envelope design depends upon the 'Skin (material used), built form, building pattern, and building scale or it's proportions. An energy effective building envelope design saved as much as 35% and 47% of total and peak cooling demands respectively. (Suresh B. Sadineni ∗, 2011)

Sustainable facade is defined as exterior that use least possible amount of energy to maintain a comfortable environment, which promotes productivity to certain material which has less negative impact on environment. Sustainable facades can greatly reduce the building's energy consumption and protect against weather conditions and moisture. Sustainable facade design is the practice of planning, construction, and operating buildings using environmentally responsible processes and efficient resources. One of the important aspects of the facade is that the window to wall ratio is only about 40 per cent, reducing the potential for solar gain.

AIM / PURPOSE

To study the importance of sustainable facade materials in building with respect to its benefits, maintenance, and climatic response.

RESEARCH METHODOLOGY

The data collection was carried out through secondary data on research papers. On research papers were the author read some sustainable facade materials/element such as trombe wall, aerogel glazing etc. From the analysis of secondary data, it was found that those materials are not being sustainable facade materials while designing still gives thermal comfortable, pleasing, relax feeling. The further research paper is based on identifying types of sustainable facade materials, thermal comfort, designing criteria of sustainable building, its design principles. Its maintenance should be used to stimulate the sensual experience i.e., vision and feeling to make sustainable facade materials based on study of research papers. The research process adopted analytical research methodology, while conducting the research author adopted analytical methodology.

LITERATURE REVIEW

Research papers referred were for understanding the sustainable aspect of building design. Sustainable building design is also known as "green design or high-performance buildings." Sustainable buildings can be defined as those buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings and the broader regional and global settings. The concept of green or sustainable building design is also transforming the construction industry albeit much more slowly. Below I have mentioned the names of the research paper and the data read from their research papers:

1. Sustainable building design, Data read: Sustainable buildings, building envelope.
2. Sustainable building solutions: a review of lessons from the natural world, Data read: - Sustainability, sustainable building.
3. Passive building energy savings: A review of building envelope components Data read: - Ventilated or double skin walls, type of glazing, etc.
4. Building envelope component to control thermal indoor environment in sustainable building: a review, Data read: - Building Envelope, Sustainable Building, thermal Indoor environment.

RESULTS AND DISCUSSIONS

1) Sustainable Building Design (Irene Lee a, 2007):

Sustainable building design is also known as "green design or high-performance buildings." According to (Raman, 2005) sustainability in buildings means minimizing the consumption of resources, i.e., water, energy and materials and increasingly, it also entails maximizing the health, safety and quality of life of the building occupants. (Blutstein & Rodger, 2001) note "A sustainable building requires more than identifying solutions to specific problems, but changes to attitudes, paradigms, processes and systems to deliver the project". Green Building Council (USGBC 2013) notes 24–50% of energy use, 30% of CO_2 emissions, 40% of water use, and 70% of solid water can be reduced for sustainable buildings.

Sustainable building design initiatives strive to transform structural developments to more environmentally conscious building design and ultimately improve the quality of life (Turner & Frankel, 2008).

The type of the structural system is one of the most important factors in sustainable design because sustainable design and construction strategies are established based on the form of the structural system. The land use, material use, energy consumption (Pinto, et al., 2013) greenhouse gas emissions, maintenance, risk management, life cycle costs (Hegazy, et al., 2012), and even recycling depend to a great extent on the selection of the structural system and the form. Sustainable design can also be divided into three principal categories: ecological, economic, and social sustainability. In terms of sustainable design strategies, structural sustainability concerns can be divided into three categories: structural materials, structural systems, and design optimization. Sustainable design is important for sustainability not just because green practices can reduce the environmental footprint of the building, but also because sustainable buildings can be used to teach those who live, work, or learn about environmental and cultural sustainability (Mika, 2014).

The purposes of sustainable development are:

1.1) Environmental Sustainability (Abraham Seno Bachrun1, June 2019):

It is the development that retains natural resources to last longer because it allows architecture to adapt with ecosystems itself, which is associated with the age of the vital potential of natural resources and the ecological environment of humans, such as climate, biodiversity, and industry. The natural damage caused by the exploitation of natural resources has reached the level of global destruction, so slowly but surely, the earth will lose its potential to support human life, from the exploitation of nature.

1.2) Social Sustainability (Abraham Seno Bachrun1, June 2019):

Architecture improves social sustainability by providing opportunities for building balance and connectivity. Socially sustainable architecture fosters the balance between the individual and the collective and between the present and the future; Also, the relationship between the individual within the building and between the inhabitants and the surrounding community is something that is done by the sustainable architecture in terms of social sustainability.

1.3) Economic Sustainability (Abraham Seno Bachrun1, June 2019):

A sustainable economic ideology is a concept that reflects the economic system itself, can be applied and applied in demonstrating efficiency and fairness in the distribution of earth resources, especially in the development of architecture. Economic sustainability refers to preserving all natural resources when we consume them so that future generations can enjoy them as well. Industrial systems are inherently extractive, exploitative, and ultimately dependent on a limited supply of non-renewable resources. The industrial system will eventually degrade and deplete the resources with which its productivity depends, and therefore, unsustainable.

2) Criteria for Sustainable Buildings (Irene Lee a, 2007):

It is obvious that a multi-criteria approach needs to be adopted for the multi-dimensional nature of building sustainability. This is also the stand taken by most of the building sustainability rating systems and guidelines. Sustainability tools, including those for evaluating building sustainability such as LEED and BREEAM were reviewed. It was found that all the tools contained environmental theme and most of them also contained social or economic themes or both. Sustainability Consultants (McCreadie, 2004), the social, environmental, and economic dimensions of sustainability are considered as core issues.

From the table, it can be seen that the economic dimension of building sustainability is concerned mainly with minimizing the whole life costs of the building, especially the on-going costs. This will allow for maximum investment returns as indicated in the SINDEX software tool developed by (Langston, 2005). Good maintenance and operation strategies will be vital in keeping the on-going costs low. This can be seen from the rating systems, United States' LEED, and Singapore's Green Mark Scheme, where points are allocated to buildings which have good or innovative maintenance and operation management and strategies. This shows that sustainable buildings should incur minimum total building costs, i.e., the initial and on-going costs, in order to maximize investment returns.

For the environmental criteria, the main objective is to reduce resource consumption and environmental deterioration. Sustainable buildings should consume resources in an efficient manner and impact on the environment minimally the various building sustainability rating systems and the guidelines in Table 1, the suggested solutions include the efficient use of energy and water, selection of appropriate materials and products, reuse and recycle resources, optimization of site potential.

For the social dimension of building sustainability, there is generally less consensus about it as compared to the economic and environmental dimensions (Levett-Therivel, 2004). Building users demand quality for their buildings. This means a safe, healthy, and comfortable indoor environment. Therefore, socially, a sustainable building must provide a safe, healthy and comfortable indoor environment.

In addition to the three criteria of building sustainability. It is conventionally considered separately under a different field, i.e., building performance. Sustainability is also about meeting the needs of humans (both present and future). Hence, the inclusion of a functional dimension to building sustainability is logical and makes the approach to achieving building sustainability more holistic and complete.

Table 1: Economic, Environmental, Social and Functional Issues considered some Building Sustainability Rating Systems and Guidelines

	Economic	Environmental	Social	Functional
Building Sustainability Rating Systems				
Leadership in Energy and Environmental Design – Existing Buildings (LEED-EB)	• Innovation in operation, upgrades and maintenance	• Sustainable sites • Water efficiency • Energy and atmosphere • Materials and resources	• Indoor environmental quality	
Sustainable Building Tool (SBAT) (Gibberd 2005)	• Local economy • Efficiency of use • Adaptability and flexibility • Ongoing costs • Capital costs	• Water • Energy • Waste • Site • Materials and Components	• Occupant comfort • Inclusive environments • Access to facilities • Participation and control • Education, health and safety	
Green Mark by the Building & Construction Authority of Singapore (Green Mark for Existing Buildings 2006)	• Building management & operation	• Energy efficient performance • Water efficient performance	• Indoor environmental quality performance & environmental protection	
SINDEX (Langston 2005)	• Maximise wealth (investment returns)	• Minimise resources (energy usage)	• Minimise impact (loss of habitat)	• Maximise utility (functional performance)
Guidelines for Sustainable Building Practices				
7 principles of sustainable construction by the Conseil International du Batiment (Kibert 2005)	• Apply life-cycle costing	• Reduce resource consumption • Reuse resources • Use recyclable resources • Protect nature • Eliminate toxics	• Focus on quality	
6 principles of building sustainability by WBDG Sustainable Committee (2006)	• Optimise operational and maintenance practices	• Optimise site potential • Minimise energy consumption • Protect and conserve water • Use environmentally preferable products	• Enhance indoor environmental quality	

It should be noted that the four facets of building sustainability are not independent. They are, instead, interlinked and trade-offs exist among them. According to (Bakens, 2005), there are so far no clear performance indicators for building sustainability. There are unresolved issues about its measurements and the weightings that should be given to each criterion. Nevertheless, the above discussions have provided a qualitative understanding of the different criteria required of sustainable buildings.

3) Sustainable Facade Materials (Kamal, 2020):

Among the different main constituents of sustainable building envelopes, facade materials have a significant contribution towards sustainable design development. "Sustainable facade" is exterior enclosures that utilize the least conceivable amount of energy to retain a comfortable indoor climate, enhancing efficiency to certain materials, which have a less negative impact on the environment.

Sustainable facades can greatly reduce the building's energy consumption and protect against weather conditions and moisture. Types of sustainable facade materials used in sustainable building envelope are as follows:

3.1) Walls (Suresh B. Sadineni ∗, 2011):

Walls are a predominant fraction of a building envelope and are expected to provide thermal and acoustic comfort within a building, without compromising the aesthetics of the building. Walls with thermal insulation have a higher chance of surface condensation when the relative humidity of ambient air is greater than 80%, provided the convective and radiative heat transfer coefficients of the exterior wall are small. There are other types of advanced building wall designs that are applied to improve the energy efficiency and comfort levels in buildings. The following sections describe such advanced wall technologies:

3.1.1) Trombe wall (Suresh B. Sadineni ∗, 2011):

A more conduction-based type (uncontrollable) of solar wall such as trombe wall or unventilated solar wall is preferable in regions with longer heating seasons. However, the problem of overheating in summer can be prevented through the use of solar shields. (Zalewski L, 2002) (Jie J, 2007). They have proposed an innovative design of PV integrated trombe wall. In this design, PV cells are affixed on the back of the transparent glass cover of a normal trombe wall. Both the heat rejected by the PV cells and the heat absorbed by the thermal mass of trombe wall are used for space heating. A theoretical analysis on a trombe wall with fin-type structured outer wall surface design suppresses the convective and infrared (IR) radiation heat losses from the wall's outer face to the glass cover thereby encouraging the conduction through the wall along with convective and radiative heat exchange to the inside of the room (Zrikem Z, 1986).

PCM trombe walls were thinner and also performed better than concrete walls. A novel concept of fluidized trombe wall system (as shown in Fig. 1) where the gap between the trombe wall and the glass cover is fluidized with highly absorbing, low-density particles is introduced. (Tunc¸ M, 1991).The solar energy absorbed by these highly absorptive particles is transferred to the indoors through fan-circulated air. A filter at the top of the air channel checks the fluidized particles from entering the indoor space.

The overall efficiency of this design is higher compared to a classical trombe wall design as the air (heat transfer fluid (HTF) is in direct contact with the fluidized particles.

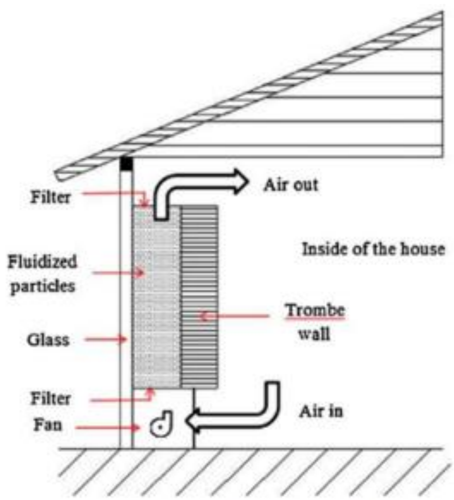

Fig. 1. A cross-sectional view of fluidized Trombe wall system with part details.
Source: Tunç and Uysal [19].

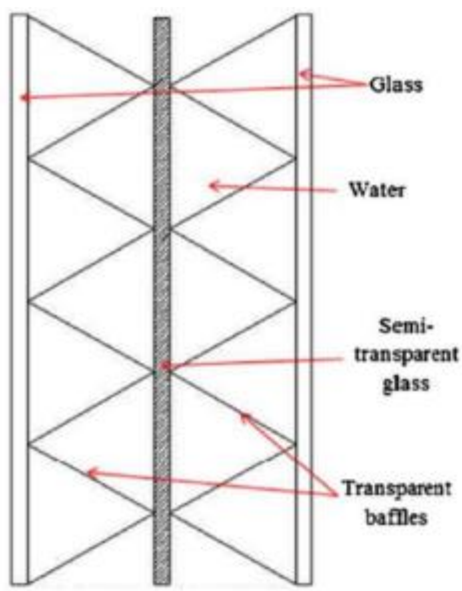

Fig. 2. A cross-sectional view of Transwall system with part details.
Source: Nayak [20].

A Trans wall (as shown in Fig. 2) is a transparent modular wall that provides both heating and illumination of the dwelling space. These walls are comprised of water enclosed between two parallel glass panes supported in a metal frame. A semi-transparent glass absorbing plate is at the center of the parallel glass panes. The incident solar radiation is partially absorbed by the water and semi-transparent glass plate, the rest of the transmitted radiation causes both heating and illumination that are required by the indoors (JK., 1987).

3.1.2) Ventilated or double skin walls (Suresh B. Sadineni ∗, 2011):
An air gap between two layers of masonry wall braced with metal ties constitutes a ventilated or double skin wall. They are also called cavity walls. There are two basic kinds of ventilated walls, one with forced ventilation in the cavity, and the other with natural ventilation (stack effect). Most commonly, ventilated walls are used to enhance the passive cooling of buildings (Ciampi M, 2003). Developed a mathematical model to evaluate the energy performance of a ventilated wall. Although energy savings for all the wall designs increase with the increase in width of the air gap, however, further increase over 0.15 m yielded only diminishing returns. A typical summer cooling energy savings of 40% can be achieved with a carefully designed ventilated wall. However, poor construction quality can introduce thermal bridge issues. Also, the parameters such as the thermal resistance of the exterior wall and relative roughness of the slabs delimiting the air duct are important.

3.2) Fenestration (windows and doors) (Suresh B. Sadineni ∗, 2011):
Fenestration refers to openings in a building envelope that are primarily windows and doors. The fenestration plays a vital role in providing thermal comfort and optimum illumination levels in a building. They are also important from an architectural standpoint in adding aesthetics to the building design. In recent years, there have been significant advances in glazing technologies.

3.2A) Types of glazing materials and technologies (Suresh B. Sadineni ∗, 2011):
State-of-the-art glazing materials and technologies that are aimed at providing high performance insulation (HPI) or solar gain control (SC) or daylighting (DL) solutions or a combination are presented in this section.

3.2.1) Aerogel glazing (Suresh B. Sadineni ∗, 2011):
Aerogels are a category of open celled mesoporous solids with a volume porosity of greater than 50%. They have a density in the range of 1–150 kg/m3 and are typically 90–99.8% air by volume. They can be formed from a variety of materials, including silica, alumina, lanthanide and transition metal oxides, metal chalcogenides, organic and inorganic polymers, and carbon. Aerogel glazing entered the contemporary glazing market in the year 2006 and is, essentially, a granular aerogel encapsulated between polycarbonate construction panels that weigh less than 20% of the equivalent glass unit and have 200 times more impact strength. Light transmission and U-value of aerogel panels are a function of panel thickness. Their high performance, low density and outstanding light diffusing properties make them an appropriate choice for roof-light applications (Bahaj AS, 2008).

3.2.2) Holographic optical elements (Suresh B. Sadineni ∗, 2011):
Holographic optical elements (HOE) are light guiding elements comprising a holographic film sandwiched between two glass panes. The incident solar radiation is redirected, at a predefined angle through diffraction at the holographic film layer, usually onto the ceiling of the building interior. This can be used as a possible daylighting application. It suffers from some setbacks such as glare effects, light dispersion, milky clearness, limited exposure ranges of azimuth and zenith angles, etc. (Bahaj AS, 2008).

4) Roofs (Suresh B. Sadineni ∗, 2011):
Roofs account for large amounts of heat gain/loss. These include a compact cellular roof layout with minimum solar exposure, domed and vaulted roofs, naturally or mechanically ventilated roofs, micro ventilated roofs, high roofs and double roofs (Suresh B. Sadineni ∗, 2011). Roof shading is one way of reducing the impact of solar radiation on the roof surface. Economical roof shading is usually achieved with local material such as terracotta tiles, hay, date palm branches, inverted earthen pots, etc. which can usually contribute to a 6 ◦C drop in the indoor temperature (Sanjay M, 2008).

4.1) Vaulted and domed roofs (Suresh B. Sadineni ∗, 2011):
Vaulted and domed roofs are quite popular in vernacular architecture. The half rim angle of a VR should be greater than 50◦ for it to show favorable influence on the indoor thermal conditions. The South– north orientation of VR is more advantageous than east–west orientation. Also, they are only suitable for hot and dry climates, due to the presence of larger beam component of the solar radiation which is effectively reflected by the curved roof surface, and not so much for hot and humid climates (Tang R, 2006). Although VRs absorb more heat during the daytime than flat roofs, they also dissipate more heat through natural convection and re-radiation. Also, during night times, typical desert climate experiences colder ambient temperatures causing the VRs to dissipate heat even faster. High thermal stratification occurs inside VR buildings, with almost 75% of the stratification taking place in the volume under the vault, keeping the lower part of the building space cool. The hot air can be exhausted near the top of the gable walls of vaults (Tang R, 2006).

4.2) Photovoltaic roofs (Suresh B. Sadineni ∗, 2011):
There have been significant efforts in recent years in integrating photovoltaics (PV) into building envelopes. PV roof tiles replace roofing material and are installed directly on to the roof structure. Ceramic tiles or fiber cement roof slates have crystalline silicon solar cells glued directly on them. Another type of roof-integrated system has a PV element (glass-glass laminate) positioned in a plastic supporting tray anchored to the roof. Due to low cost and physical flexibility, there has been growing interest in thin film PV for BIPV applications. Other types of PV roofs include sandwich PV roofing which offers multi-functionality such as electricity generation and thermal insulation (AS., 2003). Photovoltaic module-based roof systems are still widely installed on sloped or flat roofs. They are either fixed directly on a weather-proof membrane with the help of aluminum framing system with drain trays or retrofit on top of the existing tiles. The generally guaranteed life span of these structures is around 30 years. An average retrofit cost of such system is around 7400D/kWp as per the year 2003 prices (AS., 2003). The bulk of this cost is attributed to the price of PV modules. The cost of PV has gone down substantially since 2003, which would mean a lower price for these systems.

5) Building Energy Savings Potential (Suresh B. Sadineni ∗, 2011):
The building envelope can have a substantial impact on total energy consumption as it can significantly affect cooling loads, primarily due to the control of the acquisition of heat radiation through windows, and the utilization of natural lighting. A combination of passive design strategies has the potential for energy savings of about 31%. The combination can be accomplished through the design of building envelopes that include shading. The extent of Window to Wall Ratio (WWR) window ratios, the selection of glass with low shading coefficient and the utilization of natural light for indoor illumination (Košir, 2016). A passive design strategy that combines the use of external shade, reduced window area and glass usage with low Shading Coefficient grades can produce about 25% energy savings. Because the intensity of solar radiation differs for each orientation, control of external heat recovery through the window design system (fenestration system) can also be achieved through proper building orientation. The results of this study emphasize the critical role of architects in the development of a design that is not only attractive but also energy efficient (Buyya, 2010).

6) Thermal Comfort (Suresh B. Sadineni ∗, 2011):
Creating a comfortable thermal environment is one of the essential parameters to be considered in designing a building (Dewsbury, 2015). Thermal environments are considered together with other factors, such as air quality, lighting, and noise levels when we evaluate the environment of our activities. If we do not pay attention to the comfort of our place of activity, then the impact will lead to decreased productivity. Thermal comfort, as defined by ISO Standard (International Standard Organization) 7730, is a complicated relationship between air temperature, air humidity, and airflow velocity, coupled with the type of clothing and activity and metabolic rate of the inhabitants that present an expression of feeling of satisfaction with the condition Air in an environment (Yang, 2014).Comfort conditions are also interpreted as thermal neutrality, which means that one feels neither too cold nor too hot.

7) Building envelope maintenance (Suresh B. Sadineni ∗, 2011):
It is important to carry out building envelope maintenance to ensure quality living/working/industrial environments and to avoid premature failure of the building structure. Generally, building envelope repair and replacement costs contribute 20–30% of the overall building repair and maintenance life cycle costs (GR., 1994). The building envelope repair calls are the most frequent of all building repair calls, especially in high-rise structures and extreme climates (B, 1992). Investment on annual maintenance audits and professional review of the general performance of building envelope components can prevent premature and costly failures one of the commonly encountered building envelope maintenance issues is water run-off damage. Building envelopes also need to be designed and protected from two windstorm effects: windborne debris and fluctuating pressures. A review of the windstorm effects on building envelopes concludes that the fenestration of high-rise buildings is most affected due to the hurricane winds (JE., 1994). Some of the building codes and standards concerning the windborne debris and fluctuating pressures impact on the building envelope are also discussed in this review Commonly, considerable effort may be spent on examining, categorizing, and documenting the symptoms of fault (distress) rather than the fault itself. They are often classified as fault when they actually are the symptoms of fault (distress). Any identified building envelope distress may be related to one or more faults.

8) Climatic considerations of building facade (Kamal, 2020):
The basic methods for designing high performance building facades include: orienting and developing geometry and massing of the building to respond to solar position; providing solar shading to control cooling loads and improve thermal comfort; using natural ventilation to reduce cooling loads and enhance air quality in climates that allow this; and minimizing energy used for artificial lighting and mechanical cooling and heating by optimizing exterior wall insulation and the use of day-lighting.

Building facades are the barriers that separate a building's interior from the external environment. High- performance sustainable facades can be defined as enclosures that use the least possible amount of energy to maintain a comfortable interior environment.

FINDINGS/ ANALYSIS & INFERENCES

1. Trombe wall: It is preferable in regions with shorter heating seasons in order to avoid overheating in cooling season. Whereas a more conduction-based type (uncontrollable) of solar wall such as Trombe wall or unventilated solar wall is preferable in regions with longer heating seasons.
2. Transwall: The incident solar radiation is partially absorbed by the water and semi-transparent glass plate; the rest of the transmitted radiation causes both heating and illumination that are required by the indoors.
3. Ventilated or double skin wall: Ventilated walls are used to enhance the passive cooling of buildings. Energy savings for all the wall designs increase with the increase in width of the air gap.
4. Aerogel glazing: Their high performance, low density and outstanding light diffusing properties make them an appropriate choice for roof-light applications.
5. Holographic optical elements: This can be used as a possible daylighting application. It suffers from some setbacks such as glare effects, light dispersion, milky clearness, limited exposure range of azimuth and zenith angles, etc.
6. Vaulted and domed roofs: The half rim angle of a VR should be greater than 50◦ for it to show favorable influence on the indoor thermal conditions. They are only suitable for hot and dry climates, due to the presence of larger beam components of the solar radiation which is effectively reflected by the curved roof surface, and not so much for hot and humid climates. Also, during night times, typical desert climate experiences colder ambient temperatures causing the VRs to dissipate heat even faster. High thermal stratification occurs inside VR buildings, with almost 75% of the stratification taking place in the volume under the vault, keeping the lower part of the building space cool.
7. Photovoltaic roofs: PV element (glass-glass laminate) positioned in a plastic supporting tray anchored to the roof. Due to low cost and physical flexibility, there has been growing interest in thin film PV for BIPV applications. Other types of PV roofs include sandwich PV roofing which offers multi-functionality such as electricity generation and thermal insulation.

CONCLUSION

Sustainable facade materials are one of the design elements that increase the visual quality of the building. Facade surfaces add a unique value to the building and effect on people. The sustainable facade materials can reduce energy consumption and improve the living environment effectively and stimulate people’s health. To design a sustainable facade that meets the demand of the citizens from the users’ perspective. This paper reviewed various sustainable facade materials of building envelope components from an energy efficiency and savings perspective. Improvements to building envelope elements are generally referred to as passive energy efficiency strategies. Passive energy efficiency strategies are highly sensitive to meteorological factors and, therefore, require a broader understanding of the climatic factors by a designer. Building energy modelling computer codes play an important role in choosing the best energy efficiency options for a given location. Periodic energy auditing of the building envelopes, climatic consideration of facade and maintenance are important to achieve the best energy performance and extended life for a building envelope.

Currently, some of these advances in building envelope materials are easy and cost effective to adopt. Several studies have been performed to find the economic feasibility of various building energy efficiency strategies. Energy efficiency approaches sometimes might not require additional capital investment. For example, a holistic energy efficient building design approach can reduce the size of mechanical systems compensating the additional cost of energy efficiency features. Government incentives and rebates in many parts of the world are promoting market penetration and social awareness of these materials.

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SCREENS OF INDIA: OPTIMIZATION OF JAALI PATTERNS

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ABSTRACT: *Climatic conditions and natural factors along with dynamic lifestyles are frequently creating an impact on the structures. Our traditional architecture has always provided simple solutions for the tough challenges posed by such conditions. The building facades constructed are static and hence are not capable to adapt to these dynamic changes. Although, they are adjusting and adapting to the requirements of the gradual changes that the lifestyle goes through. Hence it is rightly said that change is always constant. Nowadays, the simplest solution is to install HVAC system, which leads the structure ignorant of its background. This prototypical style of architecture has started spreading even in places that cannot afford to use energy due to the introduction of this luxury. This leads to the necessity for looking back at the broken link of the traditional architecture and borrowing some of its elements after understanding its complete potential. In doing so, an element that is found, that is used beyond geographic borders and climatic restrictions are the perforated screens that are known as "Jaali" in India. By altering the depths and the apertures of Jaali patterns one could control the glare and solar insulation as well as give an unconstructive view. Making the envelope of the building more dynamic, rather than just a container.*

The research introduces an experimental study to evaluate the concepts of different Jaali patterns through stimulation and modeling. The aim is to explore the intricacies and complete potential of this element and exploit its abilities in order to adapt it in present context. The research provides information about the experimental study that is performed so as to evaluate the thermal and visual comfort. Optimized façade pattern to achieve well-lit, thermally comfortable spaces.

KEYWORDS: -–-

INTRODUCTION/BACKGROUND

A partition or curtain wall with intricate geometric patterns is known as jaali. The vital questions which helped in shaping this topic are: What is the capacity of a perforated screen? Can the shape of the geometry from one place to another determine the climatic factors? In that case, how and where can we utilize the screens in the current context? How can the comfort be achieved?

Examples of jaali's in the traditional architecture is found invariably only in hot climates. It is more popular for its aesthetical beauty found in the desert regions. The most hidden factor is its potential to deal with the challenges posed by the hot climates. For hot climates low energy design buildings must deal with three main targets; they are:

A. Appropriate ventilation.
B. Good shading.
C. Adequate day lighting

The primary function of a perforated screen is to reduce the amount of heat and excess light, and provide adequate ventilation and light, without disturbing the view, privacy, security, and aesthetic beauty.

"When the perforation percentage is less, it not just provides solar shading but also provides cooler wind inside. The night wind leaves back some moisture to be absorbed by the wood and when the sunlight heats it up, the moisture evaporates and through the wind flowing inside, brings in cooler air".

- Hassan Fathy

There are some studies that have been carried out by Sheriff et al (2010) about the Jaali for hot climates based on orientation and its specific climate requirements. This research was done to test the performance as a solar screen in front of a window or a glazed surface and it was proved to be beneficial in saving up to 30% of the cooling loads in the desert climate. Thus, depending on the function of the space balance can be achieved by prioritizing a particular quality.

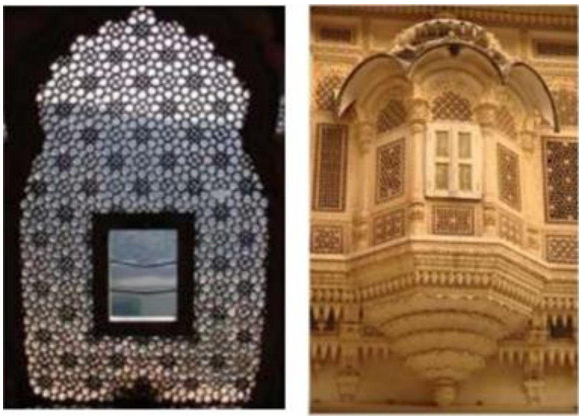


Fig. 1: Stone Jaali in Jaisalmer, India - Exterior and Interior View

2.1 ORIGIN OF JAALI

Tracing the journey of Jaali and the way it is adapted to cater a particular function and climate. The advantages and disadvantages of these perforated screens can be known after knowing the functions it can perform and why did it go out of practice. This is accomplished with the help of books, historic accounts and papers that have regarded the Jaali as an aesthetic and functional element. Jaali's now-a-days are used in front of glass, in hot climates for solar shading, in cold climates for appropriate day lighting and in some cases for pure aesthetics. Hence the transformation in Jaali over time is traced, until present conditions.

Fig. 2: Map showing the locations where the perforated screens were found in history.

"Window openings normally serve three functions: let in direct or indirect sunlight, to let in air and to provide a view. It is nearly impossible to achieve a desirable combination in a single architectural element for regions under hot climatic zone."

2.2 COMPONENTS OF JAALI

Each Jaali has different characteristics by varying the small components in the screen. Like the screen sizes varies which eventually affects the perforation aspect.

To learn what the form must tell us about its performance, the Jaali is reduced to smaller components with relation to its climatic factors it influences. So, from the examples seen, the main components are:

1. Perforation percentage
2. Thickness
3. Adaptive strategies.

PERFORATION PERCENTAGE:
It is area of the opening in the screen to the area of solid (in percentage) Its influence on the Jaali's performance:

1. Allowing solar radiation inside the space.
2. It decides the volume of air entering and going out of the space.
3. Light distribution indoors.

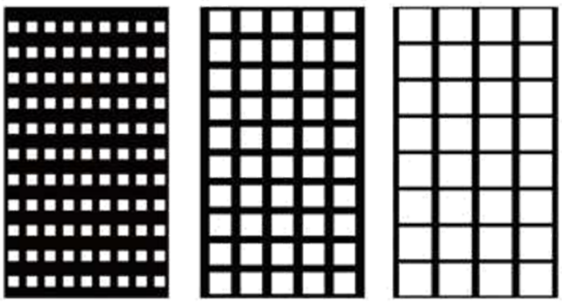


Fig. 3: Screens of the same size (450x800), with different perforation percentages.

THICKNESS:
This refers to the overall thickness of the Jaali, which influences:

1. Transfer of heat through conduction would be achieved by the thickness of the screen.
2. Right thickness will prevent direct solar radiation inside.
3. Daylight levels inside.

ADAPTIVE STRATEGIES:
Predominately history of jaali have examples of fixed jaali but eventually with the evolution in the field of design we could find the examples with certain adaptive features through our precedents.

The adaptive features involve opening the screen, depending on the requirements of ventilation and shading. Adaptive features are mostly observed in humid climatic conditions since they need operable screens for good and maximum ventilation.

Fig. 4: Adaptive features in the Jaali in Dry climate.
(Hawa Mahal, Jaipur)

The ones found in dry conditions have very small windows that are just the size of the face in some cases (Figure 5).

Fig. 5: Adaptive features in the Jaali in Humid climate. (Padmanabhapuram palace, Kerala)

ORIENTATION:
There are specific patterns of perforated screens noticed in the cases studied so far. The Kerela perforated screens are horizontal strips, the one's in Egypt are circular perforations and the Malay houses have vertical strips. Design of jaali patterns for the perforation has a close relation with its orientation. For the northern hemispherical regions, horizontal designing is preferred since the angle of sun is more vertical. In the same way, the design is vertical when the angle of sun is more horizontal. These types of orientations are most effective.
(Figures 6.a and 6.b.)

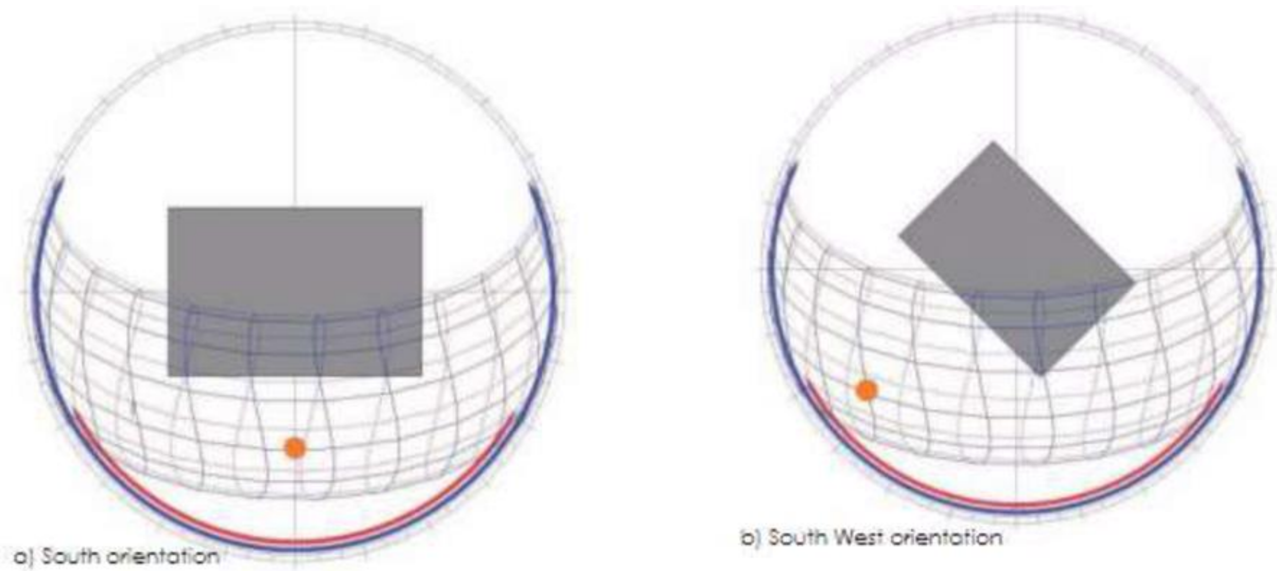


Fig. 6:a): South orientations should have horizontal screens and east west vertical.
Fig. 6b): When builds facing SW should have a combination of both.

When there is both horizontal and vertical angle of sunlight that must be avoided, a combination of vertical and horizontal pattern of shading will be most effective.

ADVANTAGES OF JAALI:
Unlike a regular window, perforated screens provide a uniform spread of daylight into the room, and light penetration reaches longer distance and glare is reduced.

It is adequate to provide continuous ventilation throughout the day when it is positioned and oriented to the prevailing wind.

DISAVANTAGES OF JAALI:
Designing Jaali for either ventilation or sun protection or controlled daylighting is simple.

The process of designing itself starting with assessing the orientation, prioritizing the functionally, and then to run a combination of depth to width ratio and to choose a balanced model.

For shading from the sun, each façade required a unique design (shape and size of the perforations).

CLIMATIC STUDY
3.1 CLIMATIC CLASSIFICATIONS

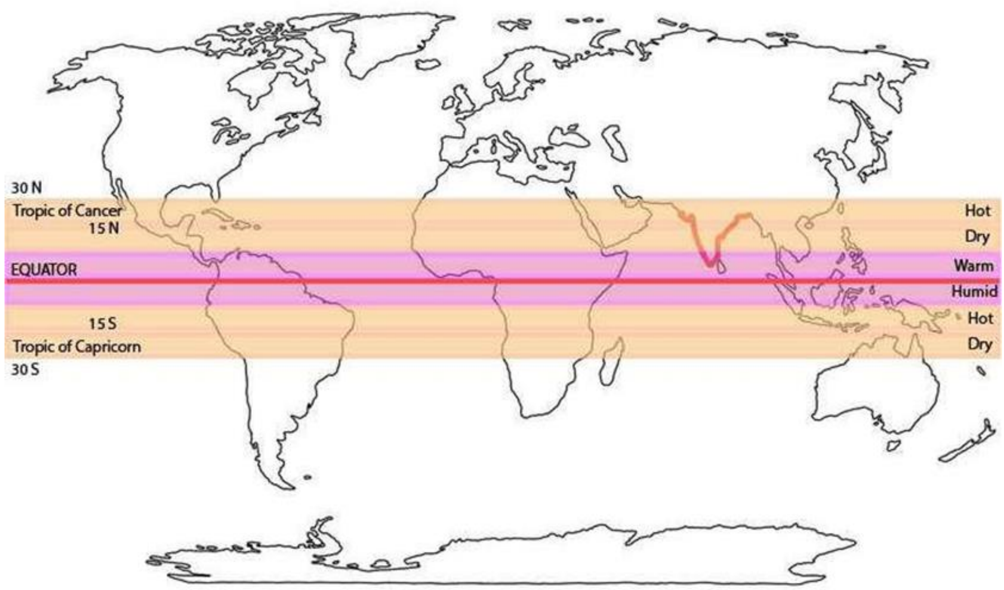


Fig. 7: Atkinson's climatic classification showing the hot climates, as humid and dry conditions with respect to the equator.

The occurrence of Jaali is not only due to the cultural requirements but even the climate is responsible for its evolution. Thus, the climatic conditions will tell when the jaali was invented and adapted.

HOT DESERT		WARM HUMID	
1.	Prevent Direct Solar Radiation	1.	Prevent Direct Solar Radiation
2.	Prevent large amount of air indoors.	2.	Allow large amount of air indoors.
3.	Increase the moisture content in the air.	3.	Reduce the moisture content in the air.
4.	Prevent ground glare	4.	Prevent sky glare.
5.	Maintain stable indoor temperature in	5.	Adequate protection from rains.
	Spite of the high diurnal variations.		

Table No. 1: Design specifications derived from the climate study for hot dry and hot humid climates.

	HOT DESERT	WARM HUMID
SEASONS	Hot Period Mild Period	No Seasonal variations
TEMPERATURE	Summer: Day- 43-49C Night- 10-18C Winter Day-27-32C Night-24-30C	Day- 27-32C Night- 21-27C
SOLAR RADIATION	Direct and strong. During dust haze periods the radiation becomes diffused.	Due to heavy cloud conditions, it is partly reflected and partly scattered. Radiation reaching ground will be scattered but strong and will cause painful sky glare.
HUMIDITY	10-55%	Average 75% throughout the year, rarely varies between 55-100%.
PRECIPITATION	Slight and variable throughout the year. Annual rainfall 50-155mm.	High throughout the year, Annual rainfall-2000-5000mm.
SKY CONDITIONS	Normally clear. Low humidity, hence, no clouds. Luminance 1700-2500 cd/sq.m. When dust suspended in the air creates white haze, it increases to 2500-10,000cd/sq.m.	Fairly cloudy throughout the year, Luminance 7000cd/sq.m. at its brightest, 850cd/sq.m at its lowest.

Table No. 2: Summary of the detailed components and specifications of both the climates.
Source: Koch-Nielsen, 2002

HISTORICAL JAALI VS MODERN SCREENS
MASHRABIYA: 12TH CENTURY

Most examples found in Cairo, Egypt and in regions of Saudi Arabia, Morocco, Egypt, Malta and Bagdad in Hot Semi-Arid climate. Mashrabiya is interpreted as “place to cool the drinking water” it is directly translated as “place to drink”. It is generally the wooden screen with intricate floral patterns. Figure 8.a and Figure 8.b shows the interior and exterior of Mashrabiya. Wooden lattice of cylinders relates to the spiral joints.

This was generally used for cross ventilation between the rooms, in some houses in Jeddah, Saudi Arabia. Hassan Fathy observed that the closed formed wooden Mashrabiya absorbs the moisture from the air in the night and in the morning evaporates sending in the cooler air.

Figure 8: Mashrabiya Saudi Arabia, Morocco, Egypt a) Interior view b) exterior view

BRICK JAALI, KERELA, INDIA:
Kerela has a hot, humid, tropical climate, so the roof pitch is steep, and the eaves come down low. The predominant construction materials are wood and brick. (Figure 9) Perforated screen here is used as another skin before the walls, for complete privacy and good ventilation." There was very little difference between urban and rural buildings." Laurie Baker.

Figure 9: Projects by Laurie Baker, Kerela, India

ARAB WORLD INSTITUTE, PARIS BY JEAN NOUVEL:
Function of Jaali: Lighting, Aesthetics
The 10-storey building has a glass façade, behind which a metallic Jaali is visible. This Jaali is made of 240 photo sensitive motor-controlled apertures, which opens and closes to control the amount of light and heat entering the building. (Figure 10)

Figure 10: Dilating façade of Institute du Monde Arabe, Paris.

THE VELODROME, LONDON, HOPKINS ARCHITECTS:
Function of Jaali: Ventilation
The indoor cycling center, that has horizontal slits on all sides, that open under the sitting space to provide subtle but effective natural ventilation (Brunelli, 2014) (Figure 11)

Figure 11: Natural Ventilation in The Velodrome, London

OBJECTIVE
There is a growing interest of designers and architects in the regions like climate responsive and sustainability, for which they generally revisit the vernacular strategies like solar panels or screens, facades, and their use in contemporary buildings. There are no evidence-based design guidelines for using these vernacular strategies which eventually leads to unsuccessful adoption practices.

Thus, there is a need to develop a strategy with proper knowledge which will eventually enable the architects and engineers to predict the energy consumption and performance. These can be improved drastically by altering the geometries.

This paper will investigate on the influence of screen shading elements, its geometries and perforation units leading to reduction of energy loads of the building. The aim is to understand historical precedents in efficient, sustainable, and performative manner.

CONTEXT AND METHOD

The idea behind designing facade panel is to control amount of daylight entering the building by using lightly tinted translucent stripes which are confined in transparent facade panel.

Inspired by Zaha Hadid's Thallus Installation, the primary exploration led to the use of transparent strip into a box. For primary experimentation a plastic strip of different proportions, with different input locations, and third by creating in between obstacles. On the basis of which the behavior of this plastic strip was observed.

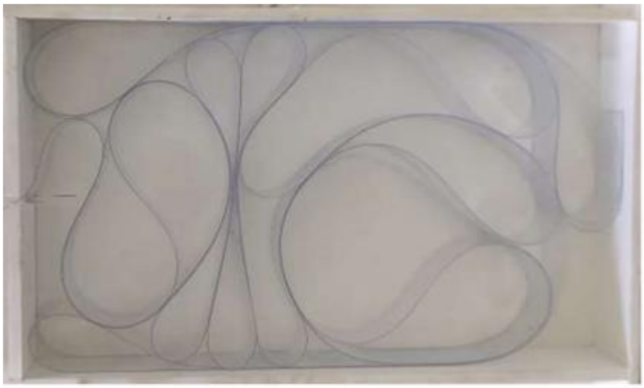
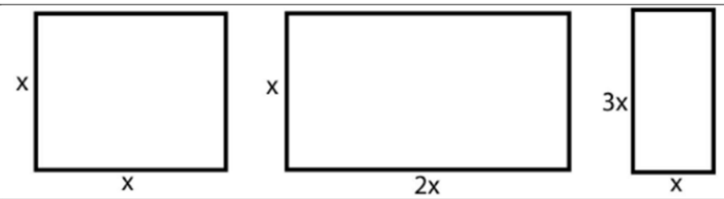
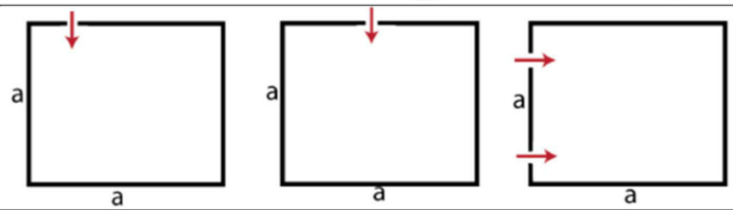


Figure12a): Initial Experimental Model.
Figure12b): Initial Experimental Model. (With obstacles)

PARAMETERS

Panel Proportions	
Input Locations	

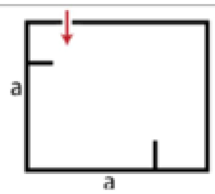
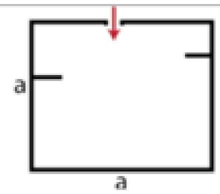
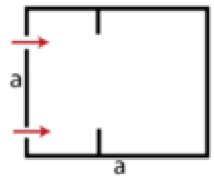
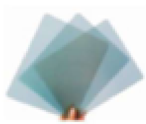
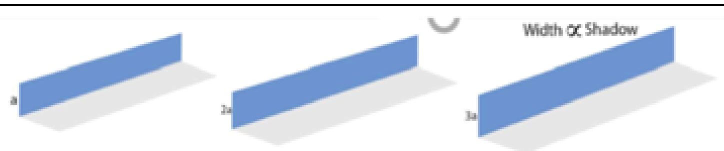
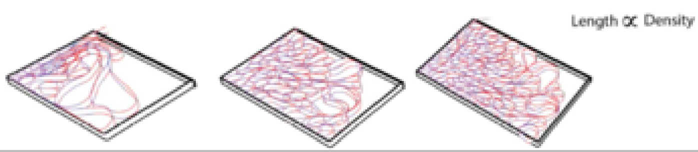
Obstacles			
Strip Material			
Sizes	254x304x0.9mm	594x841x0.25mm	594x841x2mm
Properties	They have short wavelength They affect photographic film in the same way as the visible light. (Turn it black) They are absorbed (stopped) by metals and bones. Bending Resistant.	Transparent Sheet Flexible It reflects light	Is not Transparent Bending Resistant If bend, cannot regain original shape.
Strip width			
Strip Length			

Table No.3: Parameters considered during the designing of the panel.

MECHANISM

Tools that were used for the functioning of the panel:

Arduino Board

DC Motor

Rubber Roller

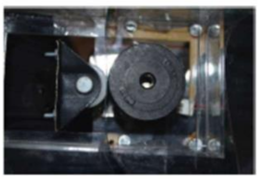
Photo Sensor

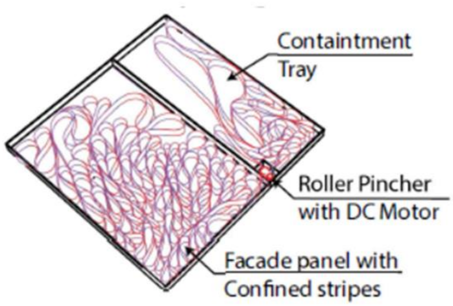
Customized Shield

Plastic Roller

ASSEMBLY
DC Motor - 12V. (1 A- Current 300Rpm)
Reduction Gare Box - (100) 3000/100
Rubber Roller above shaft.
Pinch Roller
Hall Sensor HI- 3141

ASSEMBLY DIAGRAM





CIRCUIT DIAGRAM

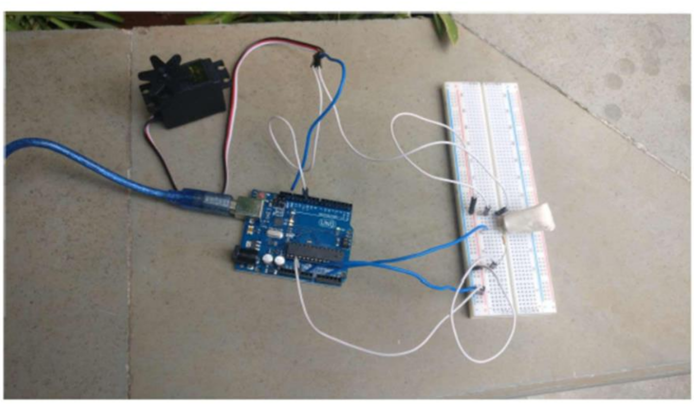


Figure13: Circuit Diagram

PHOTO SENSOR VALUES

Time	Value	Layer
11:00 AM	900	1
11:12 AM	890	2
11:14 AM	885	3
11:16 AM	879	4
11:18 AM	875	5
3:00 PM	990	1
3:12 PM	958	2
3:14 PM	919	3
3:16 PM	900	4
3:18 PM	860	5

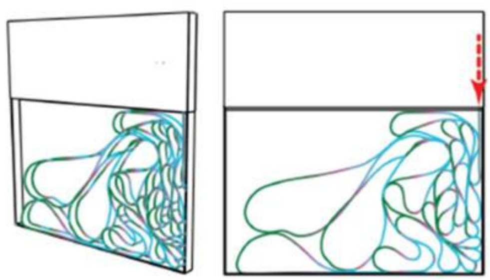
FIELD MEASUREMENTS

According to the three input locations those were studied, it was observed that the center and the vertical side location were creating a lot of obstacles in the flow of the strip from the containment tray. Also, the roller pincher had a hindrance to push the strip at the façade panel. Because of which the side location was opted.

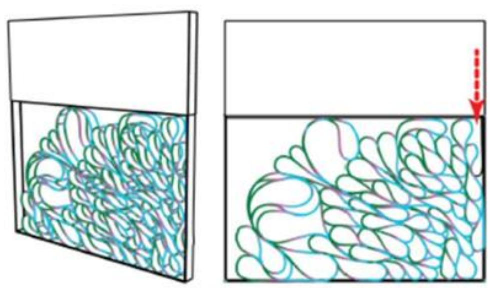
The second most important consideration was the length of the strip, so depending on the intensity of the sun, the length of strip would vary from 10 meters to 40 meters. Where in 10 meters strip would act like a buffer zone and 40 meters strip would maintain the density of the façade panel.

The motion and temperature sensors will play an important role to make the façade more kinetic. Whereas the DC Motor and the roller pincher will lead its helping hand.

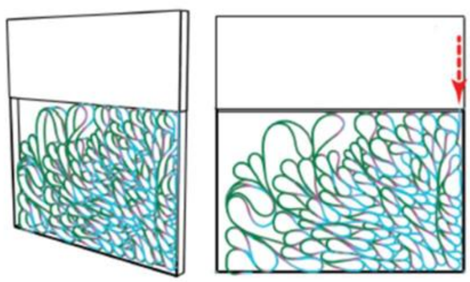
ITERATIONS – SIDE INPUT



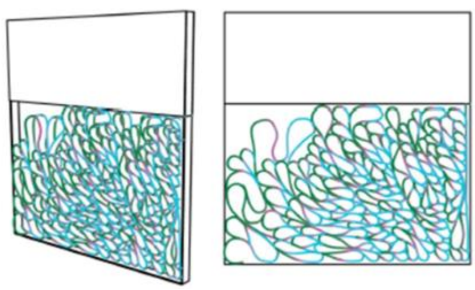
10 meters



20 meters



30 meters



40 meters

Figure13a): Iterations of panel strip from 10 to 40 mts with side input.

ITERATIONS – CENTER INPUT

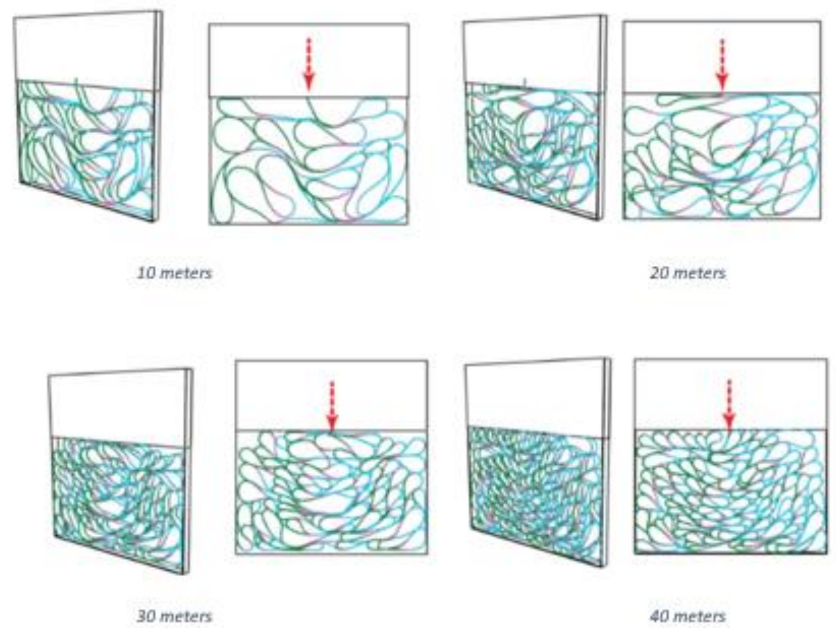


Figure13b): Iterations of panel strip from 10 to 40 mts with center input.

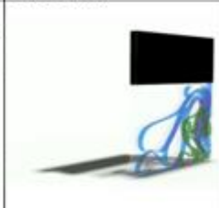
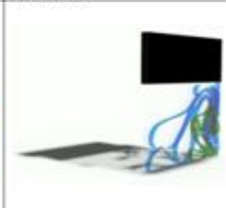
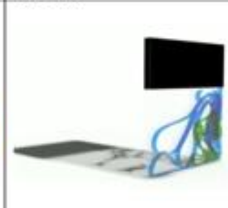
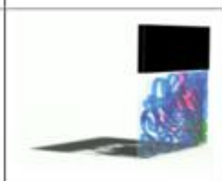
Length	9:00AM	11:30 AM	2:30PM	4:30PM
10 Meters				
20 meters				
30 meters				
40 meters				

Table No.5: Shadow analysis at different time during the day

EXPERIMENTAL DESIGN

Visual and Thermal comfort along with Lighting are the things which are affected by the screens. Although precedents have compared the performances based on the type of geometry used and its orientation. The panel that is been designed led to achieve the visual and thermal comforts in the commercial buildings, along the passages and pathways. Thus, the façade can be used for roofing as well as a shading screen on the envelope of the buildings.

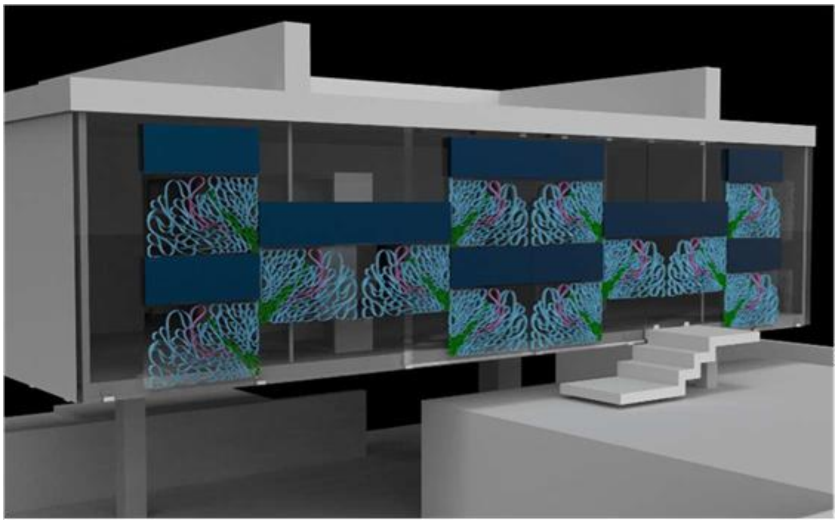


Figure14: Application of Panels on Façade

CONCLUSION

Buildings in hot climate be it hot-humid, hot-moderate, or hot-arid has a challenge at maintaining thermal and visual comfort and improving daylighting and controlling the glare. Jaali stone or marble screens are not appropriate for facades. The vernacular precedents will be more optimizing to manage the thermal and visual comfort and eventually helps in balancing the energy consumption. But the drawback is these facades or screens do not perform the same way in all the climatic zones. The screens having high perforation perform better in maintaining the thermal and visual comfort.

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13. Libraries (//www.arduino.cc/en/Reference/Libraries)
14. Comparison (//www.arduino.cc/en/reference/Comparison)
15. Changes (//www.arduino.cc/en/Reference/Changes)

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Council of Architecture
INDIA

Established in 1965, PEATA India is a forum for Practicing Engineers, Architects and Town Planners Association. Formed with the aim to safeguard the interest of practicing professionals, it is a unique effort to bring several complementary and supplementary disciplines under a single umbrella to cater to their day-to-day needs.

Right from requests to persuasion and insistence from authorities as well as the fraternity, the PEATA has paved its way to safeguard the interest of practicing professionals. The norms, conventions, and experience of hundreds of representations, discussions, negotiations, workshops, seminars and recommendations have enriched the Association with extensive experience and valuable expertise. With its rational approach towards assessing policies and their effect, the Association has carved a niche in the hearts of professionals and bureaucrats at the local, state and national levels. PEATA believes in the continuity of approach and actions towards the envisaged direction, one step at a time.

FOUNDED IN 1965
PRACTISING ENGINEERS ARCHITECTS AND TOWN PLANNERS ASSOCIATION

About Our Associations

The Indian Green Building Council (IGBC), part of the Confederation of Indian Industry (CII) was formed in the year 2001. The vision of the council is, "To enable a sustainable built environment for all and facilitate India to be one of the global leaders in the sustainable built environment by 2025".

The council offers a wide array of services which include developing new green building rating programmes, certification services and green building training programmes. The council also organises Green Building Congress, its annual flagship event on green buildings.

The council is committee-based, member-driven and consensus-focused. All the stakeholders of construction industry comprising of architects, developers, product manufacturers, corporate, Government, academia and nodal agencies participate in the council activities through local chapters. The council also closely works with several State Governments, Central Government, World Green Building Council, bilateral multi-lateral agencies in promoting green building concepts in the country.

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The International Design Competition (IDC) annually hosted by ACA is in its 9th successive year. The aim of the competition is to develop a sensitivity towards prevailing social and environmental exigencies, from the onset of their architectural careers. We at ACA believe that without this key trait neither can the world be ecologically restored, nor can it fulfil its ecological needs.

The IDC is a platform that reaches out to students across globe, inciting them to express through design their thoughts and notions taking nascent steps towards a better world. This year's theme "Building Envelope" is based on arriving at building solutions through the design of building envelopes.

A building envelope is the physical separator between the conditioned space and external environment. Building envelops play key role in a structure's energy efficiency and can account for up to 30% of the primary energy consumption. However, building envelopes are significantly more than this as they act as an integral part of the overall design and contribute to the identity of the structure in the skyline.

List of IDC 2022-23 winners (Student Category):

1. *First Winner - 2022_IDC2017 - Sharanniya Rajeev, Chennai*
2. *Second Winner - 2022_IDC2016 - G. Abinaya, Chennai*
3. *Third Winner - 2022_IDC2041 - Aditi Ranawre, Pune*

List of IDC 2022 winners (Young Architect Category):

1. *First Citation - 2022_IDC2029 - Minal Shamim, Pakistan*
2. *Second Citation - 2022_IDC2028 - Sana Hassan, Pakistan*

ADITYA COLLEGE OF ARCHITECTURE

ACA

IDC Winning Entries

WHY FACADE

A building envelope is a seal of protection for the people and things inside a structure. It's like a shell — a barrier against the world outside of the building. In the winter, the building envelope helps prevent the transfer of heat from inside to outdoors.
A building envelope is commonly defined as the separation of the interior and exterior of a building. It helps facilitate climate control and protect the indoor environment

WHY SUSTAINABLE FACADE

A SUSTAINABLE COOLING SYSTEM WITH MODERN TECHNOLOGY

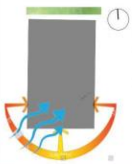
A sustainable green building can be described as structures with minimal to no negative environmental impact. In addition, these structures consume much less energy when compared to traditional structures. Use Greener Materials—A sustainable building should be constructed of materials that mini-mize life-cycle environmental impacts such as global warming.

SITE STUDY

LOCATION - -CHENNAI ,ANNA NAGAR
BUILDING -LIBRARY
HEIGHT OF THE BUILDING -15M

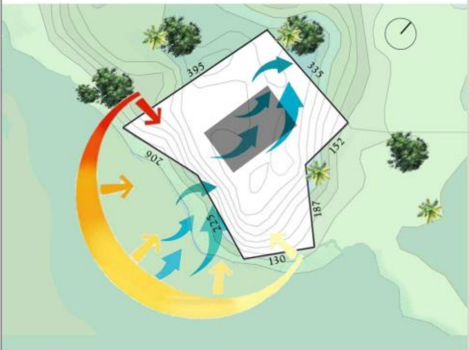
GEOGRAPHY

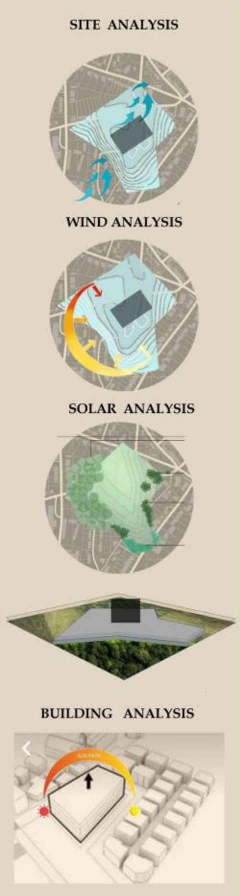
As of 2018, Anna Nagar zone had a green cover of more than 20 percent, as against the city's 14.9 percent average.

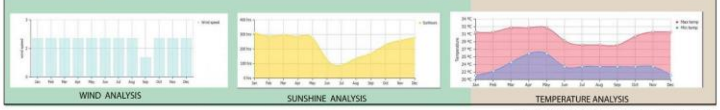


north-facing wall, where the plants can get adequate sun. If this isn't possible, consider setting up synthetic UV lighting in an indoor area.

In warm climate normaly we get light on the north and south can be managed easily , so exposed area is north and south 50-70 % of energy is reduced throgh this techniques







IDC CODE IS- 2022_IDC2017

RETHINKING WITH NATURE..........

NEW IS NOT ALWAYS GOOD

We have rich cultural and heritage which has beutifull methods . we want to enhance our traditional method

TRADITIONAL METHOD WITH NATURAL METHODS

Traditionaly earthern pots are used to cool water when we looked at the ancient times egyptian slaves were fanned the pots filled with water to blow cold on to to the furns .

HAVELI OF RAJASTHAN

Similarly in our own country all the havelis and forts are popular for channelizing air through stone and forts are popular throgh stone jailers and jerokas

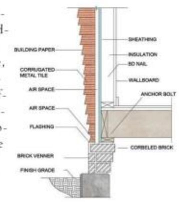
DETAILS

GREEN LIVING WALL

Maintain a comfort environment for the building occupants without having any negative impact .Designed as an enclosure that use least possible amount of energy to maintain comfort environment for the building .Improves the building aesthetic value
How is a green wall installed?
Green wall construction .Protect all floors and surfaces. Install frames. Install irrigation controller and hardscape. Install pee-planted panels. Install irrigation drip lines and sensors.
Test the irrigation system of the living wall construction.
Initiate plant maintenance.

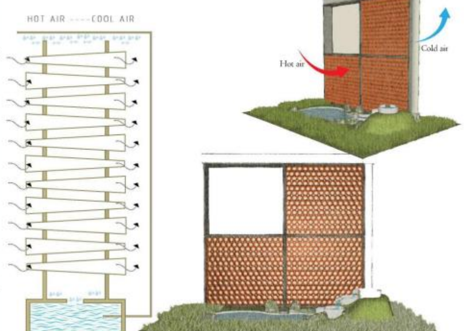
CLAY BRICK -RAINSCREEN FACADES

Use of clay brick facades and claddings transform and enhance the entire look of a building in an elegant way.rainscreen cladding on the outer layer in collaboration with a frame, weather resistant membrane, insulation, subframe, and a ventilated cavity. A rainscreen façade system can be described as a double-wall construction, whereby the outer surface protects the build from rain and other adverse weather, whilst the inner layer aids thermal insulation and helps to prevent excessive air leakage and carry wind loading.



A SUSTAINABLE COOLING SYSTEM MADE WITH WET TERRACOTTA CONES..........

When the air passes through the terracotta cones and comes out, it's naturally cooled the same way the water stays cool in the pot." The cooling system passes water through earthen cones that facilitate evaporative cooling.



IDC CODE IS- 2022_IDC2017

NATURE AS THE CENTRE UNIT

First Winner - 2022_IDC2017 - Sharanniya Rajeev, Chennai

ADVANTAGES

Most significant ,instead of giving out waste heat it consumes the acessieve heat around it .

It is not only a cooling device or system it is rather a solution how we can actualy reduce the energy that we consumes in cooling operate spaces .

No harmfull emissions is released .

Only needs natural materials

Affordable

DISADVANTAGES

It is applicable to only small and medium sized

It produces more aerodynamic noise.

ADVANTAGES

Durability.

Clay facing bricks are calcined from clay at high temperature so that they are anti-weathering and anti-corrosive.

Excellent thermal Insulation.

Enhancement of construction efficiency.

High safety.

Sustainability and Low-maintenance.

DISADVANTAGES

Clay brick's soundproof effect is poor.

ADVANTAGES

Purify the Air.

Decrease the Ambient Temperature.

Decrease Noise.

More Productivity.

Make a Building More Fire-Resistant.

Extend the Life of Your Wall.

Give Your Building More Value.

Create a Community Feel.

DISADVANTAGES

Living Walls Require Maintenance

They Can Damage Your Home if You Choose the Wrong Plants. ...

IDC CODE IS- 2022_IDC2017

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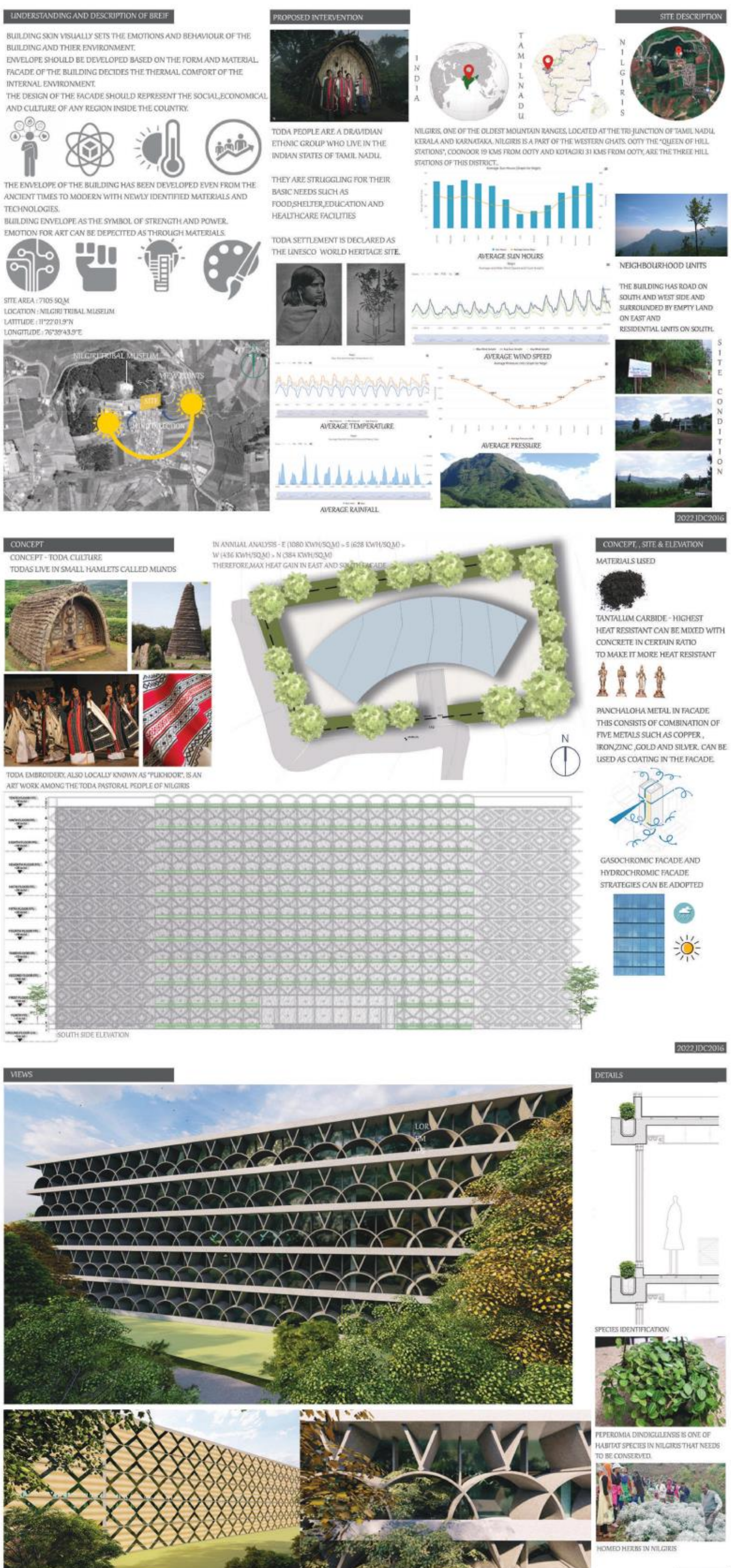
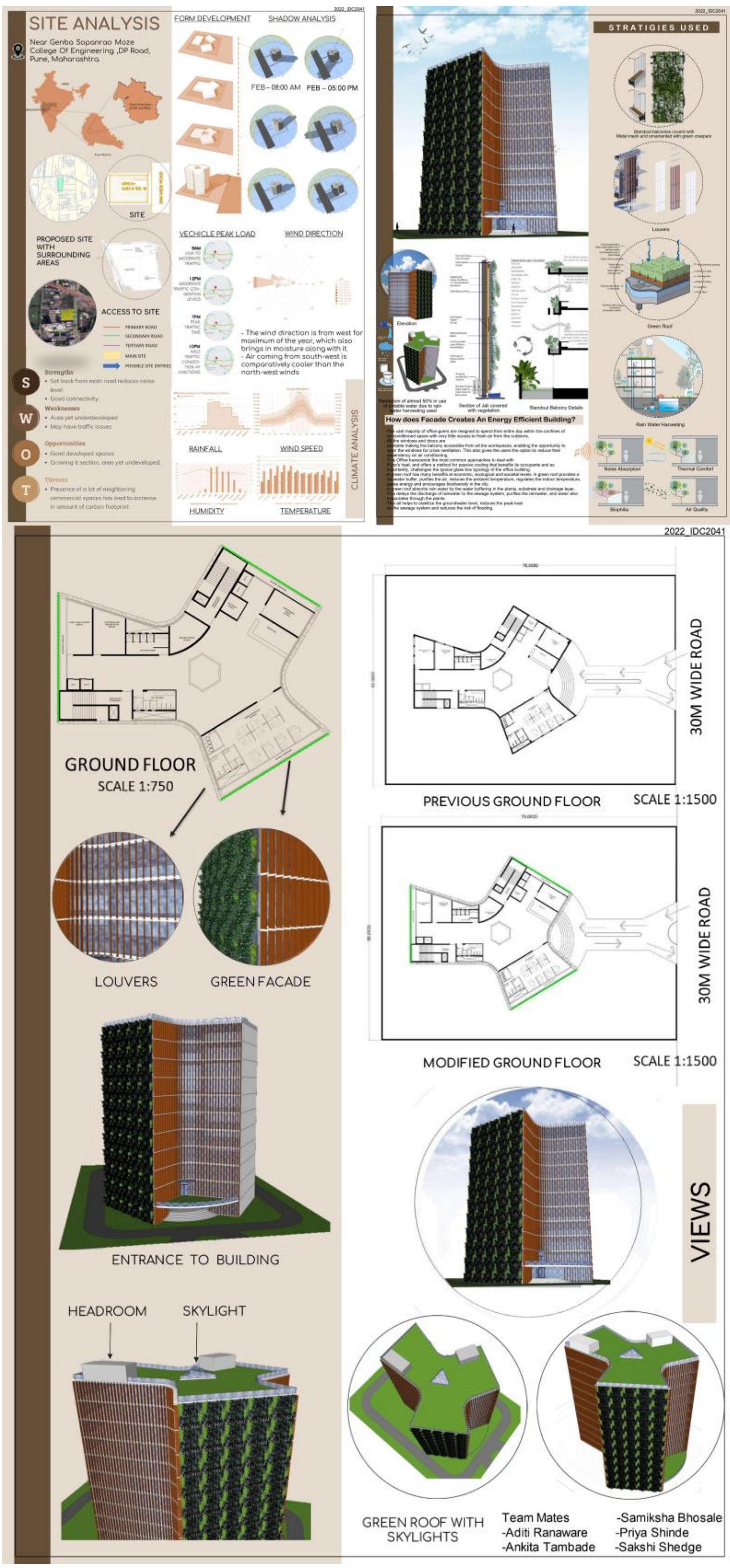
IDC Winning Entries



Second Winner - 2022_IDC2016 - G. Abinaya, Chennai



Third Winner - 2022_IDC2041 - Aditi Ranawre, Pune

SHODHADITYA (June 2022- December 2022,January 2023)

DECLARATION FORM

SHREE AMEYA PUBLIC CHARITABLE TRUST'S
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DECLARATION TO BE SIGNED BY THE AUTHOR (S)

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IDRC 2023

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