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Development and Environment Interactions – Need for Climate Responsive Campuses: Study and Proposals

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ABSTRACT: Population explosion & migration, coupled with technological movements, has resulted to the fact that Cities today are jungles, just instead of trees there are roads, building and vehicles taking over. Pertinently, the criteria for campus design today has also changed, with primary importance being given to wide roads, vehicular connectivity and high rise buildings. Through this paper, we shall be dealing with the case study of leading contemporary campuses of the country and accordingly propose the planning and Architecture guidelines for a climate responsive campus in 21st century India for Composite Climate only.

Keywords: Campus, Architecture, planning, Climate-Change, Population, education, India, city, environment.

I. INTRODUCTION

India is a vast country, 7th largest & with population of more than 1.2 billion, the second most populous country in the world. The world population stands roughly around 7 billion today, with 15,000 children being born every hour. More than half of the that is under 30 and 20 million students were enrolled in educational programs with this number increasing manifold towards 2020. In our country, the life style pattern involves a pedagogy mostly concerned with campuses. With about 75 of a 100 school going children & the third largest higher education system in the world, only after China and the United States, a large number of population is bound to study in campuses for ten to fifteen years.

The need for a healthy and environmentally sound campus becomes paramount as campuses today are being modeled as miniature cities, with little or no essence of their own. Certainly, some of the best campuses in the world have an ecosystem of their own and there is a shift in the visual acuity of an individual as soon as he enters the campus due to the aura of architecture, planning, culture and lifestyle. An educational campus provides its students with a closed learning environment where they can be with similar people and expand their knowledge by virtue of interaction and discussion.

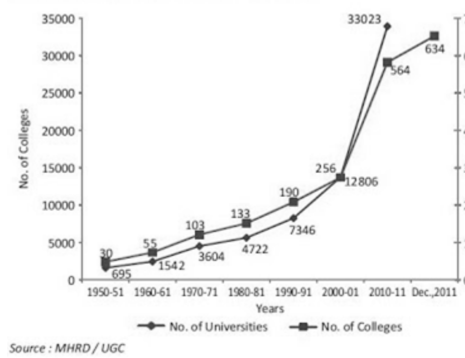

Fig. 1. Growth of Higher Education Institutions in India Source: MHRD/UGC

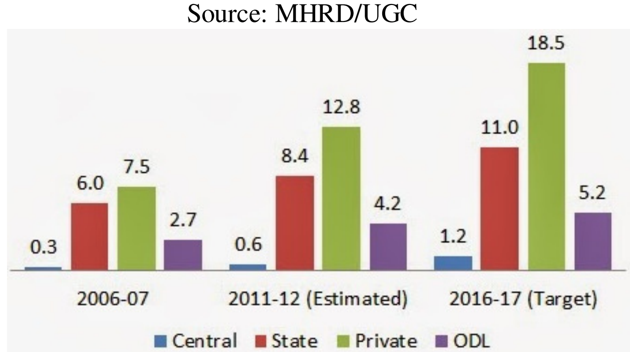

Fig. 2. Enrolment of Students in Higher Education (Millions). (Source: MHRD/UGC).

Climate change is real, the shift of seasons and variations in seasonal conditions are all taking place as we are sitting comfortably in our homes with air conditioners/heaters on, sub-consciously aware of the effects of our actions on our environment but not doing enough to save it. This can be countered by adopting a wholesome approach to building design, with incorporating solar passive techniques with modern technology to restrain the load on contemporary systems. With a vast amount of student population in the world, knowledge about this issue becomes ever important. Such knowledge becomes practical and inculcated in our everyday lives if the buildings we live in or study in stand for this cause.

II. CLIMATE

Climate of a place can be defined as the weather conditions of a place over a large period of time. Weather on the contrary is the climatic conditions of a particular place at a particular time. Climate influences the land use, the vegetation pattern and the animals that can be reared. It has been now successfully concluded that the consumption of energy in modern cities for construction of buildings or transportation hugely affects the climate of that particular region. Climate can be further divided into micro and macro climate. Micro climate is the atmospheric conditions of a place over a limited area, ranging from 1 m^2 to 1 km^2 whereas macro climate is the atmospheric conditions spread over a large area, like a country or a continent. Micro climate influences greatly in building design and outcome whereas macro climate has no such role.

The main elements of climate are:

(1)Air Temperature (2) Solar Radiation (3) Wind
(4) Air Humidity (5) Precipitation

The purpose of designing with consideration to the elements of climate for each climate zone is to provide thermal comfort to its residents. According to ASHRAE, Thermal Comfort is "that condition of mind which expresses satisfaction with the thermal environment". It is simply the range of climatic conditions at a place in which a wide majority of people, if moderately clothed, feel comfortable and will not be affected by either heat or cold. Thus, designing with the climatic elements in mind is to ensure that the habitants remain thermally sound with minimal external heating or cooling. With the advent of technology, it became possible to create artificial comfort zones within the building without much consideration to the surroundings. This lead to comfort being a synonym with high energy consumption and resource depletion. Comfort is a basic necessity for designing buildings and should be achievable with or without artificial assistance. For providing comfort to the habitants it's imperative that the designer studies the elements of climate in that particular region. For this purpose, regions having a similar climate are grouped under the same climatic zone. According to a recent Bureau of Indian Standards, India has 5 major climatic zones. These are:

(1) Hot and Dry (2) Warm and Humid (3) Moderate
(4) Cold (5) Composite

The criteria of dividing in the first four zones is if the same climatic conditions prevail in the region for more than 6 months. If not, then that region is classified into the Composite Climate zone. The composite climatic zone covers the central part of the country, with cities like New Delhi, Kanpur, Allahabad, Bilaspur and Jalandhar. This climatic zone has a variegated landscape and vegetation is seasonal. Summers are characterized by intense high solar radiation whereas winters have diffused low radiation. There is high humidity during monsoon months and reduced during the other seasons. The rains are harsh and intense during the wet periods of the year but there is reduced or no rain during the dry periods.

III. CLIMATE RESPONSIVE DESIGN

Vitruvius, the famous architect in the 1st Century B.C said "we must begin by taking note of the countries and climates in which homes are to be built if our designs for them are to be correct. One type of house seems appropriate for Egypt, another for Spain, one still different for Rome. It is obvious that design for homes ought to conform to the diversities of climate." A climate responsive design thus can be such an approach towards design which is tactful of the climatic conditions of the site and works with nature and surroundings to create comfortable indoor and sometimes outdoor spaces for human interaction. This type of design approach is beneficial as it takes advantage of the available free energy in the form of heat and light which can easily be avoided. Thus, the design for each region should be unique and exclusive, based on the atmospheric conditions of that place and the traditional practices involved and not similar in design as a result of globalization. Climate responsive design can be broadly categorized into three types, based on the approach:

(i) Passive Climatic Design: It is the type of design where the design approach is purely climate and site oriented and no auxiliary methods are applied to achieve thermal comfort for the user.

(ii) Active Climatic Design: In this type of design, auxiliary methods and mechanical measures may be applied to achieve thermal comfort for the user.

(iii) Combined Active and Passive Design: Mechanical means are adopted in addition to climatic considerations in designing a building, to achieve optimum indoor and outdoor thermal comfort for the user.

To provide passive design solutions for a campus, it's important to understand how the internal and external loads can be affected with respect to the elements of passive design.

Orientation. It is the siting of a building on a given site, which may or may not be according to the sun path and seasonal variation. Orientation of the buildings in a compound should be relative to the sun's path in that area and according to the need of heat gain or loss in that region, with respect to the fact that global warming is on the rise and in future, need would be to combat hotter summers than cooler winters.

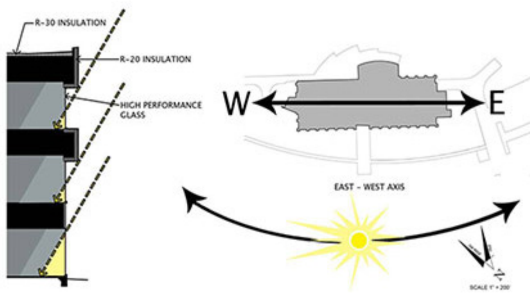

Fig. 3. Effective Building Orientation. (Source: Centre for Science Education, LEED Gallery).

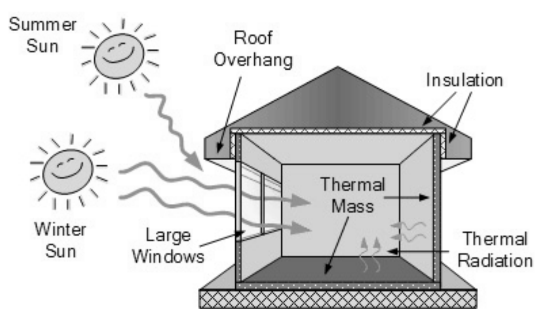

Fig. 4. Design using Thermal Mass combined effectively with other strategies.

Building Envelop and Thermal Mass. Thermal mass is defined as the ability of a material to absorb, store and radiate heat energy. High density and tightly packed materials have more thermal mass as more energy is required to change their temperature whereas lightweight materials like timber and foam have low thermal mass, as their temperature can easily be manipulated. Thus, depending upon the region of building location, use of materials vary due to their properties.

Also, day time loss and night time gain form a major factor in deciding the effective building material for a building. Thermal mass is affected by the material and construction techniques, the roof, walls as they form a major part of the building envelop and are responsible for the most amount of heat gain or loss, the size and design of openings or fenestrations and the interior and external finishes.

Day lighting. Day lighting is the amount of light that can be administered in a building. This can affect the heat gain or loss of the built mass depending upon the size of fenestration provided. Day lighting should be strategized such that maximum sunlight can enter without compromising on the heat gain or loss needs of the built form. A south side window will provide the highest quality consistent daylight, but will also administer heat gain and have thermal comfort problems where as north side fenestrations will have the best possible glare free light required for illumination, however it won't be constant. Day lighting can be provided through clerestories, skylights and roof windows apart from the conventional windows.

Shading. Shading can be of the building and of the openings in the building and can be provided from devices and mutual shading through buildings to shading through vegetation. Shading devices shouldn't block winter sun and aid in protecting from the harsh summer sun. They should be able to provide light wherever necessary without compromising on the protection from sun. In areas with extensive summers and large number of buildings, they can be placed in such a way that they shade each other collectively. It can also happen in a building through effective horizontal or vertical shading elements. North and south sides require mostly horizontal shading devices whereas east and west sides need horizontal and vertical shading both.

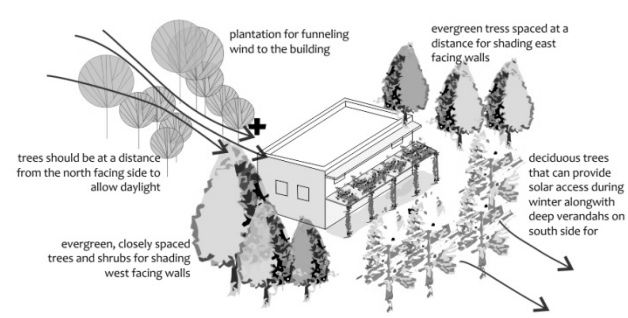

Fig. 5. Use of Vegetation for Shading and Ventilation in a Building.

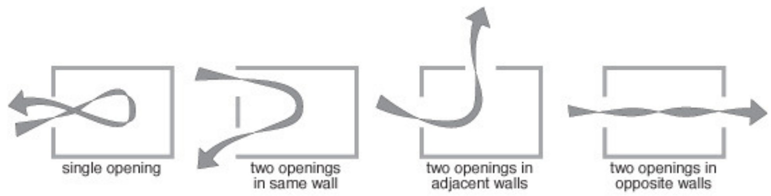

Fig. 6. Window opening types for maximum air ventilation in buildings
Source: www.commercialwindows.org

Shading by vegetation can be very effective. The best place to plant shade giving trees is by examining which windows admit the most sunlight during the peak hours in a single day during the hottest months.

Natural Ventilation. Natural ventilation is of primary importance to prevent the building from becoming a hot box and allowing a continuous supply of air movement. Natural ventilation is affected by the climate, wind direction, area and location of fenestration, size of inlet and outlet openings, volume of the room, shading devices used and internal partitions. In places where cross ventilation through courtyards is not possible, positioning of windows should be such to attain sensible air movement.

Landscaping. A landscape scheme in consideration to the landform and climate of the place can prevent direct heat gain whereas improper landscape design can aid to heat or cool the building, whichever isn't desirable in the area. It can help to create a myriad of airflow patterns and assist in natural ventilation, or help in shading of the building. Thus, trees and shrubs are the primary elements of an energy efficient landscape.

The above elements of passive design all show that applying a single element to building or site design will help in only some way, however, a collective use of these elements will not only reduce energy requirements but help built a structure so secure of its surroundings and mutually inclusive that it will remain timeless.

IV. CASE SUDIES

Indian Institute Of Management, Bangalore

Location: Bangalore, India; **Architect/Planner:** Balkrishna Vithaldas Doshi; **Client:** Indian Institute of Management; **Campus Area**: 100 acres; **Built Up area**: 54,000 sq. mt.; **Year of Commission:** 1963; **Year of Completion**: 1983; **Climate:** Moderate; **Construction Style:** Brutal Modern.

Ratio of Built form to Open Spaces: Emphasis on retaining the Garden City image of Bangalore, thus the vision of interspersing the campus with green pockets which allow for academic exchanges to be carried out beyond the classroom. The ratio of built form to open spaces is comfortable.

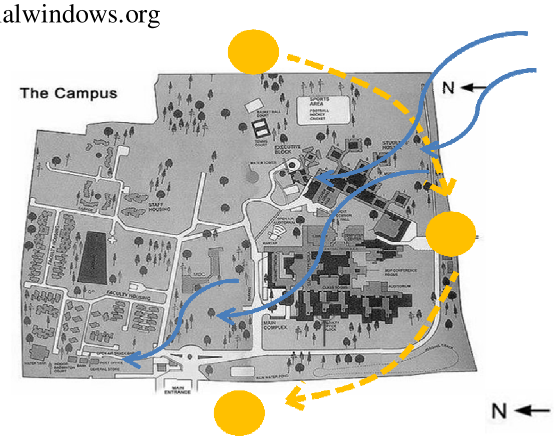

Fig. 6. The sun path and wind movement in the campus. Most buildings are oriented in the N-S direction (Source: Self).

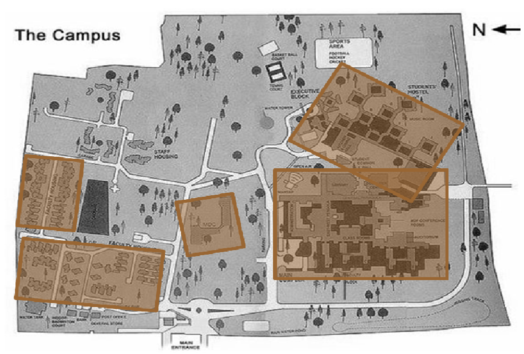

Fig. 7. The built form to open space ratio in the campus. (Source: Self).

Building Envelop and Fenestration: Only 3 materials were used in entirety which are easily available and climate intensive: Concrete, Stone and Grey Stone.

Lighting & Ventilation: Use of courtyards and triple height corridors, integration of green into buildings and extreme vegetation make the degree of air ventilation very high. Natural lighting is abundant as modulation in width of corridors and height of buildings lets for mutual shading and light in very secluded areas as well.

Insulation and Thermal Mass: Stone acts as a natural insulating material. Where stone isn't used, brick wall of 350 mm width is used. The construction of the entire complex is made simple and standardized using exposed concrete, lattices, frames and wall systems using rough blocks of local grey granite.

Energy Generation and Waste Management: The campus is naturally ventilated & air conditioning is not used. Solar cookers and heaters are installed. Waste is segregated at source, with marked bins across campus. An on-site biogas plant fuels the campus kitchen, as does energy from an array of solar cooker parabolic dishes.

Water Utilization: Presently there are sumps at 3 places on campus that can store large quantities of water and 30+ recharge wells distributed on the campus grounds. Sanitary fittings are water-efficient, with low-flow taps, bio-urinals and water-efficient toilets. Rooftop rainwater is captured in sumps and re-used for toilets in the hostel and admin blocks.

Landscaping: Like all great campuses, the landscaping has been integrated into the architecture and not away from it and merge to form a great design.

Fig. 8. IIM B Showing Laden Green Courtyards, Paramount Use of Stone and Presence of Solar Water Heater (Source: www.flicr.com)

The Energy And Research Institute, Bangalore

Location: Bangalore, India; **Architect/Planner:** Sanjay Mohe; **Client:** TERI; **Campus Area**: 4000 sq. mt.

Built Up area: 2450 sq mt.; **Year of Commission:** 1998; **Year of Completion**: 1990; **Climate:** Moderate; **Construction Style:** Modern

Ratio Of Built Form To Open Spaces: The site area was very small therefore the ratio of built mass to open spaces is high, although due to the integration of green inside the building and the playful use of levels, the built form doesn't feel uncomfortable

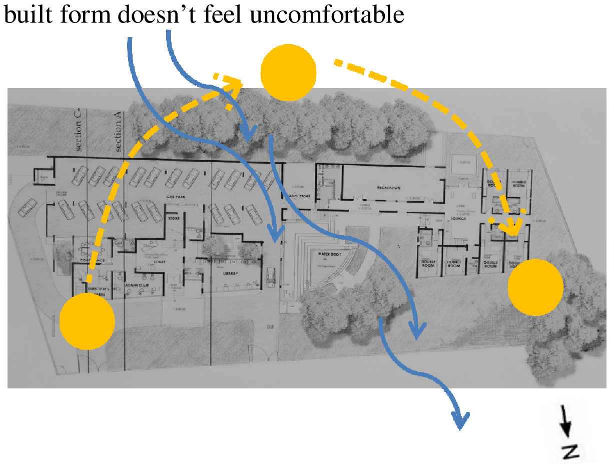

Fig. 9. The sun path and wind movement of the building.

Building Envelop and Fenestration: All windows are towards the front as there is foul smelling nallah on the backside. **230 MM** brick is used but south wall is made double, to tackle with summer sun.

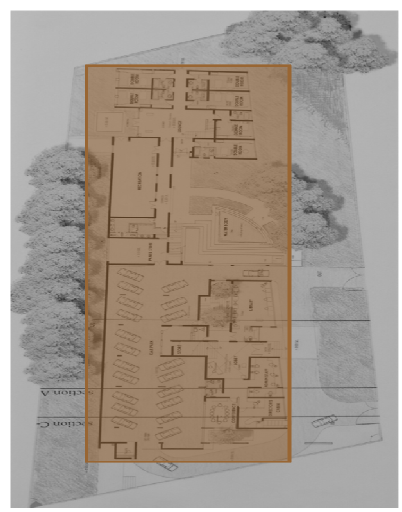

Fig. 10. The built form to open space ratio on the site.

Lighting&Ventilation: Air ventilation is enhanced by use of solar chimneys and air vents. Breeze flow over the building, creates negative pressure. Fresh air is pulled at body level to provide thermal comfort. Abundant natural light inside due to intelligently designed fenestrations. By creating atrium spaces with skylights, sections of the centre are designed so that natural daylight enters into heart of the building.

Water Utilization: Rainwater harvesting is practiced in the complex. Water runoff from the roofs and paved area is collected at various levels in small open tanks on terraces and in a collection sump.

This water is then used for landscaping and toilets. The central court houses an amphitheatre that acts as an informal gathering but holds the rainwater harvesting sump for the campus.

Energy Generation and Waste Management: A photovoltaic system is integrated with the roof skylights which provides day lighting and generates electricity. Solar water heating system meets the hot water requirement of kitchen and guest room.

Insulation And Thermal Mass: Kadappa stone is used at the back wall to absorb heat and induce convection. Local materials and materials of low embodied energy have been used wherever possible.

Landscaping: The building has been designed with landscaped courts at various levels which reduces the heat exchanges and heat flow between the structure and the outside environment and acts as insulation. Having this ground cover on the roof further reduces the impact on the environment through photosynthesis.

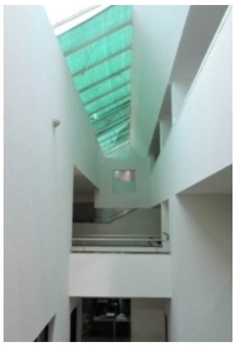

Fig. 11. Ample lighting through skylight in the atrium, facade and amphitheatre for rainwater harvesting in the office complex. (Source: Self).

V. COMPARATIVE STUDY ANALYSIS

The major understandings from the studies have been summarized in the table below.

Layout	IIM B	TERI	REMARKS
North-south orientation	In Most Of The Buildings	Oriented Along East West	Should be oriented along N-S
Planform	Rectangular, Mostly	Yes	Rectangular for easy ventilation
Windows in North-south	Most.	Most Towards North Side	Should be towards north for glare free light and south to maximize solar gain
Windows in East-West	Some, For Direct Gain	Some	Minimum number of windows
Spacing Between blocks (m)	Sufficient For Mutual Shading	Single Building	Spacing to create shaded outdoor areas for comfortable seating in summers and allow for sun in winters.
Overall height (m)	Max Height 15 Mts	Height Is 10 Mts	The blocks should be staggered for mutual shading
Air movement	Comfortable Air Movement	Comfortable Air Movement	Distance between blocks should be such for the air to pass comfortably.
Room height (m)	3.3 Mts	3.6 Mts	Minimum should be 2.7 mts
Window-to floor ratio (%)	30-40%	10-15%	Should be 20-30% in academics and 15-20% in residential
Waste Management	Proper Waste Segregation And Biogas Preparation	Waste Segregation, No Biogas	A proper waste management plan to be established
Water Management	Efficient Rainwater Harvesting System	Efficient Rainwater Harvesting System	
Energy Resources	Solar Energy For Kitchens	Solar Panels For Water Heating	

VI. RECOMMENDATIONS

A climate responsive campus cannot be achieved just by the building design. Site considerations and interactions also become a huge part of it. Thus, the major areas that should be taken in account are:

Site Strategies : Can be done by establishing an effective future growth pattern, by minimizing site disturbances, taking care of soil erosion, sedimentation and avoiding storm water run-off. Protected species of plants and animals in and around site should be taken care of. The site should be accessible to all and by all transportation, however hard paving's should be reduced and walking and cycling should be encouraged.

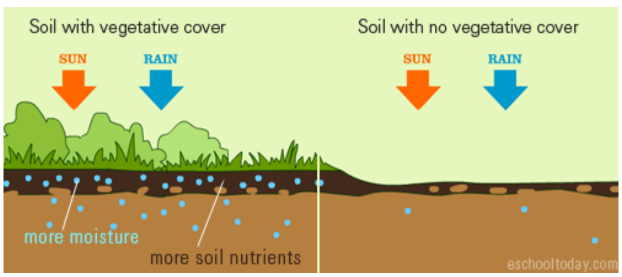

Fig. 12. Preserving top soil through vegetation. (Source: (L-R) eschooltoday.com, self).

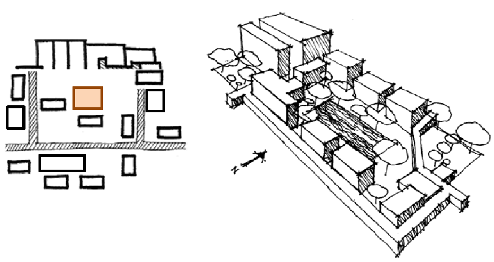

Fig. 13. Campus layout plan and orientation of building for composite climate (Source: (L-R) eschooltoday.com, self).

Architectural Design Interventions: For composite climate, the buildings should be oriented in the east west direction, thus classrooms can achieve maximum glare free light in the North directions and other rooms can be located in the south side. Thermal lag can be established through wall insulation which can serve as thermal mass during the day and release energy during night. Sloping roofs can be established as one side remains in shade throughout the day. In areas where roofs can be sloped, the material should be light in color to absorb minimum sun and use of earthen pots or cement vermiculite can be used to provide insulation. North facing windows should occupy 35-45% of WWR, South facing 25-35% and east and west facing 5-10% of WWR. Rooms can be single banked to have optimum air movement and the spacing between two buildings should be 5 times the height to have effective breeze penetration. The aspect ratio of buildings should be kept near 1:1.6 and area of openings should be 15-20% of floor area in composite climate.

Water Conservation and Efficiency: Rainwater collection strategy must be established and the landscaping should be highly absorptive. Use of native plant beds and vegetation cover can greatly reduce water needs and even so, drought tolerant plant species must be used. Low flow toilets and showers and faucets with flow restrictors aid in reducing indoor water requirements.

Material and Resource Use: Many different systems can be applied in the buildings such as domes, vaults and flat roofs. A well devised campus recycling program should be established with waste segregation bins all along. Recycling of construction materials should also be practiced. Adaptive re-use of demolition waste in construction of landscape elements can be practiced.

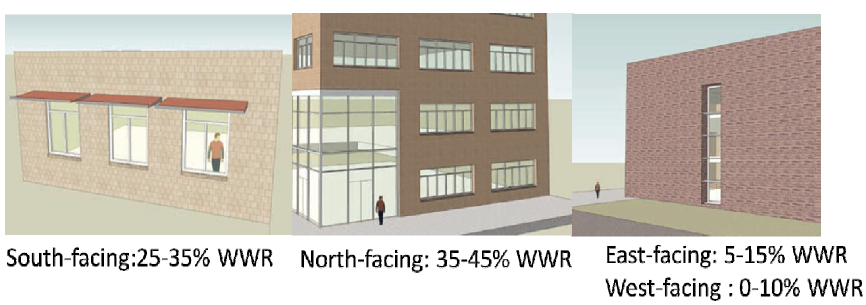

Fig. 14. Shading Strategies for composite climate in different directions. (Source: (L-R) self).

Local materials made from raw materials that are locally extracted must be favored. Consider use of recyclable and salvaged materials.

Waste Reduction: A waste management plan must be established in the campus and a central collection point should be provided for collection of waste from the campus. Recharge pits and drainage system should be well thought of and carefully established.

VII. CONCLUSION

"Every time a student walks past a really urgent, expressive piece of architecture that belongs to his college, it can help reassure him that he does have that mind, does have that soul. " --Louis Kahn

The high level goal of all campus building designs should be to design buildings that use passive strategies to create comfortable, efficient environments for learning. A carbon neutral campus plan starts with energy efficient buildings. 80% of the carbon emissions on a campus derive from energy use in buildings. Steps like above should be taken to achieve emissions reductions in the most cost-effective manner. In simple terms this means integrating sustainability deeply at the earliest stages of planning and design to capitalize on "free" strategies, such as building orientation, and to avoid costly add-ons at later stages needed to compensate for bad early decisions. When "passive design principles" are established correctly the need for lighting, cooling and heating is reduced, which allows the use of smaller and more efficient building systems and technologies.

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