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Meteorological Considerations in Environmental Protection of Large Building Construction Projects

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Abstract
Meteorology plays an important role in the design, alignment and orientation of buildings, streets and urban colonies. Mitigative measures to ameliorate adverse impacts in tropical climates are suggested.
Key Words: Urban Climates, Heat islands, Building alignments, Construction Projects

1. Introduction
Meteorological parameters of importance in Building Industry are radiation, temperature, wind (direction and speed) and rain. Adept utilization of these leads to minimum environmental impacts and power demands consequently energy conservation.

2. Radiation
In the northern hemisphere east facing walls receive an early peak of direct solar radiation soon after sunrise. In the middle of the day, the south facing wall is most favoured and in the afternoon the west facing wall. North facing walls receive direct solar radiation at the height of summer only.

In the tropics the roof is more important because of high elevation of Sun. Thermal load on the roof can be reduced by cooling roof areas with a thin layer of water or wet soil with vegetation. Roof top vegetation decreases indoor air temperature by 2°C. Absorption of solar radiation by a building depends upon the reflectivity of the building materials and the area of windows allowing penetration to the interior. In strong radiation environments use of paints and materials with high reflectivity greatly help in reducing heat loading.

In hot weather, the amount of energy extracted by air conditioning systems is inversely related to external air temperature. Flooded roofs/substantially vegetated with clinging vines or creepers cause evaporative cooling and reduce heat load. A continually wetted fence covered with vines located upwind of a building in dry, windy areas can be a very effective air cooler

In hot dry regions the attempt is to control heating the interior by cutting down solar radiation input. This is possible by keeping all openings very small and by use of shade from window blinds, verandahs, overhanging projections, trees or adjacent buildings. Mutual shading is provided by placing buildings very close to each other so that the intervening streets are narrow and remain in shade most of the time. It is also important to shade surrounding areas by trees to keep them cool.

Paved surfaces store more heat and remain hot longer than unpaved or grass surfaces. Paved surfaces radiate and reflect appreciable amount of energy into the house hence should not be close to houses/buildings.

3. Temperature
Conduction of heat into the building from the exposed walls is offset by use of thick walls made of high heat capacity materials such as earth, brick or stone. These ensure a lag of 5 – 7 hours for the peak of exterior temperature wave to reach the interior. This use of wall storage is a useful delaying practice but the heat will still arrive into the interior in the evening. It is then necessary to increase interior/exterior ventilation to remove the excess heat load. During day ventilation pathway is restricted by the small openings and shutters. At night ventilation is to be maximized to remove wall heat and to replace it with the now cooler exterior air.

In hot dry environment only slight air movement is required for evaporative cooling to be effective, however, with high humidity vigorous motion is required. In hot humid areas shade and openness is needed. Shade is even more important in the hot/dry case. This necessitates providing shade from the complete sky and not just the solar disc, since the diffuse beam input is relatively large. Openings are to be oriented to make best use of prevailing winds and local breezes and the whole building be placed on stilts in order to take advantage of the natural increase of wind speed

with height. Similarly much of the surrounding vegetation may be removed to reduce the possibility of air stagnation. Interior/exterior exchange can artificially be provided by fans.
Large temperature differences between outdoor and indoor temperatures can be achieved by (i) providing a layer of insulating material such as fiber glass or Thermo-Cole under the reinforced concrete roofing in addition to the usual layers of lime concrete and brick tiles and (ii) minimizing the exposure of the external surfaces of the buildings from direct sunshine. This can be achieved by surface reflection coefficient decided by color, exact orientation of built form decided by sun path which also decides solar radiation intensity.

The effect of Glass windows on the temperature inside the room depends upon the shading coefficient of the window panes. "Shading coefficient" is defined as the ratio of total solar heat gain (by transmitted, absorbed and re-radiated energy) for the particular shade and glass combination to the solar heat gain through a single un-shaded pane of common window glass. It differs with color, thickness and material, shape and orientation of shading device, the sun's angle and the amount of diffuse radiation. Desired shading coefficients can be attained by choosing window and shade combinations.

Relative variations of temperature for different exposures, environments, surfaces and shelters/shades are given below.

Average summer midday air temperatures (°C)

Exposure	Clear Days	Cloudy days
Sea shore	28.9	22.4
Rural areas	29.5	22.5
Open residential areas	29.7	22.4
Commercial & Dense Residential areas	30.1	22.5

Surface temperature on a sunny day (°C)

Environment	Temperature
Water surfaces *	27.5
Forests	27.5
Open fields	30.8
Greenery in Urban areas#	31.0
Open housing areas	32.2
Built-up spaces	34.7
Parking lots & Shopping centers	36.0

* A pond of 127,000 m^2 area with water reduced air temperature by 3°C unto 800m downwind. The same pond without water reduced air temperature only by 1°C up to 400m.
# Urban green areas affect up to a maximum distance of 300m downwind. Any increase of green area can only affect up to a maximum distance of 400m downwind. Temperature reduction and energy saving can be achieved by landscaping since vegetation coverage area and air temperature are inversely related.

Variation in air temperature over different surfaces on a sunny day (°C)

Surface	Temperature
Air temperature in standard screen	25
Concrete walk, no shade	35
Dark slate roof, no shade	43
Short grass, no shade	31
Within leaves of tree	27
Soil in shade of tree	26

Temperature observations above and beneath of a roof surface (°C)

Location	Temperature
Outside air temperature, screen	31.1
Dark asbestos single roof, no shade	50.0
Temperature below insulated roof	42.2
Temperature in fan ventilated attic below insulated roof	32.2

4. Wind

Buildings and streets aligned in the predominant wind direction enable flushing out heat hence prevent heat island formation as well as pollutants stagnation. Buildings perpendicular to wind experience wind loads proportional to square of wind speed. Residents experience difficulties in opening and closing the doors & windows. This usually happens in the first row while the streets in the subsequent rows are in the wind shadow and face stagnation conditions resulting in warm pockets formation and pollutants accumulation. Tall buildings create whirling eddies around and tend to accumulate dust, leaves and litter and pose a potential threat to the safety of pedestrians. To mitigate this, one approach is providing elevated through flow of car parking at the ground level and then raised towers.

Winds at 5 m/s disturb hair and causes clothing to flap. At 10 m/s dust and litter is picked up. At 20 m/s wind it is difficult even to walk. These features are observed around buildings of greater than 6 storeys or if the tower height is more than twice the height of the surrounding buildings.

Shelterbelts in the windward direction prevent strong winds hence soil erosion. These are effective only for low rise buildings. Preventing hot / cold winds reduces power demands for air conditioning/ refrigeration and thus energy conservation.

In hot humid areas airflow of 2 m/s are entirely desirable. The average indoor speed depends generally on the size of smaller opening, either inlet or outlet, while the maximum indoor speed varies inversely with the ratio of inlet to outlet size.

When a room is not cross ventilated, the average inside air movement is quite low. Two smaller openings on the same wall and with oblique wind improve the circulation within the room markedly. Since the direction of entry of wind into the room influences air movement, the airflow can be directed by the use of jalousie windows, louvers of different types or center-pivot hung windows.

Vegetation around high structures has very little use but around low structures the position and size have significant effect. Large trees upwind of a building deflect the wind over, under and around itself. Airspeed under the tree could be higher. Trees close to the building result in unsatisfactory airflow. Hedges 3 to 6 m from the buildings result satisfactory airflow distribution in the room. Screens on windows markedly reduce interior air movements. Light winds are more effectively stopped by screens than stronger winds. A 16- mesh, 30 – gauge wire screen reduces a 2.4 kmph wind by 60% while it reduces 16 kmph wind by only 25%. Oblique winds slip over the screen without penetrating into rooms effectively.

5. Rainfall

Product of peak hourly rainfall and collecting area divided by the capacity of each of the Rainfall Harvesting Pit (RHP) decides the number of RHP's to be provided. This product is useful in designing storm water drains to prevent any flooding. Similarly the product of annual average rainfall and collection area decides the storage tank capacity. Both peak hourly rainfall and annual average rainfall can be collected from Ind. Met. Dept. readily.

It may be useful to determine the Driving Rain Index (DRI). It is the sum of the products of hourly rainfall amounts and the corresponding mean hourly wind speeds. The direction in which the DRI is large is to be protected by providing extended overhangs to prevent rain entering the windows or doorways.

Based on daily rainfall observations, 24 hr rainfall averaged over 50 years is computed and isohyets are drawn over the whole of India in I.Met.Dept... Similarly 1 hr maximum (rainfall) isohyetal maps are also drawn. The latter is useful in designing storm water drains to prevent any flooding. Seasonal/annual isohyetal maps can be used to determine the storage capacity of underground tanks while harvesting rainfall.

6. Mitigating Environmental Effects on Buildings in Tropics

Adverse effects of tropical climates like high temperature, strong wind driven rain, high humidity on external finishes can be effectively combated by designing low rise buildings with wide overhanging roof eves and adequate water collection facilities. Both are aesthetically pleasing and practically well protected due to the relatively high elevation of the sun and the vertical discharge of rainwater. High-rise buildings are more problematical but the avoidance of flush curtain walling, unprotected roof parapets and the use of fins, canopies and other horizontal projections can go a long way to protect large areas of walling.

House shapes elongated in N-S direction are less efficient in both winter and summer. In every case the most satisfactory shape is one in which the house is elongated in some general E-W direction. A square building with an interior courtyard containing shade, or generally a cubical building with a portion of one wall cut out, the area being grassed and containing trees, a pool, an evaporative cooling device, or a trellis with vegetation is a compromise design for winter conditions of hot arid region and severe heat stress in summer. If the outside wall is continued around the whole building, the smaller garden environment provides a cool area within the house structure while minimizing the solar radiation impact on the outside walls of the house.

Width and Orientation of Streets & Buildings: The "tolerance" of building orientation for cross ventilation is about 60° on either side of the prevailing wind direction. The "tolerance" of orientation for solar energy utilization is only about 30° on either side of the sun's winter noon position (in latitudes above 20° N). Because of larger tolerance of solar orientation, the prevailing wind especially in the evenings should be the main factor in choosing the optimal orientation of building block, especially in hot humid regions.

Wide streets either parallel or at a small angle to wind direction improve general ventilation. Ventilation in streets perpendicular to wind direction and buildings lining these streets in a long row are hardly affected by width of the streets. Vines covering the light /white coloured walls reflect less outwards reducing the radiation impinging on the wall itself. They reduce glare in the street without adding heat load to the buildings. Deciduous vines covering walls protect from heat in summer and absorb solar radiation in winter for warming.

Trees along sidewalks are effective in reducing the reflected glare while also protecting the pedestrians from the direct sun.

Compared to the lower height buildings, upper floors of the high-rise buildings enjoy better ventilation conditions, but penetration of wind driven rain through openings is a serious problem. They are less likely to be shaded by nearby buildings. Solar radiation intensity impinging on them both, direct and reflected from roof tops of surrounding buildings, is higher than the "typical" urban buildings. Shading is thus more important.

Major environmental advantage of the inhabitants of upper floors of high rise buildings is the better view offered from their windows. While the visual environment is congested for other city dwellers, high rise apartment residents enjoy a view of distant scenes. Environmental noise levels at these upper floors are substantially lower than the typical urban buildings. Both greater distances from the noise sources and reduced noise reflection improve the noise environment.

The colour of the building walls affects not only the interior climate but also the light and glare in the streets. Light coloured walls are preferred.

Horizontal overhangs from buildings to protect the windows from solar radiation and rain can be extended over the entire length of wall so that they shade also parts of the wall below projections from direct solar radiation while hiding part of the wall above them and thus reducing glare from the street level. Greenery reduces the air temperature than those areas of exposed asphalt, concrete or sand. Trees provide shade to pedestrians. Deciduous trees provide shade during summer when it is needed and allow solar radiation for heating during winter when it is most desirable.

High-rise tower buildings built among lower height buildings around them increase mixing of air above the urban canopy with the air at ground level. Air pollution which is generally higher at ground level by mixing with the air at higher level reduces the ground level pollution. Thus high rise buildings improve the air quality at the street level around them. Also the wind speeds in the streets around them can increase up to 300% which may be welcome where street ventilation is poor.

7. Conclusions

Thermal load on the roof top can be reduced by insulation/wetting/vegetation. Roof top vegetation reduces indoor air temperature by 2°C.
Minimizing exposure of external surfaces of buildings from direct sunshine by choosing colour and orientation reduces indoor temperature from outdoor.
Alignment of buildings, streets along predominant wind direction mitigates heat island formation and pollution stagnation.
Shelterbelts effective only for low rise buildings prevent strong hot winds in summer and cold winds in winter reducing power demands for air conditioning hence energy conservation.
Peak hourly and annual average rainfall enable to design storm water drains, number of rain harvesting Pits and underground storage tanks.
Adverse environmental effects of tropical climates can be effectively combated by low rise buildings with wide overhanging roof eves and adequate water collection facilities. High rise buildings are more problematic.
Tolerance of building orientation is less for wind direction compared to solar energy hence the prevailing wind direction should be the main factor in choosing the optimal orientation of building blocks particularly in hot humid regions.

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