Thermal Performance and Energy Efficiency of Naturally Ventilated Classrooms: A Case Study on Some Urban School Buildings Located in Bangladesh

A. F. M. Mohiuddin Akhand

Department of Interior Architecture, Shanto-Mariam University, Dhaka

Abstract: **The paper mainly concentrates on the thermal performance of the naturally ventilated classrooms of the urban school buildings in Sylhet in Bangladesh. The focus lays on the significance of naturally ventilated classrooms in specific climatic zones the energy efficiency issues where some of those pictures based on the review of the prevailing ideas in the literature and case studies as well. The notion of the thermal impacts due to the natural ventilation is not merely a perceptual entity but also a physical reality. The aim behind the study is to determine the characteristic features of natural ventilation to visualize the theme of thermal environment inside of the classrooms and to understand the collective impacts from the present scenario of ventilation pattern. But, now, it has been identified that the concept of naturally ventilated buildings encompasses the energy efficiency, identity and amiability of the existent features. It comprises a significant physical comfort, healthy thermal environment and also minimizes the use of electricity and energy as well.**

***Keywords*: Natural Ventilation, Thermal Performance, Urban School Buildings, Composite Climate, Energy Efficiency**

I. INTRODUCTION

Natural ventilation involves harnessing naturally available forces to supply and removing air through an enclosed space. There are three types of natural ventilation occurring in buildings: wind driven ventilation, pressure-driven flows, and stack ventilation. The pressures generated by 'the stack effect' rely upon the buoyancy of heated or rising air. wind driven ventilation relies upon the force of the prevailing wind to pull and push air through the enclosed space as well as through breaches in the building's envelope (see Infiltration (HVAC)). Natural ventilation is generally impractical for larger buildings, as they tend to be large, sealed and climate controlled specifically by HVAC systems. Both are examples of passive engineering and have applications in renewable energy. The rationale of the study is to evaluate the thermal condition and its impact on the students' performances in the naturally ventilated classrooms in the urban school buildings of Sylhet. Sharmin et al. (2015) had disclosed the thermal environment of urban spaces plays a great role on the quality of life in a city. It directly affects people's behaviour and usage of outdoor spaces, studied on outdoor urban spaces in high-rise buddings in Dhaka city. Main aim of this paper is to a) to understand the nature of the problem, b) to address some possible recommendations, c) introduction to some design guidelines to provide a better thermal environment by natural ventilation.

II. LITERATURE REVIEW

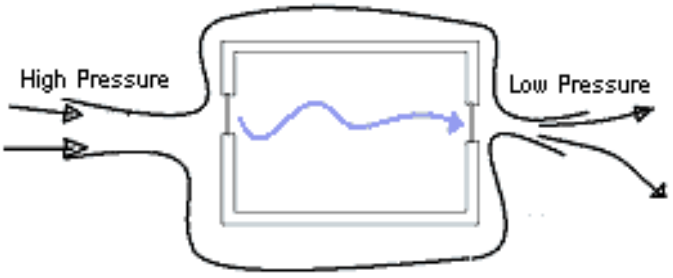
Schools is very important place for students to learn and develop their skills. Alwetaishi, et al (2017) investigated on the energy responsiveness of new and traditional school building design, where major variation in form, amount of external walls and glazing are different which had focused on indoor microclimate condition of selected schools in the city of Jeddah where the climate is hot and humid using advanced tools for monitoring.

Wong and Khoo (2003) conducted thermal comfort survey in classrooms which are mechanically ventilated by fans in Singapore. It is found that the occupants' acceptable temperature range lies beyond the comfort zone of ASHRAE standard 55. Corgnati et al (2009) carried out surveys in two University classrooms in Turin, Italy applying both objective and subjective surveys confirming that thermal comfort condition and high energy performance are complimentary to each other. Jung et al (2011) investigated subjective responses of thermal comfort of students in a University in Korea and it found that the mean Thermal Sensation Vote (TSV) of respondents is almost neutral when the PMV in the classroom moves to neutral and slightly cool, and the TSV is almost '+1.5' when the PMV moves to slightly warm. It is also reported in study's that the acceptability ratio of thermal environment is slightly different from ASHRAE Standard55-2004. It is found from thermal comfort survey at school that children are more sensitive to changes in their metabolism than adults, and their preferred temperature is lower than that predicted by the standard models (Teli et al, 2012; Yun et al, 2014). Mishra and Ramgopal (2014) have done a thermal comfort survey inside a naturally ventilated laboratory in the tropical climatic region of India.

Natural ventilation in the hot, humid situations, unconditioned ventilation air will deliver approximately one pound of water each day for each cubic foot per minute of outdoor air per day, annual average. This is a great deal of moisture, and it can create serious indoor moisture and mold problems. Ventilation efficiency is determined by design and layout and is dependent upon placement and proximity of diffuses and return air outlets. Cross-contamination occurs when pressure

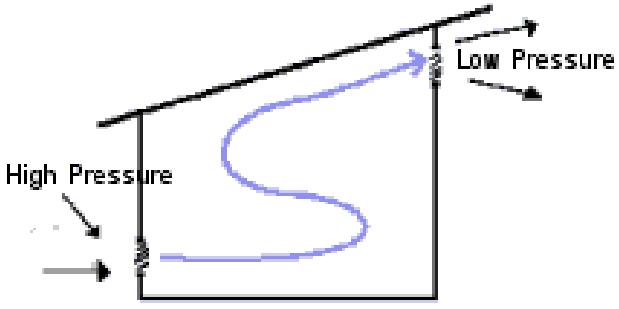
differences arise, forcing potentially contaminated air from one zone to an uncontaminated zone. Re-entry of exhaust air occurs when exhaust outlets and fresh air intakes are either too close, or prevailing winds change exhaust patterns, or by infiltration between intake and exhaust air flows. Entertainment of contaminated outside air through intake flows will result in indoor air contamination. There are a variety of contaminated air sources, ranging from industrial effluent to VOCs put off by nearby construction work. Natural ventilation can be a key element of cooling strategies in many climates. Mechanical ventilation can also be part of cooling strategies (that's the case of the ceiling fans), but it involves also other goals: remove stale and polluted air, distribute fresh air, etc.

Other than this, it may use the cross ventilation too. When people open windows in opposite sides of the house to cool the indoor temperatures, they are using cross ventilation.



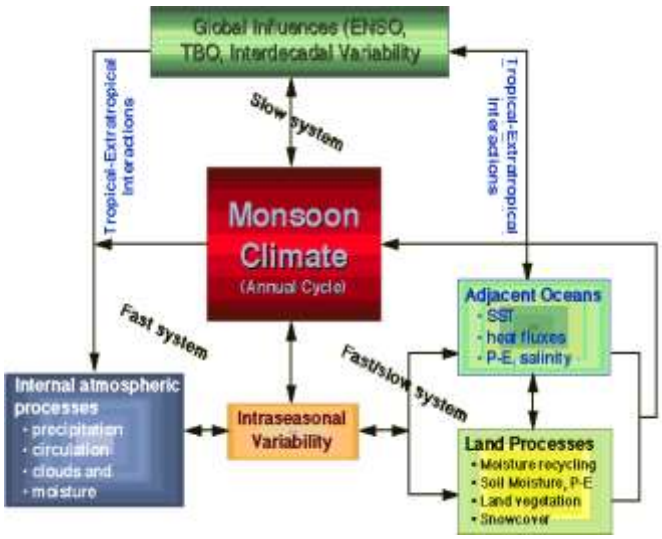
Cross Ventilation

Natural stack ventilation (also called convective ventilation) uses a physics natural law: the chimney effect or air buoyancy. In natural stack ventilation, the warmer indoor air rises up from lower living areas and escapes through the upper openings of the building, causing cold air infiltration through windows or other lower opening.



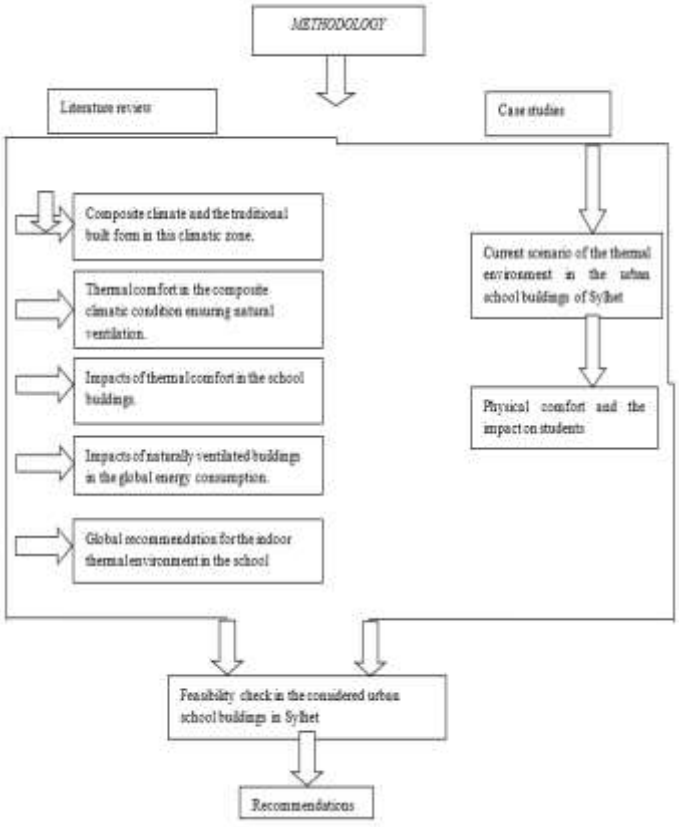
Stack Ventilation

Monsoon climate is found in India, **Bangladesh**, Thailand, the Philippines, Southwestern Africa, French Guiana, and southeastern Brazil. The stations located in monsoon climate experience plentiful rainfall like that of the equatorial climate stations but almost all of the year's rainfall is received in summer months. As they are located quite near the equator, the tropical monsoon climate experiences warm temperatures throughout the year and the average temperature of every month are usually over 70 F (21 C). The tropical monsoon climate experiences abundant rainfall like that of the tropical rain forest climate, but it is concentrated in the high-sun season. Being located near the equator, the tropical monsoon climate experiences warm temperatures throughout the year.



However, recently Zahan et al.(2021) had shown that utilization of rice husk ash with clay to produce lightweight coarse aggregates for concrete buddings including schools but this paper would like to focus on very specific accusative.

III. METHODOLOGY



Case Study Analysis and Findings

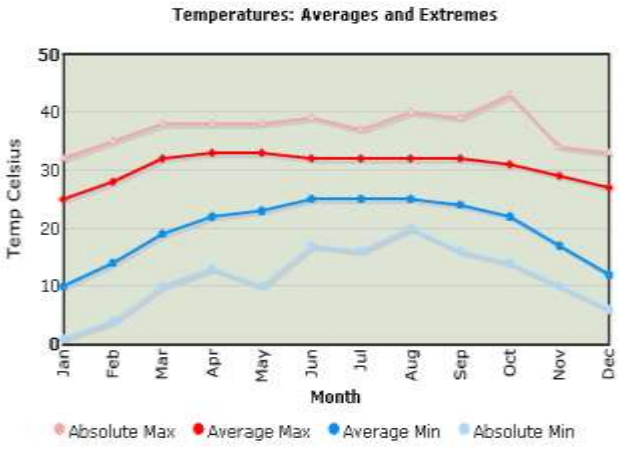
Sylhet District has an area of 3,490 km²; and is bounded by the districts of Maulvi Bazar, Sunamganj, Habiganj along with Cachar and Karimganj districts of India. The physiographic of Sylhet consists mainly of hill soils, encompassing a few large depressions known locally as beels which can be mainly classified as oxbow lakes, caused by tectonic subsidence primarily during the earthquake of 1762.

Sylhet experiences a hot, wet and humid tropical climate. The city is within the monsoon climate zone, with annual average highest temperatures of 23°C (Aug-Oct) and average lowest temperature of 7°C (Jan). Nearly 80% of the annual average rainfall of 3,334 mm occurs between May and September.

3.2 Climatic Variables:

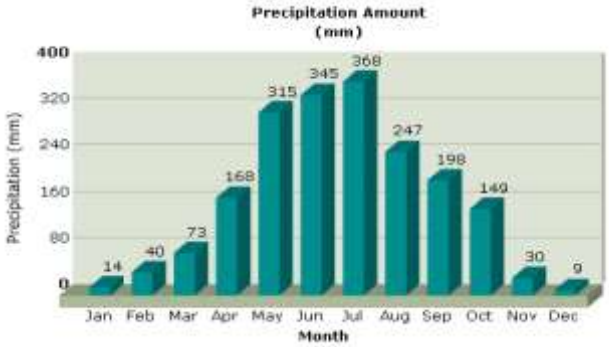
3.2.1 Temperature:

The temperature graph is shown below:



3.2.2 Precipitation:

The precipitation is shown below:



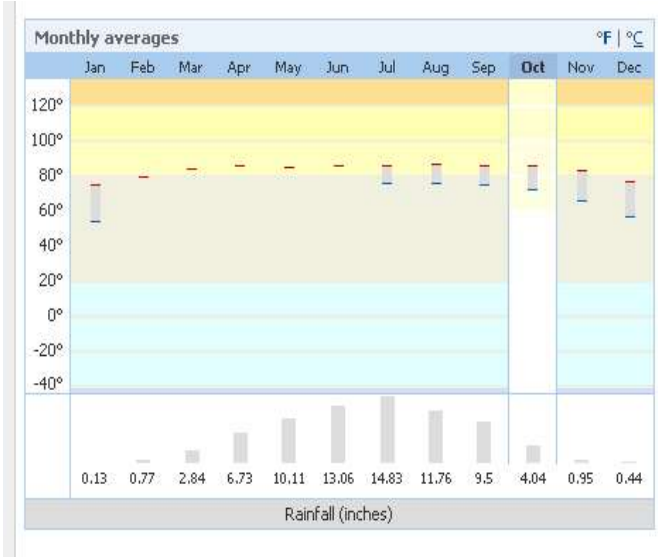
3.2.3 RAIN FALL:

The rainfall graph is shown below:

3.2.4 Wind Speed:

The wind speed graph is shown below:

3.2.5 Annual Mean Temperature And Average Rainfall : The annual mean temperature and average rainfall is shown in the graph below:



Monthly Averages			
January	Avg Low: 56°	Avg High: 77°	Avg precip: 0.13 in
February	Avg Low: NA	Avg High: 81°	Avg precip: 0.77 in
March	Avg Low: NA	Avg High: 86°	Avg precip: 2.84 in
April	Avg Low: NA	Avg High: 88°	Avg precip: 6.73 in
May	Avg Low: NA	Avg High: 87°	Avg precip: 10.11 in
June	Avg Low: NA	Avg High: 88°	Avg precip: 13.06 in
July	Avg Low: 78°	Avg High: 88°	Avg precip: 14.83 in
August	Avg Low: 78°	Avg High: 89°	Avg precip: 11.76 in
September	Avg Low: 77°	Avg High: 88°	Avg precip: 9.5 in
October	Avg Low: 74°	Avg High: 88°	Avg precip: 4.04 in
November	Avg Low: 67°	Avg High: 85°	Avg precip: 0.95 in
December	Avg Low: 59°	Avg High: 79°	Avg precip: 0.44 in

3.3 Different Climatic Situation Throughout The Year (May, October & January)

3.3.1 Month: May:

The information presented below gives detailed historical monthly average weather conditions along with exceptional weather occurrences. To maintain relevance to current weather trends the displayed information has been calculated using data collected over the past two decades. The climate profile is taken from closest available data source to Sylhet.

Temperature: Throughout the month of May daytime temperatures will generally reach highs of around 33°C that's about 91°F. At night the average minimum temperature drops down to around 23°C, that's 74°F.In recent times the highest recorded temperature in May has been 38°C that's 100°F, with the lowest recorded temperature 10°C, about 51°F.

Relative Humidity: The average daily relative humidity for May is around 79%.

Heat Index: The Heat Index is a measure of how hot it feels when relatively humidity is added to actual air temperature. From this a comfort level is calculated providing categories on how heat conditions might adversely affect someone.

Comfort Levels: Given average maximum temperatures and humidity levels you can expect dangerous heat conditions. Sunstroke, muscle cramps and heat exhaustion are likely. Heatstroke is possible with prolonged exposure and/or physical activity (see heat index for more information).

Precipitation: The average monthly amount of precipitation has been recorded at around 315 mm, that's 12 inches. Throughout the month you can expect to see rain or drizzle falling on 14 days of the month.

Wind: The average daily wind speed in May has been around 4 kph, that's the equivalent to about 3 mph, or 2 knots. In recent years the maximum sustained wind speed has reached 63 kph, that's the equivalent of around 39 mph, or 34 knots.

Fog: On average the month of May is not affected by foggy conditions.

3.3.2 MONTH (JANUARY):

The information presented below gives detailed historical monthly average weather conditions along with exceptional weather occurrences. To maintain relevance to current weather trends the displayed information has been calculated using data collected over the past two decades. The climate profile is taken from closest available data source to Sylhet.

Temperature: Throughout the month of January daytime temperatures will generally reach highs of around 25°C that's about 77°F. At night the average minimum temperature drops down to around 10°C, that's 51°F. In recent times the highest recorded temperature in January has been 32°C that's 90°F, with the lowest recorded temperature 1°C, about 34°F.

Relative Humidity: The average daily relative humidity for January is around 74%.

Heat Index: The Heat Index is a measure of how hot it feels when relatively humidity is added to actual air temperature. From this a comfort level is calculated providing categories on how heat conditions might adversely affect someone.

Comfort Levels: Given average maximum temperatures and humidity levels generally you should not anticipate any discomfort from heat (see heat index for more information).

Precipitation : The average monthly amount of precipitation has been recorded at around 14 mm, that's 1 inches. Throughout the month you can expect to see rain or drizzle falling on 3 days of the month.

Wind : The average daily wind speed in January has been around 1 kph, that's the equivalent to about 1 mph, or 1 knots. In recent years the maximum sustained wind speed has reached 70 kph, that's the equivalent of around 44 mph, or 38 knots.

Fog: On average the month of January is affected by foggy conditions on 12 days.

3.3.3 MONTH (OCTOBER):

The information presented below gives detailed historical monthly average weather conditions along with exceptional weather occurrences. To maintain relevance to current weather trends the displayed information has been calculated using data collected over the past two decades. The climate profile is taken from closest available data source to Sylhet.

Temperature: Throughout the month of October daytime temperatures will generally reach highs of around 31°C that's about 88°F. At night the average minimum temperature drops down to around 22°C, that's 72°F. In recent times the highest recorded temperature in October has been 43°C that's 109°F, with the lowest recorded temperature 14°C, about 56°F.

Relative Humidity: The average daily relative humidity for October is around 84%.

Heat Index : The Heat Index is a measure of how hot it feels when relatively humidity is added to actual air temperature. From this a comfort level is calculated providing categories on how heat conditions might adversely affect someone.

Comfort Levels: Given average maximum temperatures and humidity levels you can expect dangerous heat conditions. Sunstroke, muscle cramps and heat exhaustion are likely. Heatstroke is possible with prolonged exposure and/or physical activity (see heat index for more information).

Precipitation: The average monthly amount of precipitation has been recorded at around 149 mm, that's 6 inches. Throughout the month you can expect to see rain or drizzle falling on 10 days of the month.

Wind: The average daily wind speed in October has been around 2 kph, that’s the equivalent to about 1 mph, or 1 knot. In recent years the maximum sustained wind speed has reached 83 kph, that’s the equivalent of around 52 mph, or 45 knots.

Fog: On average the month of October is affected by foggy conditions on 2 days.

3.4 Thermal Comfort In Schools Buildings in Sylhet

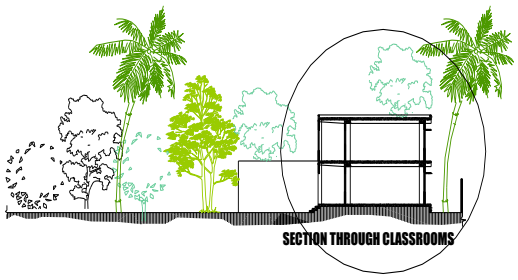
The composite climate of Sylhet might have an adverse impact on the comfort of the occupants. Most classrooms in Sylhet schools rely on a combination of cross ventilation and mechanical ventilation by fans to achieve thermal comfort.

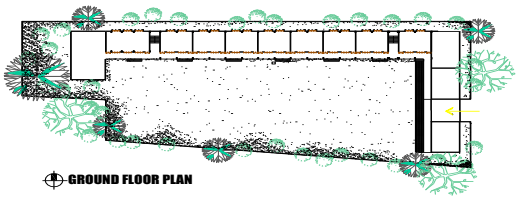
In a study conducted in a secondary school to gain an understanding of the cohesiveness of classrooms towards learning, the results showed that the thermal comfort conditions of the classrooms were slightly below the recommended level of 80% acceptability.

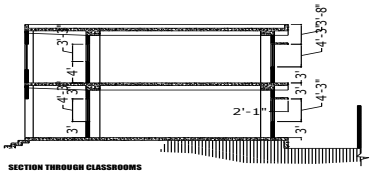
Case Studies Analysis

Case 1: Blue Bird School

Location: Mirer Moydan, Subitbazar, Sylhet
Number of students: 900 (approx)
Year of establishment: 1976
Layout as follows-





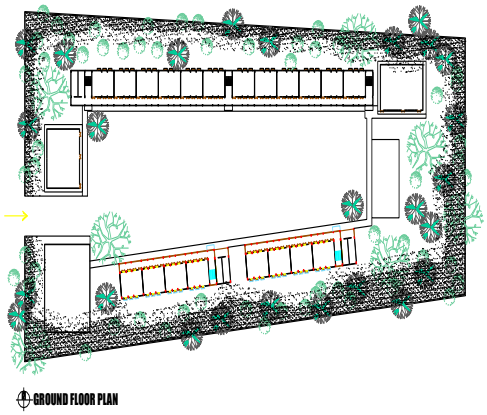


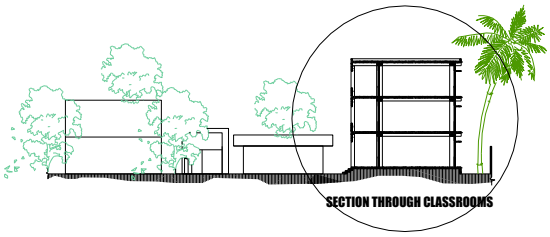
Features:

- 2' wide horizontal shading device
- Non transparent opening materials to avoid visual disturbance
- Single loaded corridor
- High student density according to the size of the classroom.
- Orientation of the classroom: north-south
- Natural ventilation with fan

Case 2: The Aided High School

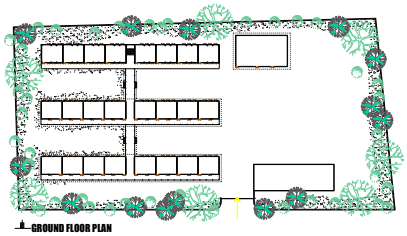
Location: Tatipara, Zindabazar, Sylhet
Number of Students: 1400(Approx)
Year of Establishment: 1928

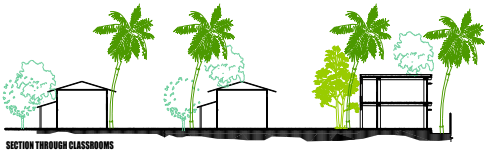


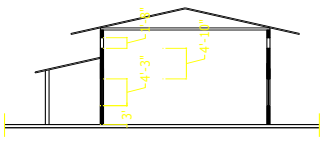


Case 3: The Pilot High School

- Location: Kalighat, Sylhet
- Number of Students: 2000(Approx)
- Year of Establishment: 1836







COMPARATIVE ANALYSIS:

Agugust 3rd Week, 2005			
SCHOOL NAME	TEMP.	RH	WIND VELOSITY
BLUE BIRD SCHOOL, Sylhet	31.4 DEG	77%	.4 ms-1
AIDED SCHOOL, Sylhet	30.2 DEG	72%	0.27 ms-1
PILOT SCHOOL, Sylhet	29.8 DEG	79%	.5 ms-1
Agugust 2nd Week, 2005			
SCHOOL NAME	TEMP.	RH	WIND VELOSITY
BLUE BIRD SCHOOL, Sylhet	29.7 DEG	79%	.6 ms-1
AIDED SCHOOL, Sylhet	29.0 DEG	75%	0.4ms-1
PILOT SCHOOL, Sylhet	30.0 DEG	80%	.7 ms-1
August 1st Week, 2005			
SCHOOL NAME	TEMP.	RH	WIND VELOSITY
BLUE BIRD SCHOOL, Sylhet	30.4 DEG	76%	.3 ms-1
AIDED SCHOOL, Sylhet	31.1 DEG	80%	0.29ms-1
PILOT SCHOOL, Sylhet	31.8 DEG	79%	.45 ms-1

*** TEMP.= temperature, RH= relative humidity

IV. RECOMMENDATION AND CONCLUSION:

Some of the design features for buildings in this climate are given bellow. As an concluding remarks it may be followed in future school building perpetration. Those are-

1. Appropriate orientation and shape of building
2. Use of trees as wind barriers
3. Roof insulation and wall insulation
4. Thicker walls
5. Air locks and balconies
6. Weather stripping
7. Walls, glass surfaces protected by overhangs, fins, and trees
8. Pale colors and glazed china mosaic tiles
9. Exhausts, Courtyards, wind towers, and arrangement of openings
10. Trees and ponds for evaporate cooling
11. Dehumidifiers and desiccant cooling

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