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ADAPTIVE MODEL TO THERMAL COMFORT STANDARDS (CASE OF EDUCATIONAL BUILDING KARACHI)

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Abstract:

In present societies, occupants spend most of their time indoors. Students spend 80% of their time in educational buildings then other types of a commercial building complex apart from at home prominence the significance of adequate internal thermal settings in the learning structures. The thermal conditions are connected to human comfort, building efficiency and energy conservation. In this study, Adaptive model is used to evaluate the heat balance approach for the naturally ventilated buildings. The adaptive approach that showed the connection among comfort temperature T_c and outdoor temperature t_o. The selected sample for the research is small-sized plots of schools of organi town Karachi. This adaptive model of **Humphreys and Nicol** is used to identify the comfort zone in naturally ventilated school buildings. The research method is based on mapping, field documentation, and quantitative measurements of inside and outside temperature and humidity levels. The aim of this research is to documentation of architectural parameters and analysis of indoor thermal performance of selected cases for providing the better working and learning environment.

Keywords: Adaptive model, Built environment, Educational building, Thermal Comfort

1. INTRODUCTION

Thermal comfort is play a very important role in providing an acceptable indoor conditions for individuals. Furthermore, in previous researches it has been observed that indoor spaces in school has been less study compare to other buildings such as offices, hotels, industrial and commercial buildings. As students have a smaller amount of resilient to adverse indoor environmental settings competed to grownups, and thus the scale of thermal effects on schoolwork operation may be greater than that on workplace performance by adults. (Haddad, King & Osmond, 2012). In present societies, individuals spend most of their time indoors. (Zomorodian, Tahsildoost, & Hafezi, 2016). The thermal conditions are linked to efficiency, comfort and energy conservation in school buildings. (Zomorodian, Tahsildoost& Hafezi, 2016)

In the case of Karachi, the general practice is observed that private school buildings are mostly constructed on small-sized lands. Because of inappropriate plot sizes, these buildings are not fulfilling the requirements for the active learning environment. The efficient learning environment is linked with the building performance and indoor environmental quality. (Akhtar, 2016) In this research, the selected private school buildings such as (Al-Rehman grammar, Abid grammar, new grammar children and Iqra real high school) were constructed on narrow plot sizes i.e. 120 to 400sq.yard. The thermal environment of such schools are not comfortable for learning environment due to these buildings are lacking in the significant design parameters like ventilation, illumination and especially fenestration system are not designed according to the solar orientation. (Akhtar, 2016). However, the indoor environmental parameters such as

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acoustic, day lighting and thermal comfort are highly important in educational building design.

This quality of the thermal environment has negatively affected on occupant behavior and productivity thus there is a need to evaluate its existing thermal conditions, building related factors and determine the comfort temperature standards so that its building design could be improved to sustain it for the better and calm environment for learners.

1.1 THERMAL COMFORT INFLUENCE ON HUMAN HEALTH

According to the ASHRAE 55-2013 “Thermal comfort is the condition of occupant feeling which is related to the satisfaction with the thermal environment. Furthermore, appropriate thermal conditions are providing comfortable indoor environment for individual.

The thermal comfort is essential part in building plan process for providing comfortable and healthier environment for individuals and has a major influence on human well-being and safety. Previous studies are reported that indoor thermal conditions are linked with the ambient temperature.

There are many researches to say that mortality can be associated with cold and heat waves (Ye et al., 2012). Heat waves and exposure of hot air was well-known to be linked with greater risk of cardiac, cerebrovascular and breathing health problems. (Songet al., 2017). According to the world health organization in the last past thirty years around 150,000 diseases are produced by climate change (Patzet al., 2005).

Thermal comfort is correlated with the human feeling and perceptions of different environmental and physical parameters. Thermal conditions are dependent on the four of the environmental factors i.e. inside air temperature, humidity, wind speed and the mean radiant temperature.

These above factors have a significant impact on the thermal environment which is associated to inhabitant gratification and energy use in the building.

Moreover, thermal comfort is important for efficiency in working environment. If occupants are working in an unsatisfactory indoor environment, which is influenced on their working performance and thinking ability. The ancillary effects of thermal conditions are to improve positivity in workplace. (Executive, 2019).

1.2 FACTORS AFFECTING THERMAL COMFORT

Generally, an individual's observation of thermal comfort is affected by:

- Temperature
- Air movement(speed)
- Humidity
- Activity level (the amount of physical work done)
- Clothing

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1.3 AIR TEMPERATURE

The better air temperature is that where, individuals feel relaxed. However comfortable temperature associated with the clothing and nature of work being performed. Generally, in the case of working environment the comfortable temperature ranges 20-24 centigrade in winter and 25-28 centigrade in summer, when people are being worn clothes according to the seasons**.** (Fuller, 2005). The mean temperature inside the building is increasing through sunlight that can penetrate inside the building through building openings this may be decreased by proper usage of internal and external shading types. (Fuller, 2005)

1.4 AIRSPEED

Increased airspeed will support the evaporation of sweat thus leading to a cooling effect, particularly if loose clothing is worn. However, if the temperature or humidity is too high it cannot be compensated for by airspeed. (Fuller, 2005)

1.5 HUMIDITY

Under the influence of raised humidity levels, the performance of simple everyday tasks becomes difficult for the occupants. This low productivity is a result of decreased comfort level, as the increase in humidity level makes a person feel warmer especially where the airspeed is low. The wind speed in raised humidity gives relief to individuals and increases the comfort level. (Fuller, 2005)

On the other hand, the lower humidity level is also the main factor for discomfort and also has health repercussions. (Fuller, 2005)

1.6 THERMAL BALANCE AND BODILY HEAT TRANSFER

The human body control temperature by maintaining a balance between heat gain and heat loss. Humans regulate heat generation and preservation to maintain internal body temperature. The internal body temperature at rest varies between 36.5 and 37.5 °Celsius (°C), which is 97.7 to 99.5 °Fahrenheit (°F) and it is controlled by the hypothalamus (in the brain) is called body's thermostat. (Fuller, 2005)

Fuller, (2005) defined that the human body sets temperature like a heater. It is constantly producing heat and then distributing it through different methods. Furthermore, human body is released heat through the process of conduction, convection, radiation, and evaporation.

Convection is the process of released hotness through the circulation of air over the skin for example use of a fan to cool off the body. Another process of heat loss is radiation through infrared rays in which the high temperature of the human body is lost through the transfer of temperature from one form to another with no physical contact involved. The last method of heat loss through the conversion of water to gas is called evaporation, as shown in (Figure-1.1)

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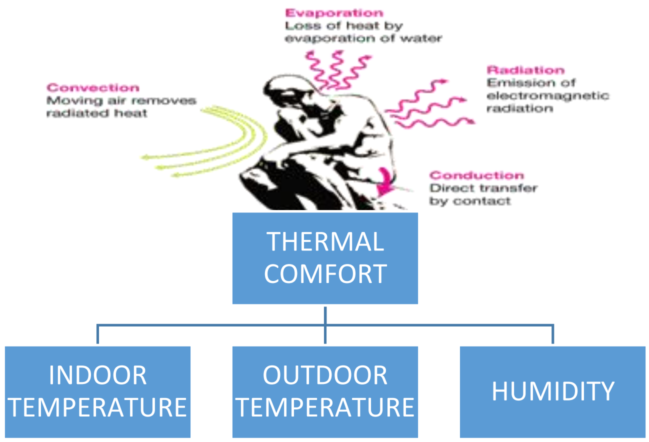
Figure 1.1: Process of thermal balance of the human body Parameters of thermal comfort



1.7 MACRO CLIMATE OF KARACHI

Kazmi, Anjum,& Iftikhar, (2011) stated that the climate is divided into six climatic regions like too cold , cold and hazy, warm and humid, hot and dry moreover composite and moderate. However, microclimatic condition for instance temperature, humidity, solar radiation, and air movement directly influence on the indoor environmental quality of building.

Karachi, being situated on the coast of Arabian Sea experience a mild climate, having summer season for the major period of the year, mild winters and very short spring and autumn. Monsoon rains from Jul to September and a high humidity level from March to November are experienced. (PMD, 2017)

Meteorological Department Karachi (MDK, 2017) observed the average maximum peak temperature of Karachi in May 2017 i.e. 38 centigrade and average minimum in January 2017 i.e. 25 centigrade. **(Figure-1.2)**

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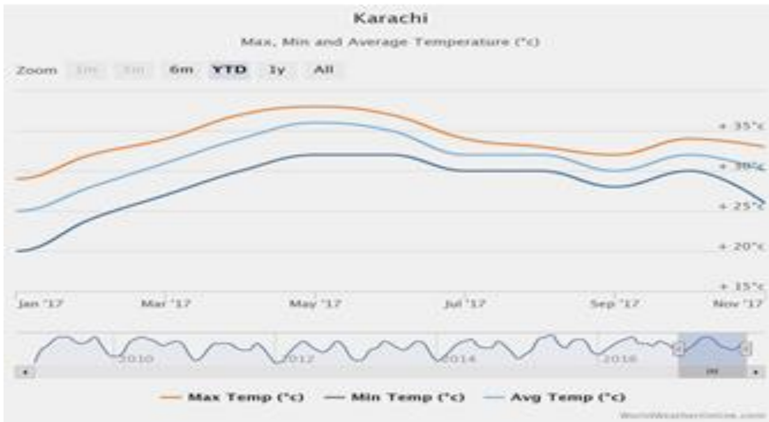
Figure-1.2: Temperature levels



Furthermore, according to MDK station, (2017) observed that January 2017 was the least humid month i.e. 25%, and July 2017 was the most humid month i.e.74 %. **(Figure-1.3)**

Figure-1.3: Humidity level

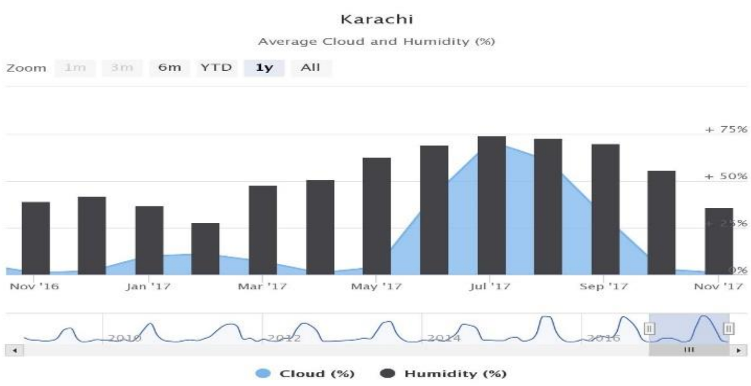


Figure-1.4: Wind speed in mph

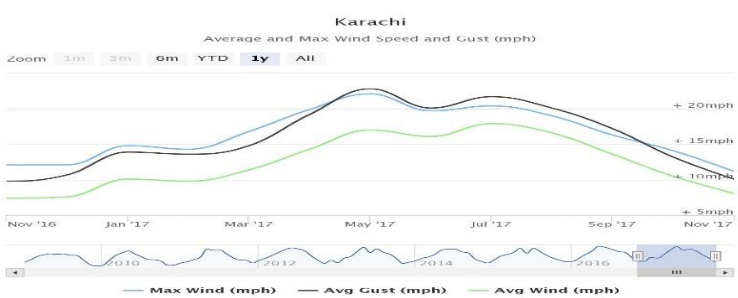


Figure-1.4: illustrates the normal wind velocity varies from 2.6m/s to 4.7 m/s in Karachi. The average maximum wind speed was observed in May 2017 such as 17 mph while the minimum average was 7.7mph since January 2017.

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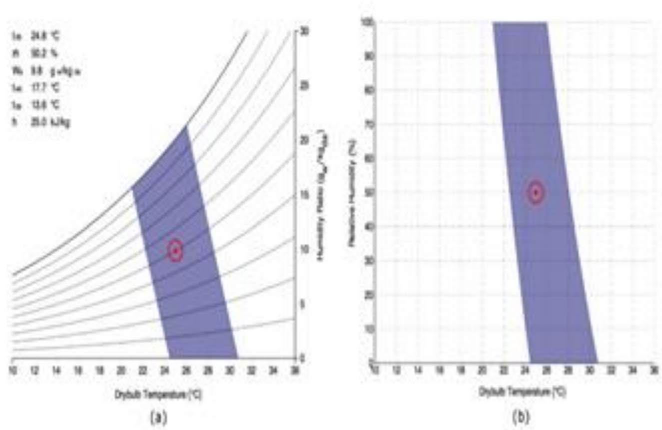
1.8 STUDIES ON THERMAL COMFORT MODELS

The research on the word thermal comfort was taking place in the initial 1920s to control the micro climate of the indoor building environment. In the middle of the 19th century it was important for perfect design of structure on the law of thermodynamics and as an open system layout. (Fabbri, 2015).

In the 1970s, Fanger's comfort model was announced. This model based on monitoring of air quality movement and formulate comfort equation. Which plot both physics and physiology of the human body were also established to shape clear, inclusive thermal perception. Numerous models of comfort monitoring were developed. These models were used to evaluate thermal indoor environment. In the 20th century, focus of studies goes to improve occupant health, safety and comfort (Fabbri, 2015)

According to the Schiavon, (2014) the PMV model is based on six principal aspects that disturb thermal relaxation. The comfort region comprises the conditions for which PMV is among –0.5 and +0.5, viewing 90% of gratified persons in the area. The red dot defines the dry-bulb temperature and moisture standards. Both the comfort zone and the red dot are interacting with each other, and their location can be changed by altering the contribution variables. This chart is describing that each point on the graph has a different dry-bulb temperature and humidity, whereas the MRT is established. The comfort zone showed in blue denotes the mixture of suitable dry-bulb temperature and humidity values, as shown in figure-1.5

Figure-1.5: Visualization of the thermal comfort zone for the same input conditions. (a) Psychometric chart. (b) Temperature-relative humidity chart



Source: Schiavon, S., Hoyt, T., & Piccioli, A. (2014, August). Web application for thermal comfort visualization and calculation according to ASHRAE Standard 55. In Building Simulation (Vol. 7, No. 4, pp. 321-334). Tsinghua University Press.

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The above charts are defined as the MRT is stable and the x-axis shows the dry-bulb temperature and y-axis illustrated as humidity. The user can examine the other psychometric variables like Dry-bulb temperature (tdb), relative humidity (rh), humidity ratio (Wa), wet-bulb temperature (twb), dew point temperature (tdp), and air enthalpy (h) that can be presented over the chart.(Schiavon, 2014)

Figure-1.6 “Timeline diagram for the development of the methods in “Thermal Comfort” from 1920 until now”

Figure-1.6 presents the timeline diagram for the progressive development of thermal comfort analysis models. It concentrated on the thermal physiology and other method, the adaptive approach is focused on human behavioral preferences and their perceptions and changeability of the individual’s metabolism According to (Brager and de Dear, 1998) there are three types of adaptation approach; physiology, psychological and behavior related adaptation. Furthermore, figure-1.6 also showed the two groups of study in thermal relief: thermal physiology and the mortal behavioral aspects. The different thermal comfort models are related with these two research clusters. The ASHRAE standard 55 also identifies both methods. The physical was recognized in **ASHRAE 55 (1981), ISO 7730 (1984)**, and adaptive behavioral aspect in **ASHRAE 55 (2004).**

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1.9 ADAPTIVE APPROACH

The adaptive model was presented by Nicol and Humphreys. This method is founded on the physical environment of human who can adapt. ASHRAE-55 standard also recognize the adaptive approach. It is defining the comfort zone for occupants which also related to thermal experiences deviations in clothing and activities.

There are three types of thermal adaptation for instance Physiological (human body response on hotness adjustment), psychosomatic and behavior related thermal adaptation.

According to ASHRAE Standard 55, the Adaptive approach is mostly used in naturally ventilated structures, without air conditioning and heating equipment installations. The standard identified that the mean outside temperature should be more than 10℃entigrade and less than 33.5℃entigrade. This model is based on the philosophy of de Dear and Brager (1998), which presented that occupants in passive building models favored a variety of temperatures that revealed the swings of the outside weather. (Schiavon, Hoyt, & Piccioli, 2014)

While occupants have natural propensity to accept varying settings in their environment. This natural preference is articulated in the adaptive model to thermal performance of structures. (EEIG, 2006).

Another relationship and model have been taken as a reference to set up the comfort temperature range such as Humphreys and Nicol (1978) is based on the adaptive approach that showed the connection among comfort temperature T_c and outdoor temperature T_o for natural ventilated constructions is given by (EEIG,2006)

$$\mathbf{T_c = 12.1 + 0.534\ T_o}$$

2.0 THERMAL COMFORT STANDARDS FOR STUDIED AREA

Nicol, (2015) describes that the comfort temperature differs from season to season. The difference of thermal comfort between summer and winter is 4.7°C in Karachi, around 6-7°C in other cities of Pakistan.

Furthermore, Nicol, (2015) suggested that the adaptive method to warm air comfort depends on the field experiments and collecting data regarding the thermal environment. The equation is established for Karachi is based on an adaptive model by (Nicol and Humphrey 1978), which is identifying the comfort temperature range. The equation is given by; $\mathbf{T_c = 12.1 + 0.534\ T}$.

"*Where Tc is plotted against the mean outdoor temperature To. This equation is utilized for free running building comfort temperature can be predicted from outdoor mean temperature*"

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2.1 SCOPE OF STUDY

The main idea of the study is limited to the field documentation, mapping and analysis of thermal conditions in selected school buildings. The study was based on a field survey and analysis of major variables (temperature and humidity) related to thermal comfort.

2.2 OBJECTIVES OF RESEARCH

1. To evaluate the comfort temperature of surveyed school buildings through adaptive approach.
2. To identify and compare the indoor and outdoor temperature and humidity levels through comfort temperature.
3. To analysis and document architectural parameters of selected school buildings

2.3 RESEARCH METHODOLOGY

This study was based on quantitative approach for data collection. The field experiments are founded on monitoring of internal and external temperature for winter and summer seasons. The readings were collected through environmental logger (AZ87792 instrument digital dual temperature & humidity). The readings of indoor and outdoor temperature were compare with thermal comfort standard temperature

Adaptive model was used to determine the comfort temperature for providing the better learning environment in selected school buildings.

The architectural parameters of selected school buildings were documented through site visits, photographs and especially information on the building-related factors such as building orientation, form, envelope, and fenestration system (opening, window sizes, and shade types) were documented through scaled drawings.

2.4 INTRODUCTION TO SURVEYED SCHOOLS

Orangi town is located in northwestern part of Karachi. The complete area of Orangi town is 60 km2 (22.78 sq mi). It is surrounded by New Karachi town to the north across the Shahrah-e-Zahid Hussain, Gulberg Town to the east transversely the Gujjar Nala stream and Liaquatabad town to the south, further, site town to the west. Orangi town is the lower income settlement with essential amenities of an urban neighborhood, in addition, it consists of thirteen formal vicinities, individually with its particular council, as shown in figure-1.7

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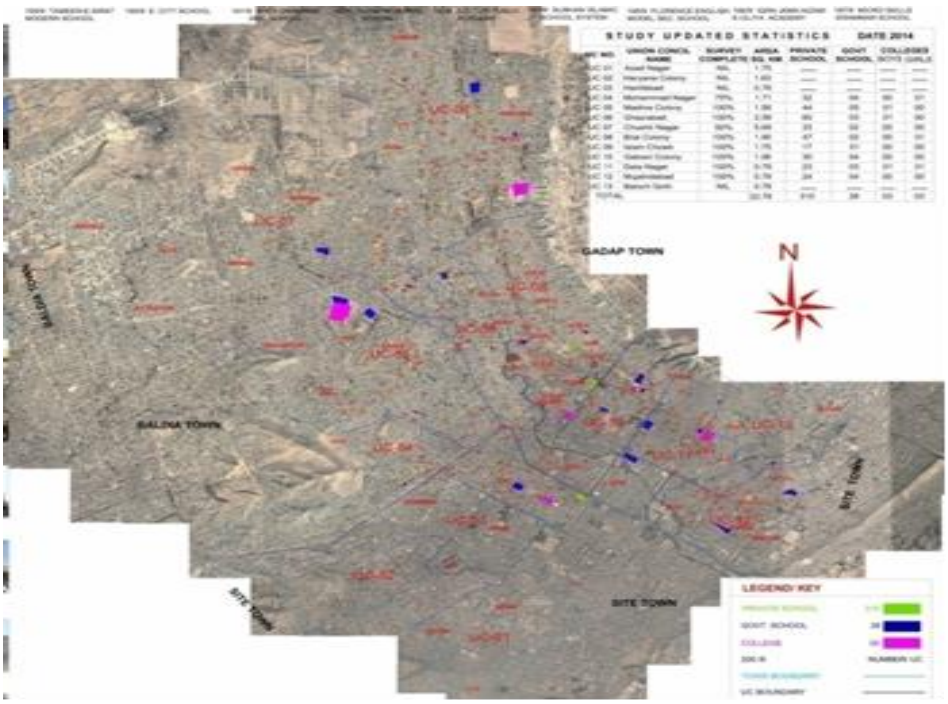
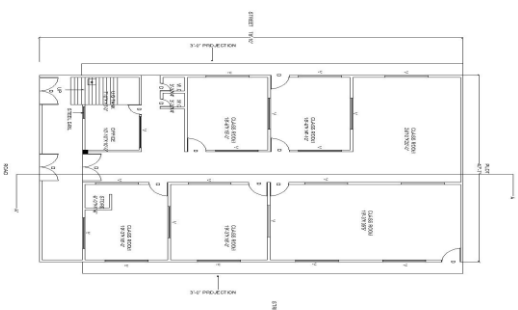
Figure-1.7 Google map of school buildings in orangi town



2.5 ARCHITECTURAL DRAWINGS

1. Al-Rehman Secondary School
Location:
Gulshan-E-Zia,Organi town
Coordinates:
24°58’55.86” N 66°58’59.47” E
Area:413 sq.yd



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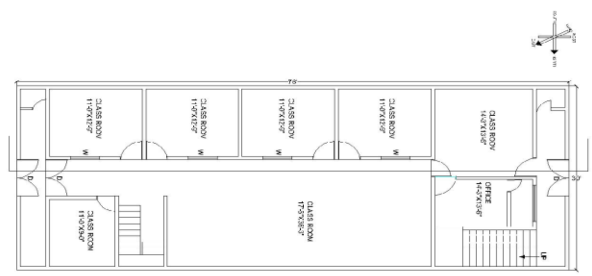
2. Abid Grammar school

Location : Gulshan-E-Zia,Organi town

Coordinates : 24°58’46.51”N 66°59’06.82”E

Area : 240sq.yd

Type of construction **:** Temporary construction



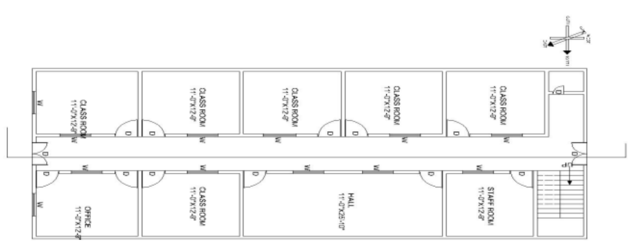
3. New Grammar children school

Location : Gulshan-E-Zia,Organi town

Coordinates : 24°58’58.44”N 66°59’15.79”E

Area : 240sq.yd

Type of construction **:** Temporary construction



4. Iqra real high school

Location : Gulshan-E-Zia,Organi town

Coordinates : 24°58’47.74”N 66°59’07.45”E

Area : 130sq.yd

Type of construction : Permanent construction Reinforced cement concrete R.c.c

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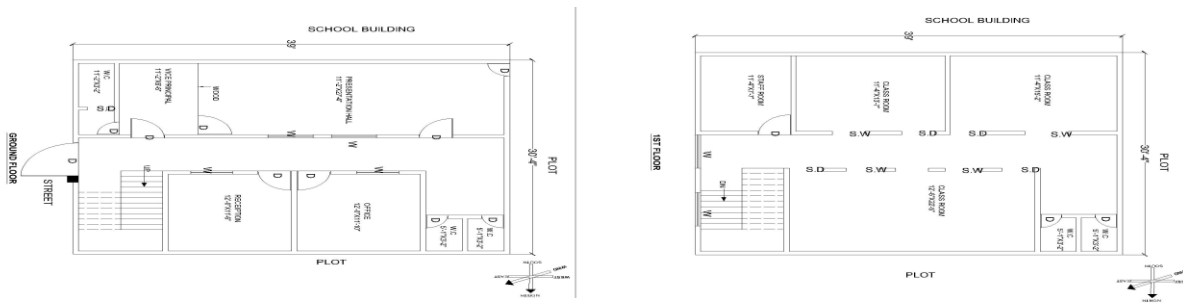

2.5 FINDING OF STUDY

2.5.1 Architectural Parameters of Surveyed Schools

AL-Rehman School:

- The shape of the building is rectilinear and layout of building is followed in closed planning. The plan is dividing into 6 classrooms and the size of the classroom is not appropriate for the learning environment as shown in table-4.2
- The structure of the school is construct from Reinforced cement concrete (R.C.C) and 6 inches' thick walls are providing for better thermal performance inside the classrooms.
- Walls and floor are finishes in the plaster and mosaic.
- Furthermore, ventilators are used in the classroom without shading devices and the ventilation system of school building is depending on mechanical devices.

New Grammar Children Secondary School:

- The shape of the building is rectilinear and (12) classrooms are arrange in the open plan layout.
- The 6" inch thick walls made from cement block masonry and roof is covered with corrugated iron sheets. Moreover, casement windows are used in the classroom without sun protection.

Abid Grammar School:

- The layout of building in rectilinear form and functional spaces are arrange in the 6 rooms in closed planning.
- The 4" inch thick wall is built from cement block masonry and corrugated iron sheets are used as a covering material for roof. Moreover, floor is finish with plaster and paint.
- Ventilators are used in classroom for fresh air and daylight.

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Iqra Real High School:

Iqra real high school have 9 classrooms on each floor and the learning spaces are arranging into three floors.

The structure of the school is made from reinforced cement concrete (R.C.C) and the walls and floor finishes are done in the plaster and mosaic tiles. Furthermore, sliding windows are used in the classrooms for the natural light and air.

Table-1.1 ARCHITECTURAL PARAMETERS

School name	Shape	No of class rooms	Min classroom size	Max class room size	No of floors	Building envelope
Al-rehman Secondary	rectangle	06	18’x15’	19’x35’	01	Closed plan
New Grammar Children Secondary	rectangle	12	11’ x 12’	11’x25’	01	Open plan
Abid Grammar	rectangle	06	11’ x 12’	17’x36’	01	Closed plan
Iqra Real high	rectangle	09	11’x13’	12’x27’	03	Closed plan

School name	**Wall thickness**	**Thickness of plaster outer and inner**	**Roof covering material**	**Roof type**	**Roof projection**	**window type**
Al-rehman Secondary School	6”	2”	R.C.C	Flat	2’-0”	Vent
New Grammar Children Secondary School	6”	2”	corrugated iron sheet	Flat	----	Casement
Abid Grammar School	4”	---	corrugated iron sheet	Flat	-----	Vent
Iqra Real high School	6”	2”	R.C.C	Flat	------	Sliding

School name	**Floor finishes**	**Wall material**	**Total height**	**classroom height**	**courtyard**	**Verandah**
Al-rehman Secondary School	Mosaic	Cement block	13’-0”	10’-6”	----	01
New Grammar Children Secondary School	Cement plaster	Cement block	11’-6”	10-6”	----	----
Abid Grammar School	Cement plaster	Cement block	12’-0”	10’-6”	----	-----
Iqra Real high School	mosaic	Cement block	30’-0”	10-0”	----	----

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2.5.2 INDOOR ENVIRONMENTAL CONDITIONS OF SELECTED SCHOOLS

Table-1.2: depicts the indoor environmental conditions. This table mentions the current situation of ventilation, daylight, and any other factors related to indoor environmental quality.

Table-1.2 INDOOR ENVIRONMENTAL CONDITIONS

School name	Ventilation	Daylight	Interior insulation	other factors Acoustic
Al-rehman Secondary School	Natural ventilation is supplemented by ceiling fans	The school building is more depend on mechanical devices like tube lights, energy savers etc	---	Acoustic level is moderate
New Grammar Children Secondary School	Natural ventilation is supplemented by ceiling fans	This school also dependent on artificial lighting system.	----	Acoustic level is high
Abid Grammar School	Natural ventilation is supplemented by ceiling fans	Most of the classroom are depend on artificial light.	----	Acoustic level is high
Iqra Real high School	Mixed and mode type of ventilation system is used for air circulation	The access of daylight in the limited spaces.	----	Acoustic level is low

2.6 Quantitative Measures of Temperature and Humidity Levels for winter and Summer Season

Table-1.3 shows the quantitative measurements of the indoor and outdoor temperature and humidity levels for winter and summer seasons. This table represents the maximum and minimum values of variables. Additionally, table-1.2 has described the comparison between outdoor and indoor air temperature.

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TABLE-1.3 QUANTITATIVE MEASUREMENTS OF TEMPERATURE AND HUMIDITY LEVELS

AL-Rehman Secondary School	Month	Max Temp outdoor	Max Temp Indoor	Min Temp outdoor	Min Temp Indoor	Min-Humidity%	Max-Humidity%
	December	20.9	25.5	20.4	20.9	30%	36%
	January	24.8	28	21.9	27	55%	63%
	February	25	29	22	28	60%	70%
New Grammar Children Secondary School	**Month**	**Max Temp outdoor**	**Max Temp Indoor**	**Min Temp outdoor**	**Min Temp Indoor**	**Min-Humidity%**	**Max-Humidity%**
	December	22.5	27	21.6	26.5	30%	38%
	January	24.3	31.7	23.9	30.6	45%	51%
	February	26	33	25	32	55	65
Abid Grammar School	**Month**	**Max Temp outdoor**	**Max Temp Indoor**	**Min Temp outdoor**	**Min Temp Indoor**	**Min-Humidity%**	**Max-Humidity%**
	December	30.4	29.7	22.7	28.2	27%	36%
	January	27.3	31.6	22.4	30.3	40%	43%
	February	29	33	24	32	45%	55%
Iqra Real high School	**Month**	**Max Temp outdoor**	**Max Temp Indoor**	**Min Temp outdoor**	**Min Temp Indoor**	**Min-Humidity%**	**Max-Humidity%**
	December	33.4	29.4	22.5	27.1	29%	35%
	January	29.8	31	23.6	28.6	41%	54%
	February	30	32	24	29	50%	65%
AL-Rehman Secondary School	**Month**	**Max Temp outdoor**	**Max Temp Indoor**	**Min Temp outdoor**	**Min Temp Indoor**	**Min-Humidity%**	**Max-Humidity%**
	March	31.5	37	28	33	38%	44%
	April	32.5	38	31	36	42%	50%
	May	32.7	39.1	32.8	37	45%	55%
New Grammar Children Secondary School	**Month**	**Max Temp outdoor**	**Max Temp Indoor**	**Min Temp outdoor**	**Min Temp Indoor**	**Min-Humidity%**	**Max-Humidity%**
	March	32	39	27	36	36%	43%
	April	33	40	30	38	41%	50%
	My	34	42	33	41.5	43%	55%
Abid Grammar School	**Month**	**Max Temp outdoor**	**Max Temp Indoor**	**Min Temp outdoor**	**Min Temp Indoor**	**Min-Humidity%**	**Max-Humidity%**
	March	32	37	27	32	35%	45%
	April	33	38	30	35	40%	50%
	May	35.2	40	32.2	36	45%	54%
Iqra Real high School	**Month**	**Max Temp outdoor**	**Max Temp Indoor**	**Min Temp outdoor**	**Min Temp Indoor**	**Min-Humidity%**	**Max-Humidity%**
	March	31	34	27	31	39%	43%
	April	32	35	30	34	43%	50%
	May	32.9	37	32.4	35	45%	54%

2.7 ADAPTIVE APPROACH TO EVALUATION OF COMFORT TEMPERATURE FOR WINTER AND SUMMER

The following below figures describes the difference between comfort temperature and the indoor temperature of surveyed schools. **(Figure-4.38A to 4.38 D)** shows that the thermal comfort Tc in the range of 22-24 centigrade while as compared to minimum indoor temperature is greater 27-32 centigrade in the winter season. However, the thermal comfort Tc for the summertime in the range of 27-28 centigrade but the minimum indoor temperature in the range of 33-41.5 °C, which is greater than the comfort temperature as measured in the summers, as shown in **figure-4.39 E to 4.39 H.**

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Figure-4.38A shows that minimum indoor temperature ranges 26-32 centigrade is observed in the winter season it is much higher than average thermal comfort

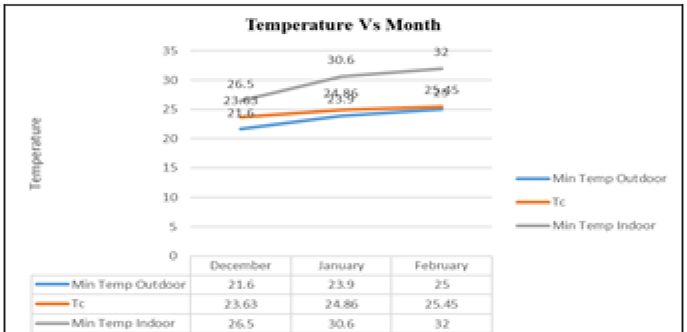

Figure-4.38A: Al-rehman Grammar School

Figure-4.38B: represents that the minimum indoor temperature ranges 20-28 °C is slightly greater than average comfort temperature T_c =23 °C in winter season

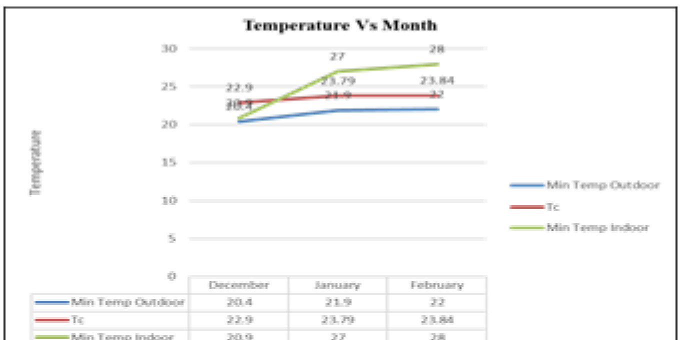

Figure-4.38 B: New Grammar children

Figure-4.38C: shows that the minimum indoor temperature range 28-32°C is deviate with the average comfort temperature T_c=24°C

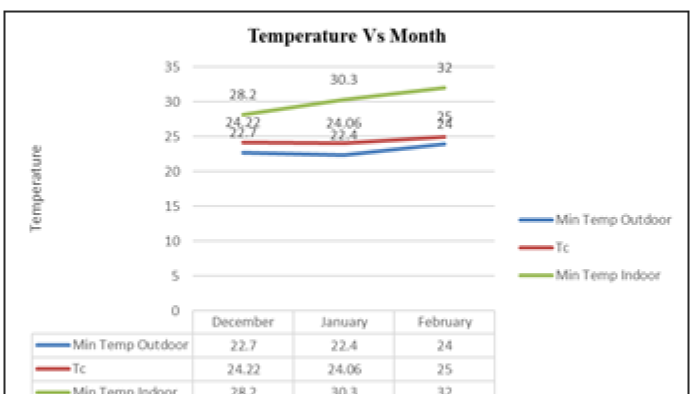

Figure-4.38C: Abid Grammar School

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Figure-4.38D: depicts that minimum indoor temperature range 27-29°C is much higher than average comfort temperature T_c=24.5°C in winter

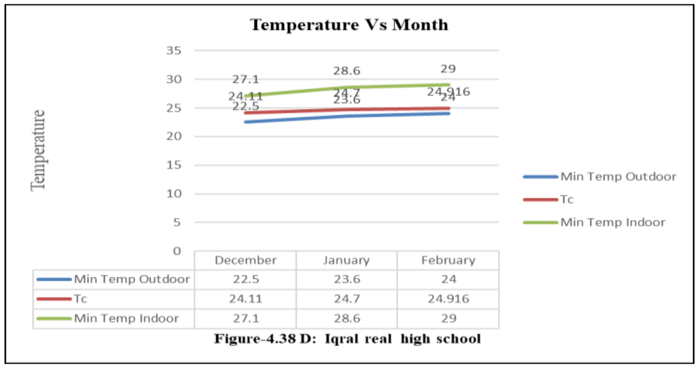

Figure-4.38 D: Iqral real high school

Figure-4.39E: represents that the minimum indoor temperature range 33-37°C is much higher than the average comfort temperature T_c=28°C in summer

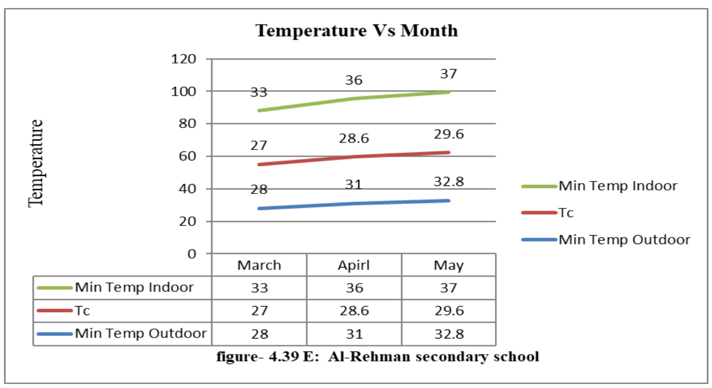

figure- 4.39 E: Al-Rehman secondary school

Figure-4.39F: represents that minimum indoor temperature range (36-41.5°C) is much higher than the average comfort temperature T_c= 28°C in summer season

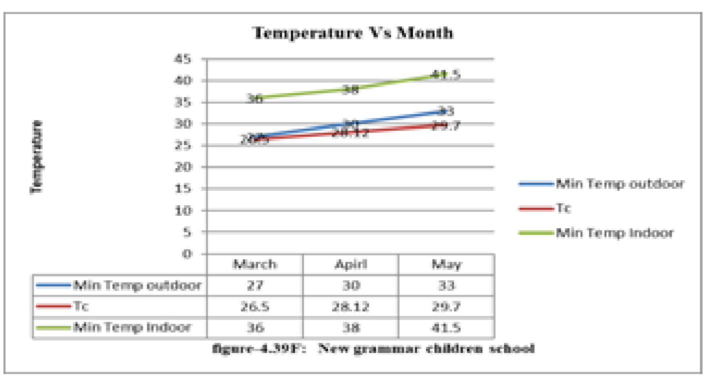

figure-4.39F: New grammar children school

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Figure-4.39G: shows that the minimum indoor temperature in range of (27-32.2°C) which is slightly higher than average comfort temperature T_{c} = 27°C in summer season

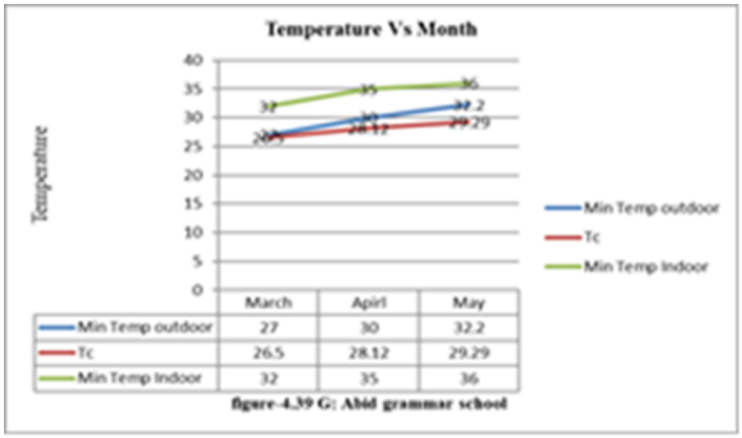

figure-4.39 G: Abid grammar school

Figure-4.39H: depicts that the minimum indoor temperature (31-35°C) is much higher than average comfort temperature Tc= 28°C in summer.

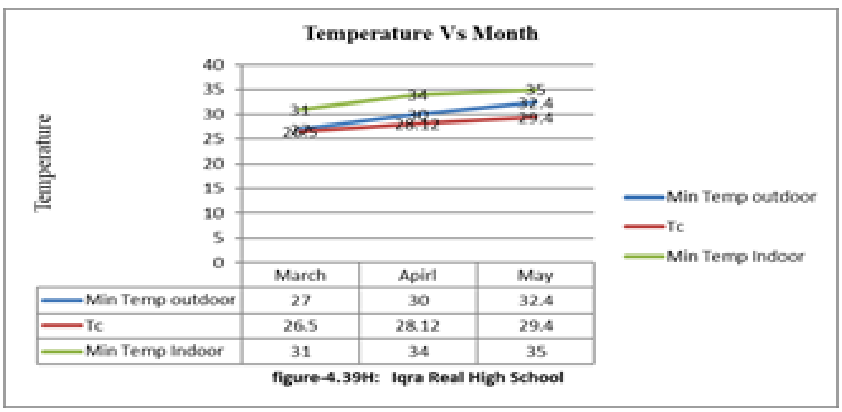

figure-4.39H: Iqra Real High School

2.9 CONCLUSION

The study concluded that the efficiency of educational environment is related with the building performance, indoor building factors like air quality, acoustic and thermal conditions. The adaptive techniques are used in this research to evaluate thermal comfort standards for the selected cases of naturally ventilated learning buildings. Furthermore, thermal performance of structures is important for providing a better working environment for end user.

The physical conditions are inappropriate of selected cases of educational buildings due to fenestration design is not properly design, indoor environmental conditions are not acceptable for learning environment and acoustic level is high, therefore it is required to improve indoor environment of such structure (table-1.1)

Moreover, field experiments were resulted that the indoor temperature values are deviated with the calculated thermal comfort standards and indoor conditions of functional spaces are inadequate for better learning environment. The occupant's productivity is also related to the thermal performance of building due to it is essential to change the opening design, material finishes and envelope design for accomplishing an energy efficient building design.

The main conclusion was that values of thermal comfort standards are (Tc = 23.5°C-24.4°C in winters and 28°C in summers) for the local climate of selected area. These readings were calculated through adaptive model. Furthermore, indoor temperature values of all selected cases were showed great difference from the calculated comfort temperature in both winter and summer seasons. Thus it is proved that the indoor temperature and humidity level are much higher than the comfort temperature ranges for winter and summers.

The equation (**$T_c = 12.1 + 0.534\ T_o$)** is derived from adaptive model relationship by (Nicol and Humphrey 1978), for moderate climate of Karachi. This model is produces satisfactory results for evaluation of thermal comfort standards.

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