

Energy-Saving Design Strategies for Non-Residential Structures in Pakistan's Arid Lowlands

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Abstract: The Buildings' Energy measures and savings in Pakistan are of paramount importance. It has been discussed for many years but attaining a coherent solution is still one of the main tasks. Energy efficiency in buildings is an important objective of energy policy and strategy in Pakistan. The HAP 4.0 Software was used for this research to calculate energy and simulated analysis of the Specific climate Zone of Multan (Subtropical continental Lowlands arid). This study aims towards for Comfort zone using cooling design strategies that predict the use of building control depending on climate, orientation of building, and material of building. The results showed that Adaptive Comfort Model ASHRE-2005 for 8760 hours per year achieving Sun shading of windows, cooling, and dehumidification increases by 25.1% and 42.1 % of Comfortable hours. Energy simulation presented that building load decreases using the double-glazed window from the East and west sides and applying such design Strategy increases the 14.8% of Comfort hours without additional investment.

Keywords: Design Energy Strategies, Energy Analysis, Simulated Analysis of Climate, Non Residential Buildings

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1. Introduction

This Research is based on the solution of Energy measure and optimization of 3 3-story university building located in Multan Pakistan. The consumption of energy in the NRB sector in Pakistan is almost 30% of its total energy and this energy consumption increases by 4.7% in the commercial sector. The energy crisis in Pakistan increased this has adversely affected the economic growth of the country. The geographical orientation of Multan's latitude and longitude (30.292267 and 71.49887) describes that the city is in a sunny and hot climate [1]. Energy Crises in Pakistan result in widespread overconsumption and excessive utilization of fossil fuels such as oil, uranium, and gas According to Nepra's yearly 2022 report 59 % of energy comes from thermal, 25% from hydro 7% from renewable, and 9% from nuclear [2]. The Country's total production of energy directly affects the energy consumption in the building sector. The state of renewable energy power projects as

of June 30th, 2023, according to the Ministry of Energy website. Thirty-six (36) wind power projects with a total capacity of 1,835 MW were operational and supplying electricity to the grid, as were seven (7) solar projects with a cumulative capacity of 530 MW and eight (8) sugar mill-based bagasse co-generation projects with a capacity of 259.1 MW. Renewable energy Capacity addition through solar and wind (MW) year of 2024-2031 cumulative capacity addition of 13,391 approximately [3] calculated the HCL by using the transfer function method for window door and fenestration. The result comparison with ASHRE after the calculation manually and software some differences were observed due to the overall heat transfer coefficient the other observation after calculating wall color based on this energy utilization [4] The designed HVAC system load observed that the orientation of buildings depends on the consumption of electricity except southern latitude of the United States [5]. Investigation of this research paper identified the orientation of the building affects the direct cooling load and energy consumption because solar heat gain for the building shows the 31% load required for the east and north living rooms and 34 % for the south side living room in winter [6]. The impact of building insulation was examined in this study. No insulation, only ceiling insulation, only wall insulation, and both wall and ceiling insulation were among the combinations of wall and ceiling insulation that were taken into consideration for the study [7]. Briefly the total cooling load results compared of a two-story building calculated by CLTD method and by Hourly Analysis Programme software [8]. HVAC System free energy emission system established and calculated auditorium tonnage capacity of 1000 seats. [9].Using HAP carrier software we can adjust values as per energy simulation data which is very accurate as compared to manual calculation

1.1 Objectives

1. This research proposes to identify the Cooling Load on buildings by using HAP software during the summer season May to October at peak hours.
2. This evaluation intends to identify the maximum comfortable hours achieved for the reduction of the building thermal load by using the best design strategies for the hot climate region of Pakistan.

2. Methodology

The methodology for finding the research objectives used for estimating energy measure and climatic conditions as per the following Procedure first step is to Analyze and simulate the building cooling load for Condition of Multan by using Hourly Analysis Programme Software. The second step is to calculate the Non-Residential building Space Load energy reduction method for using the best design strategies and maintaining the thermal load for the hot climate of Multan. The third step calculates the effect of energy usage with changing climatic conditions day by day or in the future.

2.1 Energy Consumption Evaluation of Building by HAP Software

In this research, we will calculate thermal load and estimate energy consumption using the HAP 4.0 software. The nonresidential building located in Multan requires the following information.

2.2 Building Description

The University building selected for energy modeling is a story building in the east direction that has multiple offices, a Library, an Engineering Labs area mentioned in Table 1, and a Building Ground Floor as mentioned in Fig.1 other 3 floors. For the calculation of space cooling load through building design and weather data specific conditions are needed such as building characteristics, outdoor conditions, indoor design conditions, and internal heat gain and operating schedule.

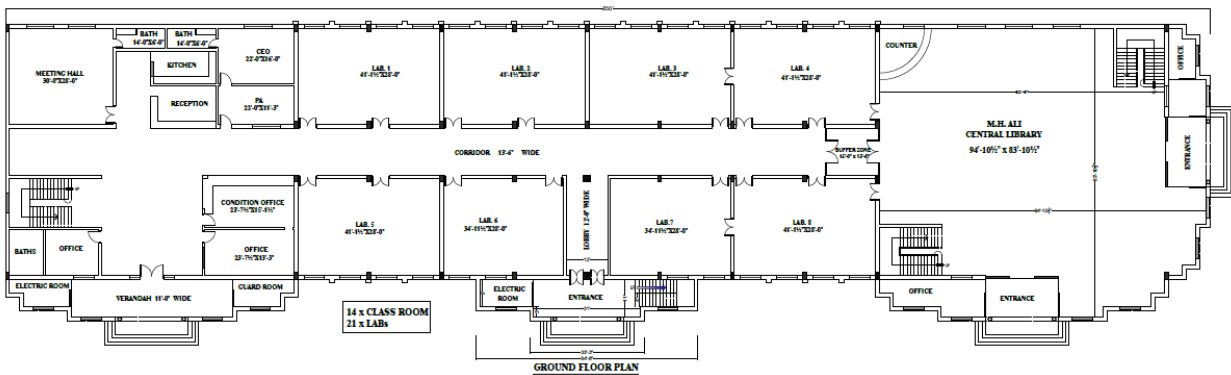


Fig: 1 Buildings Ground Floor Area of Conditioned Spaces

Table:-1 Buildings Floor Area of Conditioned Spaces

Sr.No	No Of Floor	Floor Area	Conditioned Area	No of Spaces
1	Ground Floor	29085ft ²	18118.9ft ²	15
2	First Floor	29085ft ²	14746.2ft ²	21
3	Second Floor	29085ft ²	17514.7ft ²	14
4	Third Floor	29085ft ²	16564.8ft ²	12

2.3 Design Temperature Parameters

The daily temperature profile presented the minimum temperature and maximum temperature in Multan mentioned in Fig 1. The energy simulation Design temperatures needed are as follows in Table 1.

Table 1 Design temperature Profile

Summer Design DBT	Summer Coincident WBT	Summer Daily Range DRT	Winter Design DBT	Winter Design WBT	Latitude	Longitude	Elevation
111.4 F	74.8	47.3F	74.7	60.4	30.3 Deg	71.5	400.0ft

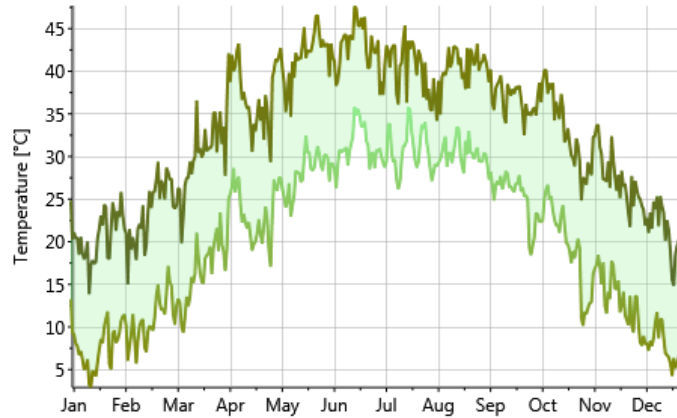


Fig 1 Daily Temperature Chart

2.4 Annually Dry Bulb Temperature VS Relative Humidity Profile

Energy measure and buildings calculation depend on the DBT and RH in % for the region of Multan. The location's Climate, seasonality, and local weather adversely affect achieving the Comfort zone temperature of May to October mentioned below graph.

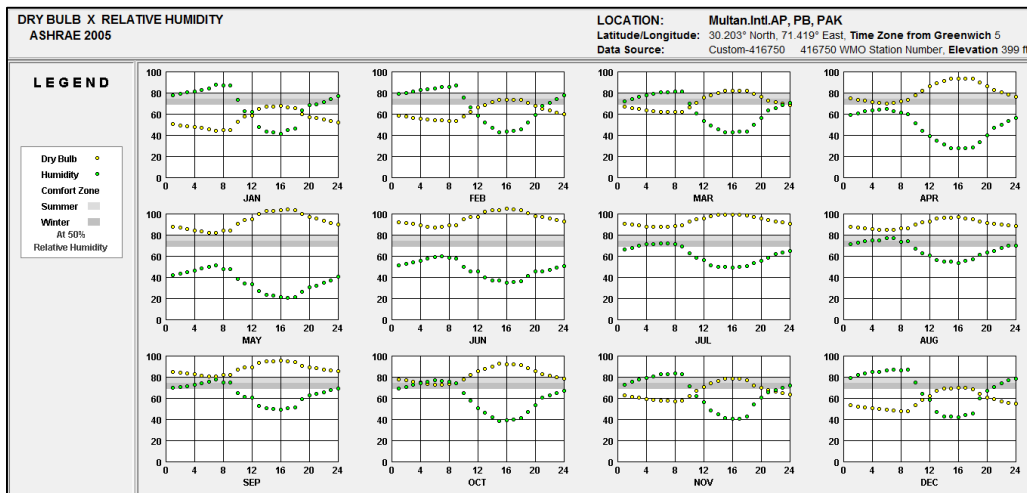


Fig:-2 Dry Bulb Temperature vs Relative Humidity

3. Building Material Data

The following Materials and data used as per ASHRE Standard Handbook wall and Roof Data with detail mentioned below Overall U value of the wall and Roof is 3.465W/m².k and 0.523 W/m².k.

Wall Properties - [Exterior Wall Of Building]							Roof Properties - [Heavy Weight Roof]						
Wall Assembly Name: Exterior Wall Of Building							Roof Assembly Name: Heavy Weight Roof						
Outside Surface Color: Dark Absorptivity: 0.900							Outside Surface Color: Dark Absorptivity: 0.900						
Layers: Inside to Outside	Thickness mm	Density kg/m ³	Specific Ht. kJ/kg/K	R-Value m ² -K/W	Weight kg/m ²		Layers: Inside to Outside	Thickness mm	Density kg/m ³	Specific Ht. kJ/kg/K	R-Value m ² -K/W	Weight kg/m ²	
Inside surface resistance	0.000	0.0	0.00	0.12064	0.0		Inside surface resistance	0.000	0.0	0.00	0.12064	0.0	
Cement Plaster - With Sai	0.512	1858.0	0.87	0.00030	1.0		Acoustic tile	19.050	480.6	0.84	0.31524	3.2	
Hollow Concrete Block	215.000	1390.0	0.84	0.16026	298.9		Ceiling air space	0.000	0.0	0.00	0.17611	0.0	
Cement Plaster - With Sai	0.512	1858.0	0.87	0.00134	1.0		102mm HW concrete	101.600	2242.6	0.84	0.05882	227.8	
Outside surface resistance	0.000	0.0	0.00	0.05864	0.0		51mm insulation	50.800	91.3	0.84	1.17289	4.8	
Totals	216.024			0.34	300.8		13mm slag or stone	12.700	881.0	1.67	0.00881	11.2	
				Overall U-Value:	2.931W/m ² /K						Overall U-Value:	0.523W/m ² /K	

Fig - Building Wall and Roof Details

The primary function of heat loss and heat gain calculation is to estimate the capacity that will required for the heating and cooling components of the HVAC system. Heat gained by walls, roofs, and windows due to temperature differences is referred to as exterior thermal load, but heat created within the building due to human activity, electric equipment, and overhead lighting is known as internal thermal load. The Energy Consumption hours 8760 result has been simulate and analyze. Air System Cooling Coil load estimates the Thermal Load individually of all floor calculated below.

Air System Sizing Summary for PACKAGE AC-Ground Floor			
Project Name: Multan University Engineering Building		02/28/2024	
Prepared by: Ali Murtaza.Co		11:59PM	
Air System Information			
Air System Name	PACKAGE AC-Ground Floor	Number of zones	1
Equipment Class	PKG ROOF	Floor Area	18118.9 ft ²
Air System Type	SZCAV	Location	Multan, Pakistan
Sizing Calculation Information			
Calculation Months	May to Oct	Zone CFM Sizing	Sum of space airflow rates
Sizing Data	Calculated	Space CFM Sizing	Individual peak space loads
Central Cooling Coil Sizing Data			
Total coil load	121.9 Tons	Load occurs at	Jun 1400 °F
Total coil load	1482.3 MBH	OA DB / WB	109.0 / 74.4 °F
Sensible coil load	1274.4 MBH	Entering DB / WB	81.0 / 65.8 °F
Coil CFM at Jun 1400	51220 CFM	Leaving DB / WB	57.7 / 56.3 °F
Max block CFM	51220 CFM	Coil ADP	55.1 °F
Sum of peak zone CFM	51220 CFM	Bypass Factor	0.100
Sensible heat ratio	0.871	Resulting RH	52 %
ft ³ /Ton	148.7	Design supply temp.	58.0 °F
BTU/(hr-ft ²)	80.7	Zone T-stat Check	1 of 1 OK
Water flow @ 10.0 °F rise	N/A	Max zone temperature deviation	0.0 °F
Supply Fan Sizing Data			
Actual max CFM	51220 CFM	Fan motor BHP	0.00 BHP
Standard CFM	50484 CFM	Fan motor kW	0.00 kW
Actual max CFM/ft ²	2.83 CFM/ft ²		
Return Fan Sizing Data			
Actual max CFM	51220 CFM	Fan motor BHP	42.08 BHP
Standard CFM	50484 CFM	Fan motor kW	33.38 kW
Actual max CFM/ft ²	2.83 CFM/ft ²	Fan static	3.00 in wg
Outdoor Ventilation Air Data			
Design airflow CFM	5651 CFM	CFM/person	15.36 CFM/person
CFM/ft ²	0.31 CFM/ft ²		

Fig 5 Air System Calculation for Ground Floor

Air System Sizing Summary for PACKAGE AC FIRST FLOOR			
Project Name: Multan University Engineering Building		02/28/2024	
Prepared by: Ali Murtaza.Co		11:52PM	
Air System Information			
Air System Name	PACKAGE AC FIRST FLOOR	Number of zones	1
Equipment Class	PKG ROOF	Floor Area	14746.2 ft ²
Air System Type	SZCAV	Location	Multan, Pakistan
Sizing Calculation Information			
Calculation Months	May to Oct	Zone CFM Sizing	Sum of space airflow rates
Sizing Data	Calculated	Space CFM Sizing	Individual peak space loads
Central Cooling Coil Sizing Data			
Total coil load	94.2 Tons	Load occurs at	Aug 1400
Total coil load	1129.8 MBH	OA DB / WB	110.0 / 74.4 °F
Sensible coil load	1045.1 MBH	Entering DB / WB	80.7 / 65.2 °F
Coil CFM at Aug 1400	42753 CFM	Leaving DB / WB	57.8 / 56.3 °F
Max block CFM	42753 CFM	Coil ADP	55.2 °F
Sum of peak zone CFM	42753 CFM	Bypass Factor	0.100
Sensible heat ratio	0.925	Resulting RH	50 %
ft ² /Ton	156.6	Design supply temp.	58.0 °F
BTU/(hr-ft ²)	76.6	Zone T-stat Check	1 of 1 OK
Water flow @ 10.0 °F rise	N/A	Max zone temperature deviation	0.0 °F
Supply Fan Sizing Data			
Actual max CFM	42753 CFM	Fan motor BHP	0.00 BHP
Standard CFM	42138 CFM	Fan motor kW	0.00 kW
Actual max CFM/ft ²	2.90 CFM/ft ²		
Return Fan Sizing Data			
Actual max CFM	42753 CFM	Fan motor BHP	35.13 BHP
Standard CFM	42138 CFM	Fan motor kW	27.87 kW
Actual max CFM/ft ²	2.90 CFM/ft ²	Fan static	3.00 in wg
Outdoor Ventilation Air Data			
Design airflow CFM	4182 CFM	CFM/person	13.58 CFM/person
CFM/ft ²	0.28 CFM/ft ²		

Fig 6 Air System Calculation for First Floor

Air System Sizing Summary for PACKAGE AC Second Floor			
Project Name: Multan University Engineering Building		02/28/2024	
Prepared by: Ali Murtaza.Co		11:53PM	
Air System Information			
Air System Name	PACKAGE AC Second Floor	Number of zones	1
Equipment Class	PKG ROOF	Floor Area	17514.7 ft ²
Air System Type	SZCAV	Location	Multan, Pakistan
Sizing Calculation Information			
Calculation Months	May to Oct	Zone CFM Sizing	Sum of space airflow rates
Sizing Data	Calculated	Space CFM Sizing	Individual peak space loads
Central Cooling Coil Sizing Data			
Total coil load	126.6 Tons	Load occurs at	Jun 1400
Total coil load	1518.8 MBH	OA DB / WB	109.0 / 74.4 °F
Sensible coil load	1350.3 MBH	Entering DB / WB	80.2 / 65.4 °F
Coil CFM at Jun 1400	56750 CFM	Leaving DB / WB	57.8 / 56.4 °F
Max block CFM	56750 CFM	Coil ADP	55.3 °F
Sum of peak zone CFM	56750 CFM	Bypass Factor	0.100
Sensible heat ratio	0.889	Resulting RH	52 %
ft ² /Ton	138.4	Design supply temp.	58.0 °F
BTU/(hr-ft ²)	86.7	Zone T-stat Check	1 of 1 OK
Water flow @ 10.0 °F rise	N/A	Max zone temperature deviation	0.0 °F
Supply Fan Sizing Data			
Actual max CFM	56750 CFM	Fan motor BHP	0.00 BHP
Standard CFM	55935 CFM	Fan motor kW	0.00 kW
Actual max CFM/ft ²	3.24 CFM/ft ²		
Return Fan Sizing Data			
Actual max CFM	56750 CFM	Fan motor BHP	46.63 BHP
Standard CFM	55935 CFM	Fan motor kW	36.99 kW
Actual max CFM/ft ²	3.24 CFM/ft ²	Fan static	3.00 in wg
Outdoor Ventilation Air Data			
Design airflow CFM	4654 CFM	CFM/person	9.60 CFM/person
CFM/ft ²	0.27 CFM/ft ²		

Fig 7 Air System Calculation for Second Floor

Air System Sizing Summary for PACKAGE AC Third Floor		
Project Name: Multan University Engineering Building		02/28/2024
Prepared by: Ali Murtaza.Co		11:55PM
Air System Information		
Air System Name	PACKAGE AC Third Floor	Number of zones
Equipment Class	PKG ROOF	Floor Area
Air System Type	SZCAV	Location
Sizing Calculation Information		
Calculation Months	May to Oct	Zone CFM Sizing
Sizing Data	Calculated	Space CFM Sizing
Central Cooling Coil Sizing Data		
Total coil load	156.0 Tons	Load occurs at
Total coil load	1871.7 MBH	OA DB / WB
Sensible coil load	1784.6 MBH	Entering DB / WB
Coil CFM at Jul 1400	75815 CFM	Leaving DB / WB
Max block CFM	75815 CFM	Coil ADP
Sum of peak zone CFM	75815 CFM	Bypass Factor
Sensible heat ratio	0.953	Resulting RH
ft ³ /Ton	106.2	Design supply temp.
BTU/(hr-ft ³)	113.0	Zone T-stat Check
Water flow @ 10.0 °F rise	N/A	Max zone temperature deviation
Supply Fan Sizing Data		
Actual max CFM	75815 CFM	Fan motor BHP
Standard CFM	74725 CFM	Fan motor kW
Actual max CFM/ft ²	4.58 CFM/ft ²	
Return Fan Sizing Data		
Actual max CFM	75815 CFM	Fan motor BHP
Standard CFM	74725 CFM	Fan motor kW
Actual max CFM/ft ²	4.58 CFM/ft ²	Fan static
Outdoor Ventilation Air Data		
Design airflow CFM	5844 CFM	CFM/person
CFM/ft ²	0.35 CFM/ft ²	

Fig 8 Air System Calculation for Third Floor

3.1 Air System Simulation Result

HAP Software Calculation Identify the much of energy consumption in each zone of the buildings. The summary results of 4416 hours of summer season have been calculated by HAP software after determining the cooling coil load and air supply in each space of the buildings shown in Fig 5,6,7,8 and Table 2 From our obtained data of the simulation results, the Terminal cooling coil load is 498.7 tonnage in the hot month are as follows. Cooling Load peak time increases at 7 AM and full cooling load is required at 1 am for achieving the comfort hours.

Table: - 2 Total Load of Building

Zone	Terminal Cooling Coil Load (MBH)	Terminal Cooling Coil Load in Tonnage
Ground Floor	1462.3	121.9
First Floor	1129.8	94.2
Second Floor	1518.8	126.6
Third Floor	1871.7	156.0
Total Cooling coil load	5982.6	498.7

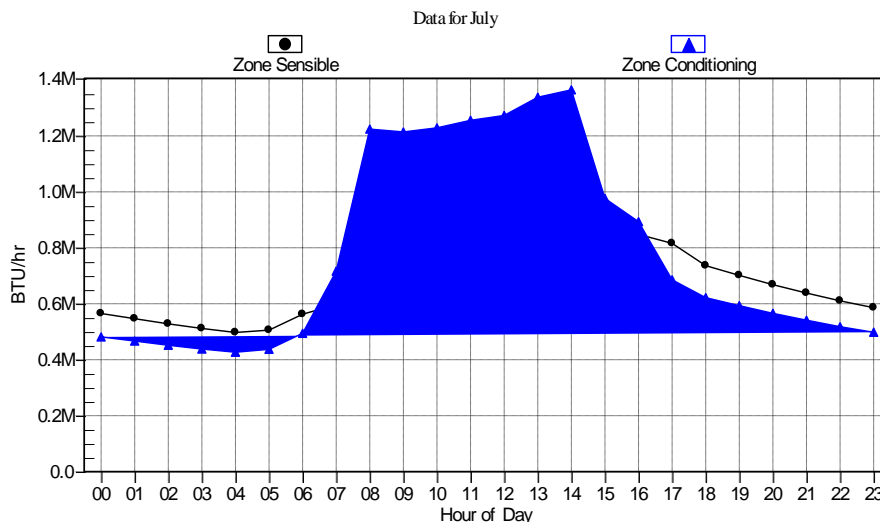


Fig 7 Hourly Design Day Cooling Load of Building Month of July by HAP Software

3.2 Design Strategies for the Region of Multan

The following analysis of percentage mentioned for design strategy by using psychometric chart Subtropical continental Lowlands’ arid zone Multan, Pakistan.

Table Comparison of Two Standard Design Strategies for Multan Region

Design Strategies	Hour s	C	SSW	HT M	HTMF	DEC	TESS	NVC	FF VC	IHG	PSD GLM	PSD GYM	HO	D O	CA D	HA H
ASHRAE 2005	Hour s	1296	2198	549	685	758	1082	151	672	1706	300	757	72	47	385	678
	%	14.8	25.1	6.3	7.8	8.7	12.4	1.7	7.7	19.5	3.4	8.6	0.8	0.	40.	7.7
													5	2		
ASHRAE California Energy Code	Hour s	850	2441	640	810	676	927	552	779	1690	300	757	13	13	390	678
	%	9.7	27.9	7.3	9.2	7.7	10.6	6.3	8.9	19.3	3.4	8.6	0.1	1.	44.	7.7
													5	6		

In this psychometric chart table 4 the first variable comfort in particular the model in climate Consultant software using the ASHRE Handbook of the fundamental comfortable model up through 2005 gave percentages of comfortable hours (14.8%) for Multan. This standard produced the most comfortable condition for Multan Pakistan. Using California codes, the Climate Consultant software calculated the percentage of comfortable hours (9.7%) for the region of Multan. ASHRE Comfortable model 2005 is suitable for design strategy. The second variable calculated through Climatic Consultant is SUN shading of the window for protection against solar radiation. The design of a building without the provision of shades results in an

increase in the internal room temperature. For Multan, the most popular cooling technique is to shade windows from the sun. The percentage of comfortable hours using the Comfortable model is 25.1%. Sun shading of windows is the most imperious design strategy for Multan. The third variable of High thermal mass calculated the 6.3% for the Multan building strategy. The quality of BM known as high thermal mass provides inertia against daily temperature variations. Because of their great density, building materials need a lot of heat energy to alter temperature. The material property can effectively raise or decrease heating or cooling and has a broad effect on interior comfort. The fourth variable of High thermal mass Flushed calculated the 7.8% for the Multan building strategy. The Method of Night Flushed vented openings are closed during the day and opened at night to remove warm air and cool the thermal mass. This tactic works well in hot climates where the midday air temperature is high, conveying unconditioned air within. The fifth variable direct evaporative cooling method software calculated 8.7% for the dry region of Multan where high temperature and low humidity in peak months April to September is a major challenge. In this method, hot dry air is blown through cool water which reduces the DBT and increases the RH in Percentage %. The sixth variable during the design strategy of building two-stage evaporative cooling is the air is cooled to a low temperature but less moisture is added to the air. According to the ASHRE standard calculated the percentage of (12.4%). This system can enhance the quality of the air which increases indoor afternoon summer thermal comfort for nonresidential buildings. The seventh variable Natural ventilation passive mode according to ASHRE model identifies and calculates the percentage (1.7%). Simplify this method means opening and closing the windows for naturally ventilated buildings. The eighth variable FFVC calculated the percentage of 7.7%. This method is used for low-windy areas. The ninth variable Sensible heat gains from inside sources such as occupants, lights, and equipment calculated the internal heat gain percentage is 19.5%. During the calculation of cooling load maximum of energy is consumed through lights and other electric equipment. The tenth variable PSDG, Low Mass calculated the percentage of 3.4%. It means low thermal mass collects stores and distributes the heat so low-mass material is placed in the shaded areas. The eleventh variable of Passive solar direct gain of high mass has been proposed by 8.6%. The twelfth variable Window Protection of Outdoor Spaces did not produce any impact on the design strategy. The thirteen variable Humidification is added water in hot air to reduce the discomfort produced the impact calculated at 0.8%. The fourteen-variable Dehumidification has a design strategy calculated at 0.5%. Air conditioner can also be an operative way to decrease the impact of humid air. The fifteen variables Cooling and dehumidification if needed to be calculated through software this design strategy calculated 40.2% for Multan. In this method, the dry bulb temperature cooled below the dew point temperature. The sixteen variables Heating and humidification if needed calculated the strategy by 7.7%. This

design strategy is very low for the condition of Multan. These all design strategic parameters will achieve the comfort zone of nonresidential buildings in Multan.

4. Result and Discussion

The result of Nonresidential buildings (University Engineering Block) describes the evaluation of energy consumption and Energy Simulation results achieved by HAP Software maximum of single-pan windows placed on the east and west sides which directly affect the internal temperature. For reducing the internal temperature double pan glazing window is used with fenestration. The University Engineering Block simulated with the data presented above and the results obtained. Building peak occupancy is from 8 am to 5 pm complete week. In the peak summer day high energy consumption is utilized. The entire yearly usage of electrical energy for space cooling is 579600.3 Kwh. The high number of spaces (61 spaces) and the limited space in each zone (50 spaces for each zone) have inevitably divided the system into four zones on each floor of the building, but the specifications and input parameters are the same as per space criteria. According to Table 5, the amount of Total cooling load required for cooling is 5982636 BTU/hr. Which can be reduced for adopt the best design strategies during the construction stage of building.

Table:-5 Software output Design Cooling Calculations

Design Cooling (Ground Floor) at Aug 1400 DB / WB 110.0 °F / 74.4 °F		Design Cooling (First Floor) at Aug 1400 DB / WB 110.0 °F / 74.4 °F		Design Cooling (Second Floor) at Aug 1400 DB / WB 110.0 °F / 74.4 °F		Design Cooling (Third Floor) AT Aug 1400 DB / WB 110.0 °F / 74.4 °F		
Zone Loads	Sensible (BTU/hr)	Latent (BTU/hr)	Sensible (BTU/hr)	Latent (BTU/hr)	Sensible (BTU/hr)	Latent (BTU/hr)	Sensible (BTU/hr)	Latent (BTU/hr)
Total Conditioning	1274406	187911	1045125	84706	1350264	168556	1784622	87046

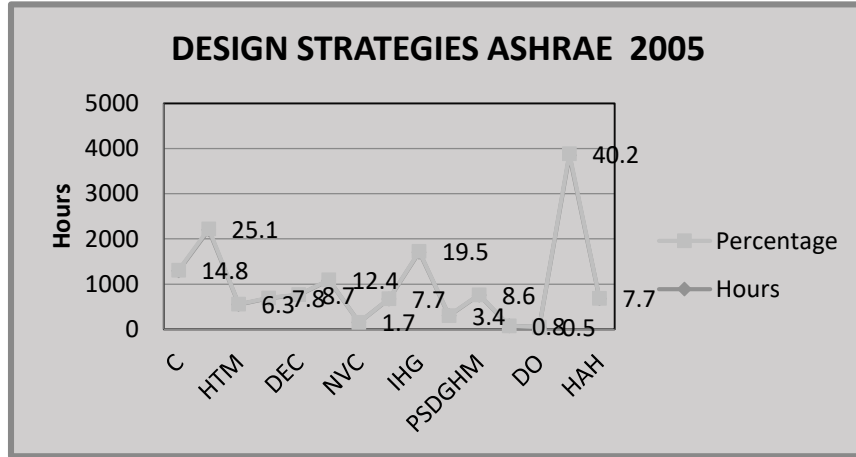


Fig:-8 Percentage of Design Strategies ASHRE 2005

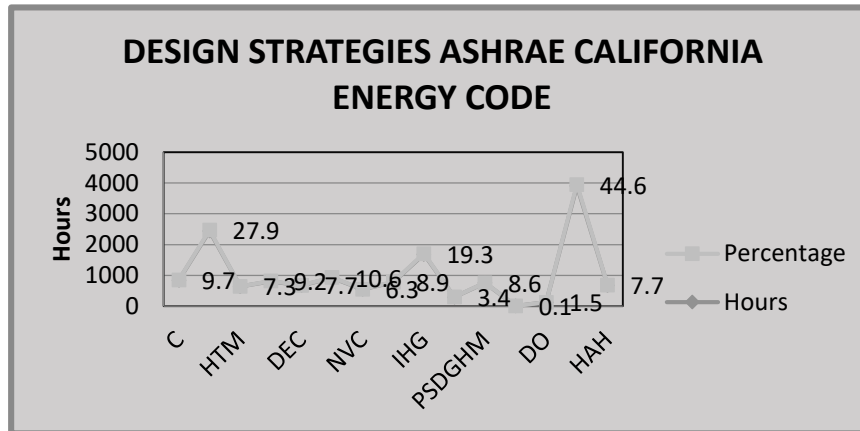


Fig 9 Percentage of Design Strategies ASHRE California Energy Code

The Comparison of the Two standards in Fig.8 and Fig.9 has analyzed the best design strategies for the subtropical region of Multan. The energy measure of this building directly impacts on Design and operational technique for the hot climate zone of Multan. Energy Conservation and thermal comfort achieved and proposes the best design strategies for achieving 100% comfort hours for the region of Multan. Sun Shading of the window is the most effective cooling strategy for Multan increasing the comfort hours by 25.1%. It's a Passive cooling approach to attain indoor temperature and humidification in an appropriate range of comfort. This strategy is needed for the region of Multan with more than 20%. The validity of these suggested design strategies for a specific situation will be further tested with the help of other simulation software. In the upcoming years, we can enhance efficiency and reduce energy consumption by using the best design strategies using the adoptive comfort model in ASHRE Standard 2005. This Study illustrates that the Subtropical Region where summer remains long and hot gives enormous savings. This study shows that applying small measures

can give a huge saving. It is apparent that the simple measure of setting the thermostat at 21C higher point and Natural Ventilation increases the 672 hours of comfort saves 14.8% of energy without any additional investment and deprives of distressing the comfort level.

References

- [1]. Ahmad, K., Badshah, S., Rafique, A. F. A simulated case study of an office building in Pakistan to improve the energy efficiency. *International Journal of Engineering and Advanced Technology*, 04(2), 7-9, (2014).
- [2]. www.nepra.org.pk
- [3]. <https://power.gov.pk/SiteImage/Publication/YearBook>, (2022-23).
- [4]. Omar, Calculated the hourly cooling load due to different kinds of wall, roof, and fenestration using the transfer function method (TFM).
- [5]. Andersson B., Wayne P., Ronald K. The impact of building orientation on residential heating and cooling. *Energy and Buildings*, 8; 205–224, (1985).
- [6]. Khan, A., Arif, S., Alamgir, K. Comparison of buildings thermal loads against building orientations for sustainable housing in Pakistan. *Mehran University Research Journal of Engineering & Technology*, 31, 431-436, (2012).
- [7]. Adnan, Shariah, Brhan Tashtoush, Akram Rousan “Cooling and heating loads in residential buildings in Jordan” *ELSEVIER, Energy and Buildings*, 26 (1997), 137 -143, (1996).
- [8]. Azhar, Kareem Mohammed, Ranj Sirwan Abdullah, Iyd Eqqab Maree “Comparison between Hand Calculation and HAP programs for estimating total cooling load for Buildings” *ZANCO Journal of Pure and Applied Sciences, ZJPAS* (2016), 28 (4); 90 -96, (2016).
- [9]. Rutvik, Lathia, Jaymin Mistry "Process of designing efficient, emission-free HVAC system with its components for 1000 seats auditorium" *ELSEVIER*, (2016).