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DESIGN STRATEGIES AND GUIDLINES FOR TROPICAL COAST OF PAKISTAN, USING CLIMATE CONSULTANT

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ABSTRACT: *The performance and design of climate responsive buildings requires a detailed study of different attributes of climate. Climate Consultant proposes different design strategies suitable for a particular climate using a characteristic analysis. The variety of analysing climatic parameters for a particular location is facilitated with the help of available human thermal comfort models (HTCMs). This paper gives a comparative analysis for the application of various HTCMs using a weather profile of Karachi city in Pakistan. The software results are analysed using an EPW (Energy plus weather) data file from online data base of US Department of Energy. The software lists 20 guide lines based on the design strategies and criteria defined earlier for each model. Their comparative analysis helps in outlining commonalities in effective design methods. The architectural orientation, natural ventilation and the envelope materials were found to be the most workable approaches for hot humid climate of Karachi***.**

KEYWORD: Climate Consultant, Human thermal comfort model, climate responsive design, architectural orientation, natural ventilation, envelope materials

INTRODUCTION

Initially before 90's, the indoor design temperatures in Pakistan were based on ASHRAE standards; 26 °C in cool season and 21 °C in the hot season irrespective of the building location in Pakistan. These temperature standards were defined through laboratory studies. (Nicol and Raja 1997). The new thermal comfort standards were proposed in 1996 based on transverse and longitudinal surveys conducted in five major climatic regions of Pakistan. The Enercon in 1994 worked with a team of Oxford Brooks University, UK for setting appropriate indoor temperature standards for Pakistan. Their surveys showed that there is a definite relationship between indoor comfort and outdoor conditions in line with an adaptive approach to thermal comfort. (Nicol, Raja et al. 1999)

Naturally ventilated buildings in selected cities	Climate		
	Hot dry	Hot humid	Temperate
Islamabad	13		
Karachi		6	
Multan	11		
Peshawar	2		
Quetta	9		

Table 1 Sites of thermal comfort field surveys based on humidity condition (Nicol and Humphreys 2002)

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The result of this survey was incorporated in BECP. The (Nicol and Humphreys 2002) study classifies the five cities of Pakistan as hot dry (hd), hot humid (hh) and temperate (temp) on the basis of their humidity condition to achieve thermal comfort. The field study was based on the meta-analysis of the naturally ventilated buildings. The table 1 shows the results of Pakistan's dataset and their climatic classification according to the humidity condition in naturally ventilated buildings (ASHRAE sites of thermal comfort field surveys). The conducted field survey in selected naturally ventilated buildings does not represent the large samples for identifying humidity conditions. However based on the current study model of climate classification, four zones of Pakistan are identified as hot dry. Karachi is the only city from identified classification as representative of hot humid condition. The humidity is dominant in this city due to low elevation and is an additional challenge which must be considered for future guide line of building envelope.

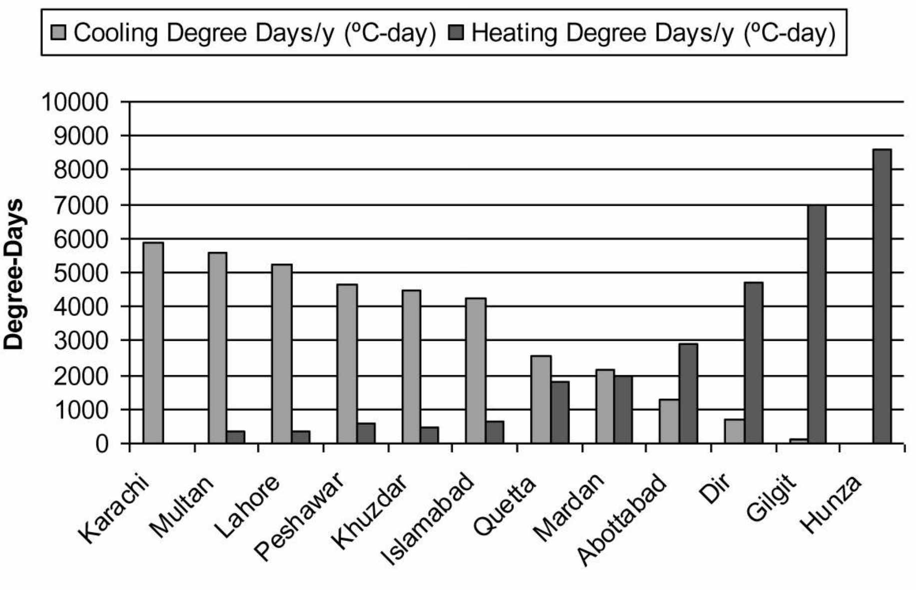

Figure 1 Cooling and heating degree days for 12 cities in Pakistan (Khalid and Raza 2013)

The figure 1 shows heating and cooling degree days for 12 cities of Pakistan. Amongst all the cities, Karachi has the highest cooling degree days due to its mild sunny weather resulting in reduced demand of heating in winter. However, most of the cities are dominated by cooling energy needs because of increased cooling degree days.

Karachi is the largest and densely populated coastal city of Pakistan. Its geographical location is 24.9^{o}N and 67.13^{o}E with an elevation of 22MASL. The adverse impact of climate change is visible in Karachi due to the proximity of sea. The urban morphology of a typical house is based on private (bed rooms, study area, store, and kitchen) and semi-private zones (lounge, drawing and dining rooms). A typical area for an urban house ranges between 75-500 m^2, with significant number of middle income houses having approximate area of 200m^2 (Khalid and Raza 2013)

The energy conservational techniques and passive design methods are not so common throughout the country. The life style of inhabitants and construction pattern in building sector of Karachi has led to inefficient energy consumption. In order to address the summer cooling demands, split air conditioners are widely used.

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The climate responsive building can be an effective cost efficient strategy for the residential building sector requiring an in-depth analysis of Karachi's climate. The houses must be designed to increase indoor comfort without the use of air conditioners. (Milne and Kohut 2010) The (Khalid and Raza 2013) study has demonstrated that a saving of 78% could possibly be managed using energy conservation and passive techniques.

Objectives

The objective of this research is to propose climate responsive design strategies and guidelines using four HTCMs of Climate Consultant for coastal regions.

METHODOLOGY

This study uses EPW file for the climatic analysis and identification of design guidelines for Karachi. The EPW file contains hourly data for all 8760 hours per year, based on actual data recordation from the site. (Milne, Liggett et al. 2007) All calculations are made in metric units and a criterion has been defined for each selected model. The current analyses take the default values available for each HTCM within the Climate Consultant software.

Comfort models in Climate Consultant

Climate Consultant provides a choice between four comfort models which are named as option 1, 2, 3 and 4 respectively in this paper.

1 California energy code comfort model (option 1)
2 ASHRAE standard 55 and current handbook of comfort model (option 2)
3 ASHRAE handbook of fundamental comfort model up through 2005 (option 3)
4 Adaptive comfort model in ASHRAE Standards 55-2010 (option 4)

Psychrometric chart

The psychrometric chart is a combination of various dots, representing temperature and humidity of each 8760 hours per year. It illustrates indoor or outdoor conditions and their relation to human thermal comfort. (Yasmin Bhattacharya May, 2009) The psychrometric charts are based on the selection criteria defined earlier for each comfort model as option 1, 2, 3 and 4. The Climate Consultant analyses the distribution of this psychrometric data in each design strategy zone to create a unique list of design guide lines. (Milne, Liggett et al. 2009) In this study, these charts are based on comfort indoor plot option of Climate Consultant and provide design strategies for all the months of a year. Similar passive heating and cooling design strategies propose different percentage for each of the option 1, 2, 3 and 4.

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No	Seasonal strategy	Design strategies	Option 1		Option 2		Option 3		Option 4	
			%	hrs	%	hrs	%	Hrs	%	Hrs
1		Comfort	8.2	716	14.4	1259	19.9	1732	0	0
2	Cooling	Sun shading of windws	30.6	2684	28.3	2476	29.1	2550	0	0
3		High thermal mass	0	0	0	0	0	0	0	0
4		High thermal mass night flushed	0	0	9.4	825	0	0	0	0
5		Direct evaporative cooling	0	0	0	0	0	0	0	0
6		Two stage evaporative cooling	15.3	1336	0	0	7.7	676	0	0
7		Natural (adaptive comfort) ventilation	0	0	0	0	0	0	39.1	3422
8		Fan forced ventilation	13.2	1152	0	0	11.3	989	0	0
9	Heating	Internal heat gain	12.8	1119	13.6	1194	13.2	1159	0	0
10		Passive solar direct gain low mass	0	0	0	0	0	0	0	0
11		Passive solar direct gain high mass	7.2	630	7.8	686	7.2	630	0	0
12		Wind protection of outdoor spaces	0	0	0	0	0	0	0	0
13		Humidification only	0.3	30	0	0	3.5	310	0	0
14		Dehumidification only	3.5	310	10.0	873	34.5	3022	0	0
15	Systems	Cooling add dehumidification if needed	52.7	4617	49.7	4350	21.0	21.0	0	0
16		Heating, add humidification if needed	2	173	2.0	173	2.0	2.0	0	0

Table 2: Design strategies (DS) for Karachi, using Climate Consultant

Design guidelines[i]					Impact on different options			
No	Similar	Similar in 3	Similar in 2	Dissimilar	Option 1	Option 2	Option 3	Option 4
1	35				X	X	X	X
2	33				X	X	X	X
3	56				X	X	X	X
4	42				X	X	X	X
5		47			X		X	X
6			65				X	X
7	17				X	X	X	X
8			25				X	X
9			27				X	X
10	32				X	X	X	X
11	37				X	X	X	X
12		59		`	X	X	X	
13		38			X	X	X	
14		43			X	X	X	
15		46			X	X	X	
16			66		X	X		
17			30		X	X		
18			61		X	X		
19			26		X	X		
20			57		X	X		
21			18		X	X		
22			60		X	X		
23				45	X			
24				66		X		
25				40		X		
26				24		X		
27				68			X	
28				20			X	
29			53				X	X
30				19			X	
31			36				X	X
32				34				X
33				49				X
34				39				X
35				58				X
36				62				X
37				54				X
38				55				X

Table 3: Design guidelines (DG) for Karachi, using Climate Consultant

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DISCUSSION

According to option 1, 2 and 3, the most effective cooling and heating design strategies for the climate in Karachi are natural ventilation during summer and to increase internal heat gain in winter. (Table 2) The obstruction of summer sun will help to avoid overheating of the envelope. It will be quite challenging to design the window and its shades so that they allow winter sun and block the radiations in summer. Additionally, the adaptive comfort ventilation in option 4 is the only effective strategy with a percentage impact of 39.1% on psychrometric chart. The adaptive ventilation is facilitated with the air motion in warm humid climates to produce a cooling effect.

The table 2 gives a comparative analysis of the design strategies defined in the selection criteria. It is obvious that the option 3 has highest comfort hours. The options 1 and 3 have the largest similarity in DS. The cooling design strategies of, sun shade for Windows (28.3-30.6%), two stage evaporative cooling (7.7-15.3%), and fan forced ventilation (11.3-13.2%) give almost similar comfortable hours. The fan forced ventilation is a special feature of Climate Consultant and has been recently added to support the low windy areas, where wind movements are affected by the natural or manmade obstructions. (Milne and Kohut 2010)

Similarly, the most popular heating design strategies that are common in the options 1, 2 and 3 are internal heat gain and passive solar direct gain high mass. The cooling add, dehumidification is also an considered design strategy found common in first three options but it is relatively few percentage of comfortable hours (21%) in the option 3. (Table 2)
The following observations have been interpreted from the table 3;

In each four options, there are sequential of 20 DGs proposed by the Climate Consultant software. These guidelines are specific to the climate of Karachi so each guideline must be considered in a defined order, starting with the first as most important and so on. Combining all the four options provided in the climate consultant, there are total of 38 design guidelines (DGs) which can be considered for climate responsive building envelope design in Karachi.

Amongst 38 DGs, only 7 DGs are common in all the four options. (Table 3)

There are 5 DGs which are similar in any 3 options. The CEC, ASHRAE 55 and the ASHRAE 2005 have 4 options in similar. (Table 3)

There are 12 DGs that are similar in any two combinations of Climate Consultant. So, California energy codes (CEC) and ASHRAE Standards 55 have largest similarities compared to other options of Climate Consultant. (Table 3)

It has also been found that ASHRAE adaptive comfort options have largest dissimilarities. Amongst the 14 dissimilar DGs in various four options, there are 7 DGs that have dissimilarity with the other three available options. The ASHRAE 55 and ASHRAE 2005 have 3 dissimilar DGs in each option. And CEC has just 1 DS dissimilar in all four options. (Table 3)

Similar design guidelines

Following DGs have been found either similar or close to similar in all four options.

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Design guideline			
No	Similar	No	Close to similar
35	Good natural ventilation	38	Raise the indoor comfort thermostat
33	Long narrow building floor plan	43	Use light colour building materials and cool roofs
56	Screened porches and patios	46	Energy Star appliances
42	Ceiling fans or indoor air motion	47	Use open plan interiors, louvered doors, jump ducts
17	West oriented plants	59	Air conditioning
32	Minimize or eliminate west face glazing	18	Small building area
37	Window overhangs or operable sunshades (awnings)	25	Well ventilated attics with pitched roofs
		26	A radiant barrier (shiny foil) in roof
		27	Raise building above ground to avoid dampness
		30	High performance glazing (Low-E, insulated frames)
		36	openings facing up-wind
		53	Porch, patio, and lanai
		57	North shaded glass with vertical fins
		60	Earth shelter, occupied basement or earth tubes
		65	High ceilings and tall operable (French) windows protected by deep overhangs and verandas.

RESULTS

Summarizing the above suggestion of the DGs which are found either similar or close to similar, the following guidelines are found effective for the hot humid weather of Karachi.

Natural ventilation

Natural ventilation is one of the most important influencing design guideline. It has wide impact on the orientation and window design for increasing the indoor comfort. The architectural planning should encourage the cross ventilation through orienting the plan to encourage the prevailing breezes. The architectural elements particularly all types of opening (windows, doors, ventilators, patios, and courtyard) can play an effective role to strengthen the planning. Additionally, protection of the openings must be provided through shading devices (both vertical and horizontal) and recessed opening. Natural ventilation is one of the passive comfort cooling strategies that works well together with air cross movement. Its affect can be further increased with the use of fan.

Architectural orientation

The ideal orientation of an architectural plan in such climate is north to south. This orientation encourages the presence of large operable glass windows to work with the natural cross ventilation strategy effectively. But the west facing orientation can also be protected through increased vegetation and to minimize glazing. The high ceiling in occupied public zones specifically lounge (where residents spent most of their time) can also encourages natural ventilation.

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Envelope design

The architectural elements like wall, roof and window must have a required minimum level of thermal resistance. It can be made possible with the use of locally available insulating materials, increased thickness, and double glazed pan windows. The right choice of material and their correct selection for each envelope component must be a high priority. Keeping the building size small with appropriate floor area, will have less cooling needs. This concept also supports the Karachi's social structure of housing where apartment buildings are equally popular as compared to rest of the country.

CONCLUSION

The California code gives some similarity to ASHRAE standards when applying to Karachi contextual climatic conditions and vice versa. The traditional passive house strategies are still most popular in designing the climatic responsive buildings for Karachi. It takes help from the existing climatic features to modify the indoor comfort conditions. Natural cross ventilation, orientation design, envelope materials and other architectural strategies that put these requirements together can be effective in designing climate responsive residences in Karachi.

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[i] This paper uses the same numeric representation of design guidelines as described in climate consultant software.

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