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Title: "Passive Building Design Criteria and Techniques for Human Thermal Comfort in Residential Buildings of Semi Arid Climate in India with Focus on Delhi"

ABSTRACT

Delhi as case study in this research and capital of India with a high level in growth and its challenges such as population increase, energy problem, and environmental pollution with a composite climate is a suitable case for a challenge in India and world to achieve passive building methods for residential buildings.

Conclusions of collected data and analysis of Delhi climate can be explained as:

Collected climatic data through ISHRAE, IWEC, MDI, and IWO showed Delhi is included of composite climate area but according to ASHRAE standard it is included in very hot-dry climate with extreme temperatures between -0.6°C to 47°C. Maximum average temperature in summer is 44.3°C in July and Minimum average temperature is in January 5.2°C. Minimum relative humidity is in December 9% and maximum in February, March and August 99%. Adaptive thermal comfort was realized as the best method for passive building design. Adaptive thermal comfort average for Delhi is between 22.2°C in January to 28.1°C in June. According to sun radiation, south facing is the best for Delhi buildings. Sky cover is high in July 88% and August 87% as hot months and in February 85% as cold month. Adverse dominant winds through north and north-west during winter and east and south-east during summer. Suitable temperature for cooling and heating in 4.0 meter depth. It is possible to increase temperature by heating and humidification together and reduce temperature by cooling and dehumidification together. Sun shading is needed in 80% of hot months. Requirement of 30% heating and 50% cooling during a year. It was observed 17°C maximum difference between minimum or maximum dry bulb temperature to average thermal comfort temperature in January, February and July. According to psychrometric charts, in summer cooling and dehumidification with 48.9% and adaptive comfort ventilation with 34.9% and in winter heating and humidification with 50.1% and heat gain with 19.1% were more effective criteria. Psychrometric charts showed passive building design principles and techniques can make 100% daily hour thermal comfort in a year.

Based on climatic analysis, some passive principles presented as recommended passive strategies and criteria such as the following:

Best building orientation was realized south through solar radiation and wind analysis. Using deciduous trees for south and dense plants for east and west, dense ever green trees for north and north-west are recommended for shading during summer and protect to unwanted winds.

Compact building shape and self-shading forms. The best roof angle was calculated as 52 degree. Living spaces should face to the south and service spaces should face to north or west. Bigger size openings for south and using double glazed windows with wooden, PVC or aluminum or combination of them frame was recommended. Window wall ratio less than 0.5 and window to floor area ratio 0.11 to 0.25 was recommended. Horizontal shading devices for south and vertical shading devices for east and west with carefully calculation. Using porches, verandahs, patio, and pergolas for shading are very useful in all orientations. Adding internal shading devices help to reduce heat gain during summer. High mass construction reduces 25% of required energy for heating. It works for reducing heat loss in summer too.

In this research some passive building design techniques were presented such as:

Natural ventilation is the most important cooling techniques. It was recommended by cross ventilation and stack effect ventilation. Size of openings for south façade was 11%-25% and other facades 3%-5% for better ventilation. Wing walls are very effective technique for ventilation too. Air-vents on roof are very simple techniques for stack-effect ventilation. Evaporative cooling with indirect cooling on surfaces was recommended. Radiant barriers, cool roofs, and green roofs were recommended . Ground coupled system with using 4.0 meter depth air can be used in winter and summer. Direct solar gain, solar wall, double façade are heating techniques in summer and by shading can be used as cooling techniques. Vegetation and clerestories are very simple and effective techniques that can be used in all buildings and houses. Courtyard was recommended as a complete system. It can be combined with all techniques especially vegetation, water body, downdraught system, shading devices and other passive principles and techniques.

Recommended Future Works

It is necessary to research about human thermal comfort based on other models especially Predicted Mean Vote (PMV) model.

it is very important to classify buildings according to floors (levels), area, architectural types for example single stories, single buildings, complexes, shapes (forms), also buildings orientations, materials and many other information. Then it will be possible to understand more important requirements in principles and techniques.

It is necessary to focus on each one of these suitable principles and techniques in separate researches to do laboratory and experimental analysis on them and achieve more exactly answers.