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EVALUATION OF EXISTING COOLING SYSTEMS FOR REDUCING COOLING POWER CONSUMPTION

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ABSTRACT

As energy costs rise, and the public becomes more aware of the environmental damage arising from current energy use patterns, more people are looking into passive as a way of reducing the amount of energy used. In India, just as much energy, if not more, may be used for cooling in summer. Thus, a properly designed building in India should be designed to require a minimum amount of energy for cooling in the summer. This work was designed to estimate the cooling load power consumption during the summer in the month of July. The actual cooling load for cooling systems of a seminar hall with various applications was recorded during the peak load period of the year (July). The records were used for estimating the total power consumption of the cooling systems in this region. According to this estimation, the cooling systems power consumption in this region accounted for more than 60% of the total power consumption during the peak load period of the year. A computer program was developed for simulating the effect of various parameters on cooling load of the building. According to the simulation results, use of double glazed windows, light colored walls and roofs, and insulated walls and roofs can reduce the cooling load of the buildings more than 15%.

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INTRODUCTION

Air-conditioning system is responsible for a significant part of total energy consumption in building. Capacity of Air-conditioning system is determined according to total cooling load of building. Building cooling loads consist of heat gains through opaque external surfaces and fenestration areas of the building and internal heat gains. Architectural and physical properties of building, such as thermal mass, structural material and its shape, are the most important parameters, which influence the space-cooling load. Another parameter is local climate. In contrast, energy consumption for electrical appliances and lighting and for summer cooling has been less analyzed and regulated, although electricity demand has risen strongly in the last few years and high thermal loads in buildings have led to increasing installation capacities of electrical cooling equipment. The loads are partly due to the continuing attraction of highly glazed buildings, where the prevention of solar irradiance transmission is difficult, but also to rising internal loads through computer equipment, electrical lighting and other appliances Unwanted thermal energy can accumulate in buildings and dwellings from a variety of sources, such as heat from interior appliances, equipment, and occupants; solar radiation; and radiation or convection-induced heat transfer and air infiltration through walls. Passive cooling involves designing buildings and selecting construction materials in a way that reduces heat absorption and conduction through the roof and walls. The goal of these systems is to minimize, or eliminate Different effective techniques such as free cooling, natural ventilation, thermal mass and night cooling can used in order to reduce the cooling load. Over the past few years, concern towards energy efficiency and incorporation of passive cooling systems in buildings has increased. In earlier times, when energy was not available in its most popular form, i.e., electricity, building designers had to rely on natural ways and means for maximizing comfort inside the building envelope. A major difference between ancient times and today's situation is that today, none of the major resources namely, land, money and time are available in abundance. This has led to a situation where passive features must be designed more scientifically and technically as compared to the past. Literature related to contemporary building design reveals that there are numerous examples displaying success stories in different climatic conditions, worldwide. In India, there are several showcase buildings such as a solar passive house in hot arid zones in India (Bansal and Minke, 1995) and a passive-cooled building for semi-arid zones (Srivastava et al., 1984) using wind tower, earth berm and evaporative cooling systems. Attempts have been made to design sustainable buildings for hot and dry climates using optimal building form and layout. On the other hand, there are buildings like MLA hostels in Simla, for cold climatic conditions using passive heating concepts (Majumdar, 2002). The first platinum rated LEED accredited building of India also displays use of passive cooling systems in building design (CII-GBC, 2004). There are also some examples of unsuccessful passive cooling systems. Bakiwala (2002) has prepared a report on non-functional passive features concluding that the failure was primarily due to two reasons:

- Inadequate design calculations or design by gut-feel
- Over-expectation from the passive feature.

COMPONENTS OF COOLING LOAD

The total building cooling load consists of heat transferred through the building envelope (walls, roof, floor, windows, doors etc.) and heat generated by occupants, equipment, and lights. The load due to heat transfer through the envelope is called as external load, while all other loads are called as internal loads. The percentage of external versus internal load varies with building type, site climate, and building design. The total cooling load on any building consists of both sensible as well as latent load components. The sensible load affects the dry bulb temperature, while the latent load affects the moisture content of the conditioned space. Buildings may be classified as externally loaded and internally loaded. In externally loaded buildings the cooling load on the building is mainly due to heat transfer between the surroundings and the internal conditioned space. Since the surrounding conditions are highly variable in any given day, the cooling load of an externally loaded building varies widely. In internally loaded buildings the cooling load is mainly due to internal heat generating sources such as occupants, lights or appliances. In general the heat generation due to internal heat sources may remain fairly constant, and since the heat transfer from the variable surroundings is much less compared to the internal heat sources, the cooling load of an internally loaded building remains fairly constant. Obviously from energy efficiency and economics points of view, the system design strategy for an externally loaded building should be different from an internally loaded building. Hence, prior knowledge of whether the building is externally loaded or internally loaded is essential for effective system design

MATHEMATICAL FORMULATION AND ANALYSIS

In the present work TETD/TA method has been used. Through this method hourly cooling load have been determining for different material of roof and walls. All these parameters have been determined for different building materials, different convective heat transfer coefficients on inside and outside surface, different surface conditions and with varying outside climate conditions

DESCRIPTION OF THE MODEL

Our model is a seminar hall in N.C.College of Engg, Israna (Panipat) having longitude 76oE, latitude 30oN of size 12.65m length, 12.29m breadth and 3.66m height having walls made of bricks with plaster on inner and outer side of north, south, east and west wall and roof is of concrete, mud puska.plaster and tiles.24% area of the north wall is of glass. There are two wooden doors in the south wall. There are three windows opening in the glass area. Walls are facing to north, south, east and west. Corridor is provided on south side and on east and west side there are adjoining rooms which are condioned.So direct radiations reach from only north and south side.

DIFFERENT PASSIVE MEASURES AND THEIR EFFECTIVENESS

For the seminar hall cooling load was calculated for different passive measures using various types of insulation and their application on roof as cooling load is not much affected by insulation on walls. Moreover air was considered as insulator in the form of cavity. Also changing the absobtivity of outer surface of roof and walls was considered as a passive measure.

- Impact of Light color as passive measure
  The coefficient of absobtivity of N-S wall and roof was changed by applying a coating of light color. At 1500 hours, the cooling load of untreated was 76.8

KW and the same for N-S wall and roof treated with light color was 73.2 KW.The coefficient of absobtivity for light color is 0.44 and that of dark color is 0.88.Lower absobtivity reduces sol-air temperature on N-S wall and roof. comparing the two treatments one that of light color and other that of dark color difference in peak cooling load is 3.6 KW

- Impact of white wash as passive measure
  The coefficient of absobtivity of N-S wall and roof was changed by applying a coating of white wash..At 1500 hours, the cooling load of untreated was 76.8 KW and the same for N-S wall and roof treated with white wash was 70.8 KW.The coefficient of absobtivity for white wash is 0.25 and that of dark color is 0.88.Lower absobtivity reduces sol-air temperature on N-S wall and roof. comparing the two treatments one that of white wash and other that of dark color difference in peak cooling load is 6 KW

- Impact of double glazed window as passive measure
  At 1500 hours, the cooling load of untreated was 76.8 KW and the same for with double glazed window was 75.1 KW.Comparing the two treatments one that with double glazed windows and other that with single glazed windows difference in peak cooling load is 2 KW(approx)
- Impact of insulation on roof as passive measure
  Four insulating materials were considered and applied on the surface of the roof. The analysis showed that with sand wool(k=0.038 W/mK) insulation 50mm thick, cooling load at 1500 hours was reduced to 68.78 KW from 76.8 KW cooling load of untreated seminar hall. For seminar hall with polyestrene(k=0.031 W/mK) insulation 40mm thick it was 68.79 KW,with plywood insulation 25mm thick it was 73.69 KW and with Al 1100+polyurethane(6.4mm thick=0.023 W/mK) it was 69 KW.

- Impact of insulation on N-S walls as passive measure
  Two insulating materials were considered and applied on the surface of the walls. The analysis showed that with sand wool (k=0.038 W/mK) insulation 50mm thick, cooling load at 1500 hours was reduced to 75.37 KW from 76.8 KW cooling load of untreated seminar hall. For seminar hall with polyestrene (k=0.031 W/mK) insulation 40mm thick it was 75.49 KW.
- Impact of white wash in combination with double glazed window and sand wool of 50mm on roof as passive measure
  The coefficient of absobtivity of N-S wall and roof was changed by applying a coating of white wash. At 1500 hours, the peak cooling load of untreated room was 76.78 KW and the same with treatment was 65.86 KW

- Impact of white wash in combination with double glazed window and plywood of 25mm on roof as passive measure
  At 1500 hours, the peak cooling load of untreated room was 76.78 KW and the same with treatment was 67.88 KW

- Impact of white wash in combination with double glazed window and polystyrene of 40mm on roof as passive measure
  In combination with double glazed windows and polystyrene of 40mm as passive measures cooling load at 1500 hours was reduced to 65.85 KW from 76.8 KW cooling load of untreated seminar hall.

- Impact of white wash in combination with double glazed window and Al 1100+polyurethane of 6.4mm on roof as passive measure
  At 1500 hours, the cooling load of untreated was 76.8 KW and the same for with combination with double glazed window and Al 1100+polyurethane of 6.4mm on roof as passive measure was 66.94 KW.In this passive measures Al 1100 act as reflector and to decrease the absobtivity of roof surface and hence reduce the cooling load.

- Impact of white wash in combination with double glazed windows+ polystyrene of 40mm and with false ceiling on roof as passive measure.
  Impact of white wash in combination with double glazed windows, polystyrene of 40mm and with false ceiling on roof as passive measure. In combination with white wash double glazed window, polystyrene of 40mm and with false ceiling on roof used as passive measures. At 1500 hours cooling load of seminar hall in combination of double glazed windows, polystyrene of 40mm is 65.85 KW and with all above combination with false ceiling, cooling load of seminar hall is 65.65 KW.On average there is only 0.2 KW difference with or without false ceiling

- Impact of white wash in combination with double glazed windows, sand wool of 50mm and with false ceiling on roof as passive measure
  In this combination white wash double glazed window, polystyrene of 40mm and with false ceiling on roof used as passive measures. At 1500 hours cooling load of seminar hall in combination of double glazed windows, sand wool of 50mm is 65.85 KW and with all above combination with false ceiling, cooling load of seminar hall is 65.63 KW.On average there is only 0.2 KW difference with or without false ceiling

Table 1
Different cases used in cooling load simulation for seminar hall

Case	Title	Description
1	Base Case	Building with ordinary walls(dark color) and roof, ordinary glass
2	Effect of outside color of Roof and Walls.	Like case 1,with light color on roof and walls
3	Effect of double glazed window.	Like case 2,with double glazed window

4	Effect of Sand wool the roof.	Like case 3,with sand wool on the roof
5	Effect of Sand wool the walls.	Like case 4, with sand wool on the walls
6	Effect of extruded polystyrene foam the roof.	Like case 5,with extruded polystyrene foam on the roof
7	Effect of extruded polystyrene foam the walls.	Like case 6,with extruded polystyrene foam on the walls
8	Effect of plywood the roof.	Like case 7,with plywood on the roof
9	Effect of outside white wash of Roof and Walls.	Like case 8,with outside white wash on the Roof and Walls
10	Effect of Aluminum 1100 flat and polyurethane the roof.	Like case 9, with Aluminum 1100 flat and polyurethane on the roof.
11	Effect of combined white wash+ double glazed window+ Sand wool on the roof.	Like case 10, with combined effect of white wash+ double glazed window+
12	Effect of combined white wash+ double glazed window+ plywood on the roof.	Like case 11, with combined effect of white wash+ double glazed window+
13	Effect of combined white wash+ double glazed window+ extruded polystyrene foam	Like case 12, with combined effect of white wash+ double glazed window+
14	Effect of combined white wash+ double glazed window+ Aluminum 1100 flat and	Like case 13,with combined effect of white wash+ double glazed window+
15	Effect of combined white wash+ double glazed window+extruded polystyrene foam+False Ceiling	Like case 14,with combined effect of white wash+double glazed window+ extruded polystyrene foam+False Ceiling
16	Effect of combined white wash+ double glazed window+ sandwool+False Ceiling	Like case 15,with combined effect of white wash+ double glazed window+sandwool+False Ceiling

Table 2 Results of simulation of cooling load for seminar hall on cases of Table 1

Case	Peak Sensible cooling load(W)	Peak Latent cooling load(W)	Peak Total cooling load(W)	Reduction (%)
1	45312.47	27866	73178.47	4.68
2	47280.15	27866	75146.15	2.12
3	40916.61	27866	68782.61	10.41
4	47509.76	27866	75375.76	1.82
5	40930.65	27866	68796.65	10.39
6	47628.36	27866	75494.36	1.67
7	45821.29	27866	73687.29	4.02
8	42972.51	27866	70838.51	7.73
9	41137.97	27866	69003.97	10.12
10	37993.78	27866	65859.78	14.23

11	40015.09	27866	67881.09	11.58
12	37984.91	27866	65850.91	14.22
13	39072.63	27866	66938.63	12.81
14	37784.25	27866	65650.25	14.49
15	37766.81	27866	65632.81	14.51

CONCLUSION

The main objective of the work was to provide the comfort condition in a seminar hall by using passive measures .After analyzing the result obtained by simulation the following conclusion can be obtained.

As flow of heat through roof is maximum because it is directly exposed to sun, hence when passive measures applied on roof then it will be the most effective

Application of combined white wash+ double glazed window+ extruded polystyrene foam+False Ceiling was an cost effective measure for reducing the peak cooling load during the month of july. Application of this passive measure reduce the peak cooling load up to 15%.

REFERENCES

[1] ASHRAE, 1997. ASHRAE Handbook of Fundamentals, New York. American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

[2] M.S. Hatamipour a, H. Mahiyar b, M. Taheri, Evaluation of existing cooling systems for reducing cooling power consumption.

[3] Jorge L. Alvarado, Wilson Terrell, Jr., Michael D. Johnson, Passive cooling systems for cement-based roofs.

[4] Environmental Building Guidelines for Greater Hyderabad — Ver. 1.1(2008), Window design for day lighting, solar control and ventilation

[5] Mehmet Azmi Aktacir, Orhan Büyükalaca ,Tuncay Yılmaz , A case study for influence of building thermal insulation on cooling load and air-conditioning system in the hot and humid regions

[6] Refrigeration and Air-conditioning by C.P.Arora

[7] SP 41, Handbook on functional requirements of building (Other than industrial buildings), Part 1-4, Bureau of Indian Standard (1988)

[8] A Thesis on Study and Evaluation of Passive Measures to create comfort conditions in buildings by Vijay Kumar Bajpai