WALL ORIENTATION AT DELHI-NCR REGION WITH RESPECT TO SOLAR RADIATIONS

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Abstract: Unlike flat roofs, building walls are not only orientation sensitive but also one of the most important building element for heat gain. Also, orientation is one of the most basic but most effective technique of passive solar design. Although many passive design techniques may not be suitable in present times but orientation considerations are still relevant and can protect a building from a good amount of solar loading and thus provide ample opportunities of energy conservation in buildings. Delhi-NCR is among the areas which are observing maximum growth at present in India. If this development is based on suitable energy conservation techniques like orientation, it would be great service not only to building industry but also to the nation and environment. It could be easily achieved by avoiding worst orientation at design stage itself. Hence orientation of buildings at DELHI-NCR for maximum solar heat gain in summer has been obtained through simulation technique. Sol-air temperature, azimuth angle, solar flux and various other parameters involved have been found out at each day of every months of the year at a time interval of 15 minutes. Subsequently, mean maximum sol-air temperature and corresponding solar azimuth/orientation for each month has been obtained which can be utilized to make the building energy efficient. Although nowadays several simulation software are readily available for energy analysis of a whole building designed without pre-consideration of orientation but if an architect consciously designs a building, avoiding wall surfaces from facing worst orientation, it would further make it very energy efficient by reducing sufficient amount of heat gain.

Introduction

Buildings play a huge role in annual fuel and energy consumption, as well as greenhouse gas emissions. In the United States, buildings consume 39 percent of the annual energy and 68 percent of the annual electricity. Buildings are also responsible for emitting 38 percent of the carbon dioxide, 49 percent of the sulfur dioxide, and 25 percent of the nitrogen oxide found in the air [1]. Buildings used more than 38% of all U.S. Energy and 76% of U.S. Electricity as per 2014 data, out of which Residential sector used 37%, Commercial sector 35%**,** Industrial HVAC and Lighting 3% and Other Industrial sector utilized 24%**.** The building sector's share of electricity use has grown dramatically in the past five decades from 25% of U.S. annual electricity consumption in the 1950s to 40% in the early 1970s to more than 76% by 2012".[2]."Globally the building sector accounts for more electricity use than any other sector, 42 per cent. No wonder considering that we spend more than 90 per cent of our time in buildings. With increasing urbanization, higher in developing countries, the number and size of buildings in urban areas will increase, resulting in an increased demand for electricity and other forms of energy commonly used in buildings"[3]. "Reducing energy use in buildings is one of the most important ways to reduce humans' overall environmental impact. This is because buildings account for 40% of worldwide energy use, far more than cars and airplanes combined. For many buildings, energy use is the largest environmental impact. As much as, 90% of a building's environmental impact comes from the energy used during its lifetime" [3]. Aforesaid situation is a prediction for developing countries like India in the times to come as it would travel on the path of development.

Hence there is huge responsibility on architects to design buildings which require less energy for their functioning during their life time using passive techniques; orientation being one of the major techniques in this regard. Climatically building is defined as an envelope which separates outside natural environment from inside building environment. As outside environment changes rapidly with changing weather conditions such as diurnal and seasonal variations, many physical parameters of outside environment may not be suitable for healthy/ comfortable living. Such unsuitable thermal/physical conditions affect dwellers physical and mental comfort and functioning, resulting not only in loss of efficiency but also affect their behavior and related problems/developments. The purpose of building envelop is thus to act as moderator in keeping the inside environment within physical comfort limits or close to it to protect the users from aforesaid climatic hazards. It signifies that envelop must act as intelligent object understanding the human requirement. This envelop may be designed to act like that by employing proper building materials, design strategy, site selection/proper site elements design, construction techniques and building form.

Delhi Physical Development and Electricity Demand

"Delhi was a small town in 1901 with a population 0.4 million. Delhi's population started increasing after it became the capital of British India in 1911. During the Partition of the country, a large number of people migrated from Pakistan and settled in Delhi. Migration into the city continued even after Partition. The 2001 Census recorded 138.51 lakh population of Delhi with 3.85% annual growth rate and 47.02% decennial growth rate during 1991-2001(a4) [4]".Delhi is not only present and historical capital of India but also second most populous and one of fastest developing city of India with a metropolitan population of 11,034,555 (census 2011) without NCR (National Capital Region) population. Delhi population (urban area) is further estimated to be about 36,060,000 in 2030[5].

Table 1[6].
Population of Delhi UA, Greater Mumbai UA, and Kolkata UA, 1991 and 2001 Censuses and 2007 Estimate

Urban Agglomeration (UA)	Census population (millions)		Average annual growth rate (%) 1991-2001	Estimated ** population (millions) 2007
	1991	2001		
Delhi UA official	8.5	12.9	4.2	16.6
Delhi UA "redefined"*	10.1	16.2	4.7	21.5
Greater Mumbai UA	12.6	16.4	2.7	19.3
Kolkata UA	11.0	13.2	1.8	14.7

* Includes areas outside the Delhi NCT in neighboring states added by authors.
** Estimated assuming that the 1991-2001 growth rate has remained constant.
Source: Registrar General of India, 1991 and 2001 censuses and authors' estimates ("redefined" Delhi UA and all 2007 estimates).

As the population is increasing, electricity demand of Delhi is also increasing. Delhi's power demand reached 5925 MW, highest in 2014 which is almost thrice of Kolkata (Around 2100 MW), almost twice of Mumbai (Around 3400 MW), nearly two and a half times, the power the seven North Eastern States draw together (around 2500 MW), almost one and a half times the peak power demand of Orissa (around 3990 MW), over two and a half times, the peak power demand of Bihar (2750 MW) [7]. The CSE (Delhi-based non-profit Centre for Science and Environment) analysis also showed that Delhi's peak demand has doubled in the last 10 years, growing faster than the population of the city. It registered an all-time high peak demand in June last year at 6,006 MW. This demand was higher than combined highest ever peaks of Mumbai, Kolkata and Chandigarh. CEA (Central Electricity Authority) projects Delhi's peak will cross 6,300 MW this year (2016) and 12,000 MW by 2021. Delhi's peak power demand (MW) over the years was in 2014 (July 15) 5925 MW at 3: 20 pm, 2014 (July 11) 5810 MW at 3: 58 pm, 2014 (July 10) 5789 MW at 4: 11 pm, 2013 (June 6) 5653 MW, 2012 (July 5) 5642 MW, 2011 (August 2) 5028 MW, 2010 (July 1) 4720 MW... 1961 (86 MW), 1947 (27 MW) and 1905 (02 MW). On the other hand the capacity of the capacity of Delhi's power stations is approximately only 3035 MW, station wise being of Badarpur Thermal Power (705 MW), Rajghat Power Station (135 MW), Gas Turbine Power Station (270 MW), Pragati Power Station(330 MW), Pragati Power Station-II Bawana (1500 MW), and Rithala Power Station (94.8 MW) [8].

The 68th Nation Sample Survey of Household Consumption of Various Goods and Services in India found that in 2012, about 412 out of every 1,000 households in urban Delhi owned an air conditioner or air cooler as compared to the national average of 77. The survey noted that while ACs accounted for only 15 per cent of the national average, in metro cities their share can be as high as 60 per cent. AC sales have been growing at a healthy 8 to 10 per cent annually and the industry is expecting it would accelerate to 15 to 20 per cent in coming years*. Nationally, energy demand from ACs is expected to increase 10 times by 2030. [9].

Thus new physical growth is also taking place at a very fast rate in Delhi and around Delhi in Noida, Greater Noida, Faridabad and Gurgaon/ Gurugram, but if takes place according to principles of energy efficient building design, it would be great service to the nation and environment, as it would help in reducing the projected electricity demand, requirement of precious natural resources like coal and resultant environmental pollution. Orientation is one of such important principles.

Heat Transfer in Buildings

The Sun, through it solar/thermal radiations, is the main source of thermal energy on planet Earth. Areas on the Earth, receiving more solar radiations have warm climate, while those receiving fewer amounts of solar radiations have cool climate. This is due to curved nature of the Earth surface which causes different angle of incidence for solar radiations on different parts of the Earth and as per Cosine law. Outside warm/cool air causes heat transfer through all outside faces of the building. Outside air temperature is almost the same on all faces of building envelop and hence causes equal heat transfer. But the faces which receive direct solar radiations receive extra thermal energy causing additional heat gain. This additional heat gain depends on orientation of the wall. In normal conditions when the direct solar radiations are not incident on the wall, heat gain/loss inside a room through a wall is represented by following equation

$$Q = U * A * (T_o - T_i) \quad \text{--------- Eq.No.1.}$$

Where, Q = heat gain/loss (in J/s or W), U = over all heat transfer coefficient (W/ m2) of the wall, A = wall surface area (m2) and (To – Ti) is difference in temperature between the outside air and inside air of the building. U is further defined as, $U=1/\Sigma R$ and $\Sigma R = (1/H_o) + (R1+ R2+R3+\ldots) + (1/H_i)$. ΣR is the total heat transfer resistance faced in process of heat transfer between outside and inside environments. When direct solar radiation fall on the outside face of the wall, it causes additional heat flow as explained above. In such a case To is replaced in eq.no.1 by Ts (solar air temperature), an imaginary temperature. Sol air temperature is defined as the temperature which will cause equivalent heat transfer through the wall as in case of direct solar radiation coming on the wall. Thus eq.no.1 is modified and expressed as follows:

Q = U * A * (Ts – Ti) --------- Eq.No.2.

Where Ts (sol air temp) = To + a * I / Ho, To = outside air temperature, a = absorption coefficient of outside wall surface, I = solar radiation intensity incident perpendicular to the wall, Ho = outside wall surface thermal conductance, Hi = inside wall surface thermal conductance. From Eq.No.2, it is clear that for any building wall, value of A (surface area) and U (over all heat transfer coefficient which depends on the type of wall materials and their properties) are fixed, but value of (Ts – Ti) may change from time to time due to amount of incident direct solar radiations intensity I, its absorption by the outside wall surface (value of a) and value of Ho. When there are no solar radiations, value of factor I becomes zero and hence Eq.No.2 becomes Eq.No.1.

Orientation of Buildings at Delhi

Orientation is a passive design technique to place a building in such a way that it receives maximum benefits from solar radiations and wind as per climatic requirements. While orientation with respect to the Sun is important in all types of climates, wind preferences is desirable in certain cases only as wind changes its direction and speed very easily due to obstacles before any building which are common in urban environment. Further in air-conditioned buildings cross ventilation/natural wind is not preferable. As found and mentioned at * above, trend is increasing to install air-conditioners at a very fast rate even in residential buildings while most of the offices and commercial complexes are completely air conditioned and consume large amount of electric energy. Completely passive designed buildings are neither desirable nor preferred by people. Hence here emphasis is on designing conditioned buildings with maximum benefits from orientation with respect to solar radiations.

From eq.2, it is also clear that for any building wall, value of A (surface area) and U (over all heat transfer coefficient which depends on the type of wall materials and their properties) are fixed. But value of Ts may change from time to time depending upon value of To and amount of incident direct solar radiations (value of I); changing from 0 (during night or when wall is shaded from direct solar radiations) to its maximum value. Thus maximum value of Ts can be found through simulation technique along with value solar azimuth/ sun direction when maximum value of Ts occurs. So if maximum value of sol-air temp (Ts) is found out in a year, it can be assumed that maximum heat transfer would also take place at that time. If solar azimuth is also found out at that time it would give the solar position at which it causes maximum heat transfer in the building and hence would be worst orientation during summer months.

Focus of this paper/discussion is thus to find out worst orientation so that no wall of the building orients towards this direction while designing a building by the architects.

TABLE 2

Delhi climatic data (Source: India Meteorological Department (record high and low up to 2010 & NOAA (extremes, sun and humidity, 1971–1990)

months	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Year
Record high (MX) °c	30.0	34.1	40.6	45.6	47.2	48.7	45.0	42.0	40.6	39.4	36.1	29.3	48.7
Average high (MN) °c	20.5	23.9	29.6	36.3	39.5	39.2	35.4	34.1	34.1	32.8	28.2	23.1	31.4
Average low °c	7.6	10.4	15.6	21.3	25.8	27.9	27.4	26.6	25.0	19.1	12.9	8.3	19.0
Record low °c	-0.6	1.6	4.4	10.7	15.2	18.9	20.3	20.7	17.3	9.4	3.9	1.1	-0.6
Average rainfall mm	19.3	22.1	15.9	13.0	31.5	82.2	187.3	232.5	129.8	14.3	4.9	9.4	762.3
Average rainy days	1.3	1.8	1.6	1.2	2.5	4.6	9.4	9.8	5.5	1.0	0.5	0.9	40.1
Average RH %	63	55	47	34	33	46	70	73	62	52	55	62	54
Mean monthly sunshine hours	214.6	216.1	239.1	261.0	263.1	196.5	165.9	177.0	219.0	269.3	247.2	215.8	2684.6

DELHI WIND DIRECTION [10]

SIMULATION RESULTS FOR DELHI

ENERGY ANALYSIS OF A BUILDING AT DELHI=NCR, INDIA.
NAME OF THE BUILDING: experimental
LOCATION: DELHI
LONGITUDE: 77.13.48 E
LATTITUDE: 28.36.36 N
ALTITUDE: 227.0 MTS
PROGRAMMER: AR. NAWAB AHMAD
RESULTS ARE AS FOLLOWS

TABLE 3
Simulation Results

Parameters	Months of the year											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
MX	20.5	23.9	29.6	36.3	39.5	39.2	35.4	34.1	34.1	32.8	28.2	23.1
MN	7.6	10.4	15.6	21.3	25.8	27.9	27.4	26.6	25.0	19.1	12.9	8.3
MTSOLN	42.241	45.709	50.639	55.147	56.579	56.531	53.221	51.861	53.372	52.714	48.356	43.914
MTSLN	14.057	14.455	14.992	15.508	15.944	16.2	16.137	15.742	15.158	14.589	14.158	14.0
MTH1N	30.867	36.830	44.880	52.625	59.153	63.0	62.005	56.129	47.375	38.831	32.375	30.0
MALTN	32.876	36.469	41.127	45.651	48.320	48.637	47.727	46.170	43.390	38.732	33.913	31.24
MTIX	1365.7	1351.0	1337.5	1331.4	1294.3	1280.1	1279.8	1289.9	1307.4	1331.5	1350.4	1364.5
MTIDN	800.76	829.832	826.55	787.567	757.570	732.959	721.754	729.302	774.360	790.641	783.39	779.52
MTIDV	672.32	666.215	622.280	550.36	503.561	484.116	485.341	504.885	562.557	616.281	649.82	666.47
MTIDH	434.76	494.468	543.68	563.16	565.782	550.111	534.062	526.120	531.943	494.759	437.19	404.29

Where
MX = mean monthly max air temperature (available climatic data),
MN = mean monthly min air temperature (available climatic data),
MTSOLN = mean monthly value of sol air temperature (with respect to a vertical wall oriented towards the sun),
MTSLN = mean monthly time when max sol air temp occurs.
MTH1N = solar azimuth angle from south direction towards west when max sol air temp occurs.
MALTN = mean monthly solar altitude angle when max sol air temp occurs,
MTIX = mean monthly value of solar constant,
MTIDN = mean monthly direct solar radiation,
MTIDV = mean monthly component of direct solar radiation on vertical surface (walls),
MTIDH = mean monthly component of direct solar radiation on horizontal surface (roof) when MTIDV is max,

Here MTSOLN, MTSLN, MTH1N, LALTN, MTIX, MTIDN, MTIDV, and MTIDH are calculated values as per program.

Note: The value of Ho has been assumed to be 22.7 Wm-2K in calculations for sol air temperature.

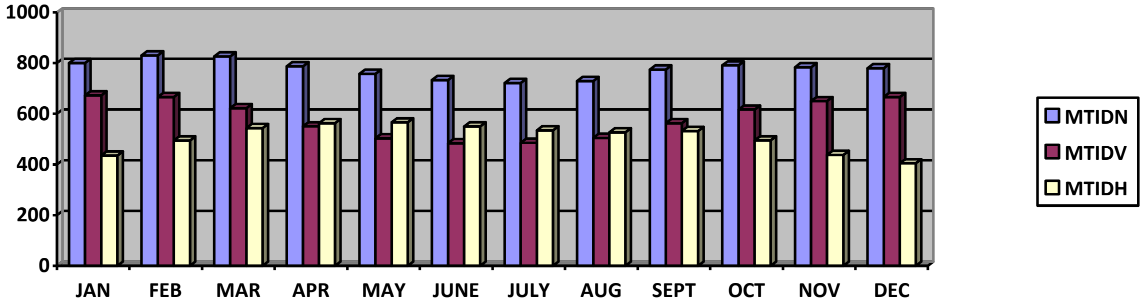


FIGURE X: VALUES OF MTIDN, MTIDV AND MTIDH WHEN SOL AIR TEMP IS MAX IN ANY MONTH. ALTHOUGH! HORIZONTAL COMPONENT OF SOLAR-RADIATIONS INCIDENT UPON ALLS/VERTICAL SURFACES (MTIDV) IS LOWER IN SUMMERS, HORIZONTAL COMPONENT OF SOLAR-RADIATIONS (MTIDH) INCIDENT UPON WALLS/VERTICAL SURFACES IS HIGHER IN SUMMERS WHICH COMBINED WITH HIGHER AIR TEMPERATURES CAUSES

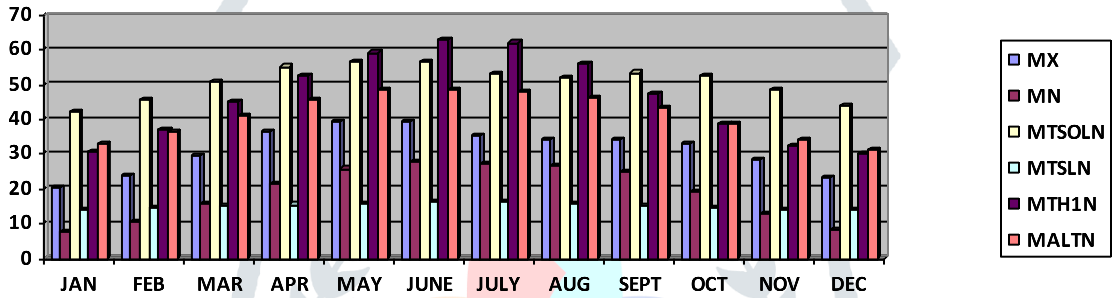


FIGURE X: VALUES OF MX, MN, MTSOLN, MTSLN, MTH1N AND MALTN WHEN SOL AIR TEMP IS MAX IN MONTHS (COLLUM CHART COMPARATIVE PRESENTATION)

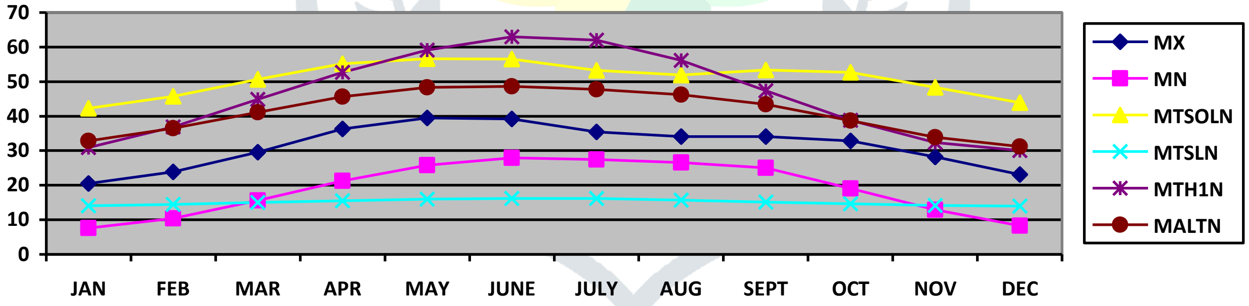
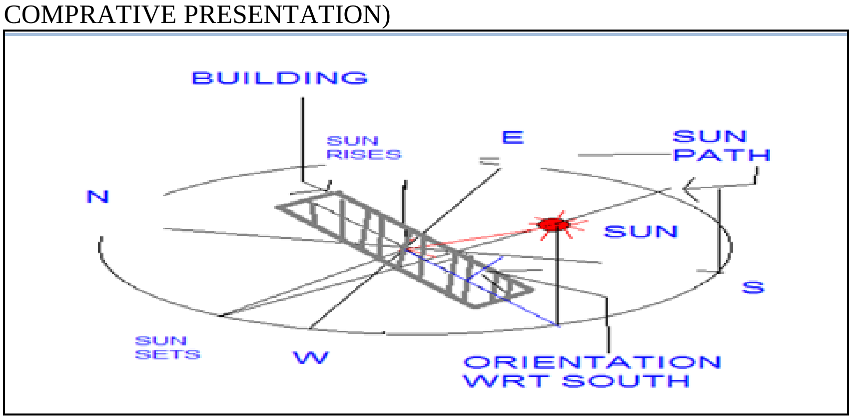


FIGURE X: VALUES OF MX, MN, MTSOLN, MTSLN, MTH1N AND MALTN WHEN SOL AIR TEMP IS MAX IN MONTHS (LINE CHART COMPRATIVE PRESENTATION)



Conclusion:

From above simulation results it is found out that maximum values for two months i.e. May and June considered hottest, for sol air temperature, solar azimuth and time are as follows

Month	sol air temperature	time of occurrence	solar azimuth	solar altitude
May	56.579	15.944	59.153	48.320
June	56.531	16.2	63.0	48.637

Hence worst orientation may be taken as average of solar azimuth values of these two months

i.e. (59.153 + 63.0)/2 = 61.0765 degree South-West, occurring around 4 PM. i.e. at around 4PM. when Sun is at around 61 degree west of south it will cause maximum heat transfer/heating on a such a vertical surface/wall which is oriented towards it during two warmest months of May and June. During other months worst orientation would be different but would cause less heat stress to the building occupiers due to relatively lower values of sol air temperature. In fact it is desirable to have more heat transfer during winters and hence in above calculation only two warmest summer months have been considered. However worst orientation shall be considered as 59.153 degree west of south occurring during the month of May at around 4PM.

Mean value of worst orientation for eight warm months i.e. March, April, May, June, July, Aug., Sept, and Oct. can be calculated as (44.880+52.625+59.153+59.153+63.0+62.005+56.129+47.375+38.831)/8 =

423.998/8 = 52.99975 or 53 degree

While for four winter months i.e. Nov., Dec., Jan. and Feb. would be (32.375 + 30.0 + 30.865 + 36.830)/4 = 130.07/4 = 32.5175 degree west of south and would be beneficial.

Hence it may be concluded that while designing a building at Delhi-NCR special precaution shall be made so that the direction of worst orientation is avoided to reduce heat loading which is around 241º azimuth. Further all surfaces facing south-west direction shall be treated to have low absorption of solar radiations incident upon them to make the building more energy efficient.

References:

[1]. Autodesk University. LEED and Sustainable Practices-Motivation-http://auworkshop.autodesk.com/library/bim-green/leed-and-sustainable-practices.

[2]. Energy Information Administration (EIA). *Annual Energy Review 2014*. Washington, DC: U.S. Department of Energy, 2014. Available at: http:// www.eia.gov/forecasts/archive/aeo14.

[3]. page 18.1, Module 18: Energy Efficiency in Buildings, http://africa-toolkit.reeep.org/modules/Module18.pdf, Sustainable Energy Regulation and Policymaking for Africa, Energy Efficiency.

[4]. http://shodhganga.inflibnet.ac.in/bitstream/10603/113853/9/09_chapter%204.

[5]. http://worldpopulationreview.com/world-cities/delhi-population/

[6]. http://www.prb.org/Publications/Articles/2007/delhi.aspx, O.P. Sharma, Population Reference Bureau's India consultant and former deputy director of census operations in India and Carl Haub, Conrad Taeuber Chair of Population Information at PRB.

[7]. Delhi's power demand reaches 5925 MW, highest ever (net doc)

[8]. Delhi Electricity Regulatory Commission, Annual Report FY 2011, pp 31.

[9]. Economic Survey of Delhi, 2005-2006, page 2. Chapter 1, Introduction

[10]. file:///F:/1Z%20DELHI/Wind%20direction%20-%20New%20Delhi%20-%20Climate%290Robot%20India.html.