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Analyzing Sun Angles of Solar Time Dial for Design of Building Envelope Components for the Region of Andhra Pradesh, India

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Abstract

The solar radiation is a major factor for thermal condition in built forms. The residential and commercial buildings consume 45 to 55 percentage of the energy for thermal comforts. It was evident that the higher the energy consumption through fossil fuels leads to the remittance of CO_2 in the atmosphere. Building industry in India is having predominant share for consumption of energy resulting in the 22% of CO_2 emission into atmosphere. Environmental quality and conservation of fossil fuels may become important in the context of limiting of GHGs emission. So the present paper deals to curtail the direct beam radiation on the building envelope in 'hot and humid' regions of Andhra Pradesh so that the internal heat gain, diffusivitity, solair temperature and time lag of heat flow in to the building can be influenced for providing better thermal condition . This will lead to the reduction of energy consumption and energy savings in the buildings.

Angle of incidence of solar beam radiation dose play a major role to admit the amount of heat in to the building internal spaces through its envelope. Sun angle varies from time to time and this Local solar time is a measure of sun's actual position with respect to the sun path from east to west. This work sheds light on understanding the importance of angle of incidence of solar beam radiation in designing various architectural elements like Jali's, shading devices, built form projections, inclined/ vertical walls, and also to analyses the drama of light & shade by pergolas for different directions of envelope surface facing towards different directions with respect to sun-path and with reference to surface azimuth, day of the year, declination, hour angle, location consideration and with different inclinations' of the façade / exposed wall . This paper tries to establish the best possible ways of shading the building with regard to orientation of a built form, effective textured wall, chajja projections, roof projections, trees /shrubs and functional jail design for various azimuth angles for four cities of Andhra Pradesh of India so as to reduce the amount of heat gain from solar beam radiation to facilitate to contribute to thermal comfort and conserve the conventional energy by natural means.

Keywords: *Shading device, Envelope design, Fenestration design, Sun angles, Solar time.*

Introduction

Building sector consumes more than 40% of energy produced globally *(International Energy Agency, 2013).* India is a vast south Asian country, with 1/6th of the world population. The economic growth of the country has been constantly increasing with a rate of 4.5% whereas the power production with in the country has been increasing 9% per annum in compound *(Das et al., 1999).*India has been suffering from the shortage of power because of lack of generation as per the demand. In India nearly 20% of the power will be wasted in the transmission and distribution losses *(Sajal Ghosh, 2002)*. Upcoming energy requirement for next 10 to 12 years is about 100,000MV. HVAC systems have become popular and having highest share of power consumption when compared to fans, ductwork systems, cooling and heating appliances. Therefore natural ventilation systems and strategies at this current era has become the fundamental methods in energy efficient building design*(Khan, N., Su. Y., and Riffat, S (2008).*

From the beginning of 20th century construction technology got matured enough to adopt more amount of openings with less volume consuming structural members. The design of exterior skin of the building has been taken advantage of this. Since the beginning of 21st century the design of exterior finish with high amount of window to wall ratio has become common practice in international style of architecture.

However this will allow the unwanted radiation from the sun and ambient temperature into the building. Hence making the built form more vulnerable to heat gain and thermal discomfort within the building. Therefore, the building envelope which divides the outdoor and indoor should take care regarding the ambient atmospheric temperature changes like solar irradiancy, wind velocity, humidity etc., here this study sheds light on the design of shading devices which helps in shading walls and openings resulting in the reduction of thermal discomfort and building energy consumption.

It is evident that shading devices plays a prominent role in reduction of heat gain within the building, experiments in laboratory shows that energy efficiency performance can be increased upto 1/4th. Traditional *(Gratia, E. and Herde, A. D. ,2007).* Traditional shading devices which commonly under practice in India were Jalis, chajjas and mutual shading techniques. This paper helps in determining the design shading devices with respect to prevailing sun angles and solar time.

Figure 1 Brick Jali wall, CII; Hyderabad.

Figure 2 Shading by balcony projection in Chennai (Architect Dr.S.Ramesh)

Figure 3 3 Shading by Pergolas in Lodhi colony Delhi (Architect : Dr.S.Ramesh)

Need of study

Climatic condition plays a major role in heat gain / loss within building. Rate of heat gain / loss, range of heat gain or loss depends majorly on the type of climate. Current study focused the effect of shading devices on thermal performance these studies have shown that shading devices have a great impact on the energy saving capabilities of any given built form (*Palmero-Marrero and Oliveira, 2010). It was emphasized that*and West windows of residential buildings in climate of Hot and Humid regions of Singapore and yield 2.6% to 3.2% of cooling energy savings chieved with the help of 30cm deep horizontal shading device (chajja) outside the windows. Further the shading device length upto 60cm worked out the savings of energy increased upto 5.85% to 7.06% of cooling loads. When the depth of shading device further increased then the savings has increased upto 8.27 to 10.13% (*Wong and Li, 2007*). envelope shading device in Taiwan has proven to be a best strategy to decrease cooling energy consumption *(yu et al., 2008).*In recent past there are plenty of researches were carried out to investigate the performance of facade shading devices and their effects on building's energy consumption. The present study is to investigate even further to determine the potential performance of various shading devices in shading the building façade with relation to various solar angles and possessing azimuth angles. This study will provide guidance to Architects and Engineers in designing the shading device with the help of user friendly table, which are explained in the later part of the paper.

Andhra Pradesh is one of the most densely inhabited state of India. It ranges from 18.6 to 13.2 N latitude, and 84 to 46 East longitude. Andhra Pradesh is experiencing majorly warm and humid type of climate. Some of the parts in the state has been experiencing warm and dry type of climate. Andhra Pradesh naturally has surplus amount of sky clearance and thus possess high amount of solar radiation. Average solar radiation 600 MJ/m^2 per annum in hot and humid region of Andhra Pradesh.

India has 5 climatic regions as per ECBC and Andhra Pradesh region falls under warm and humid region of the country. Hence the further analysis has been conducted on 4 cities in Andhra Pradesh and user friendly tables were generated these cities to find out the details like Sun rising local standard time, angle of solar beam radiation which helps the designers in determining the shading devices and hence designing shading devices as per the given context.

Location considerations

Andhra Pradesh is known as rice bowl of India. It is 8th largest state in India and 10^{th} populous state in India. Study areas consist of 4 cities ranging from Four cities are selected at the difference of one degree longitude.

4 places has been considered from the 4 different regions of the state, considering the climatic conditions and relative geographical locations of the selected regions. Visakhapatnam is a highly populated city within the city which is located at the northern part of the state, Vijayawada is located at the central location of the state, Anantapur is located at the southernmost part of the state, Tirupati is the 3rd most populated city of the state which is located at the southern part of the state. Below diagrams show the shading aspects of the southern wall and fenestrations for mentioned azimuth angles.

Table 1 Cities from four Various geographical locations of the state with one degree latitude difference

Study area – Warm and Humid Climate; Cities with 1 Lakh population (2011 Census)				
City Name	**District**	**Area Km^2**	**Latitude (N)**	**Longitude (E)**
Visakhapatnam	Visakhapatnam	540	17.68	83.21
Vijayawada	Krishna	61	16.5	80.64
Tirupati	Chittoor	27	13.4	79.2
Anantapur	Anantapur	47	14.41	77.39

The sun angles for four identified cities of Andhra Pradesh as indicated in table 1 sun angles were analyzed with reference to solar noon/ standard time to work out appropriate s chajjas projections, Jali walls, building projections etc., the same can be further critically analyzed with reference to number of thermal discomfort hours in a day / days in a month /months in an year of all four stations of Andhra Pradesh. Critical components related to solar/ sun angles considered in the analysis are given below.

Solar time and Sun-Path

Solar time and local standard time is different from each other. Local solar time is derived by the actual sun position on the sun path of each particular day, whereas the local standard time is derived based on reference meridians. Local standard time is derived from the equation below (Iqbal, 1983)

Local standard time equation:

Where L_{st} is the standard meridian and L_{loc} is the location meridian; E is the equation of time i.e

LST = 4(L_{st} – L_{loc}) + E (1)

Where

E = 229.2 (0.000075 + 0.001868 Cos B – 0.032077 SinB – 0.014615 Cos 2B – 0.04089 Sin 2B).

Where

$B = \frac{360}{365}(d - 81)$;

Where d = angle of declination.

Time mentioned and discussed in this paper is only solar time until or unless mentioned it as a local standard time.

Analysis of sun angles for shading:

With regard to the Architectural design process for development of basic concept and sustainable practices it is essential to work on climatic considerations to reduce the consumption of the conventional energy, designing natural means of comfort and conservation of fossil fuels. The relation of vertical / inclined and horizontal planes and its configuration is geometric in nature between any surface of any inclination or orientation with respect to the time. The description of sun's position with respect to the object can be made using many angles (*Benford and Bock, 1939*).

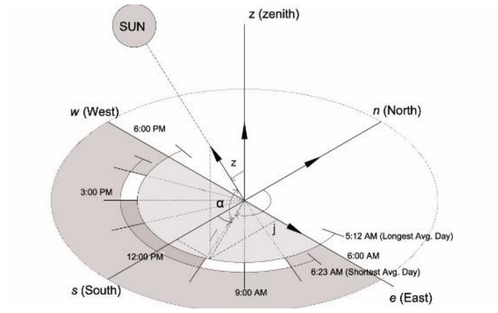


Figure 4 Sun Angles and description

ϕ **Latitude angle**: The position of the object or surface with respect to equator i.e North to equator viz positive or South to equator viz Negative; -90 ≤ φ ≤ 90.

Declination angle δ **:** the angular position of the sun at solar noon (when sun is on the local meridian) with respect to the plane of the equator, north positive; $-23.45^o \le \delta \le 23.45^o$..

β **Slope**: The angle between the plane of the surface in the question and horizontal; $0^o \le \beta \le 180^O$. (Beta > 90^o. means that the surface has a downward facing wall component)

γ **Surface Azimut angle**: the deviation from the projection on horizontal pane of the normal to the surface from the local meridian. With zero due to south, east negative and west positive; $-180^o \le \gamma \le 180^O$

ω **Hour Angle:** the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15^Oper hour; morning negative and afternoon positive.

zZenith angle: the angle between the perpendicular to the earth's surface and the line to the sun the angle of incidence of the beam radiation on the horizontal surface.

αSolar altitude angle: the angle between the horizontal and the line to the sun, that is, the compliment of the zenith angle.

Solar azimuth angle: the angular displacement from south of the projection of the beam radiation on the horizontal plan, displacement east of south are negative west of south are positive.

The declination delta can be found from the approximate equation of (Cooper, 1969)

Shading Analysis of built up areas

Declination angle is an angle derived from the suns position and angle of the sun relative to the earth's equators position. By the variation created by the earths axial movement suns declination angles varies with particular rhythm and the relation it follows is given below. Suns declination is majorly depending on the day we are calculating the sun's declination. For various computational purposes n has to be the time of the year i.e nth day of the year out of 365 days an year.

Declination angle:

$$\delta = 23.45 \sin\left\{360\left(\frac{284+n}{365.25}\right)\right\}, \qquad (2)$$

n =n^{th} day of an year of 365 days

Solar Beam Radiation

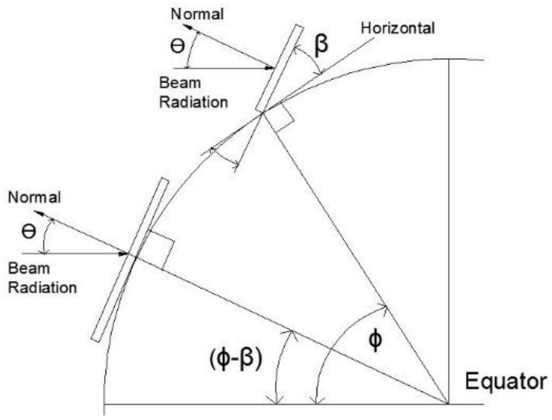


Table 2 Angle of Solar Beam Radiation

Angle of beam radiation - Variations of earths distance from sun and angle of declination as mentioned above has been changing constantly. These variables will affect the angle of suns radiation falling on any given surface. Hence Ө is an angle between the solar beam radiation and normal from any given surface. The complex relation among the θ_T angle of beam radiation to the various above mentioned sun angles

$$\begin{aligned}\cos\theta_T &= \sin\phi\sin\delta\cos\beta\\ &-\sin\delta\cos\phi\sin\beta\cos\gamma\\ &+\cos\phi\cos\delta\cos\omega\cos\beta\\ &+\cos\delta\sin\phi\sin\beta\cos\gamma\cos\omega\\ &+\cos\delta\sin\beta\sin\gamma\sin\omega\end{aligned} \quad (3)$$

Where

δ = Declination angle, Declination angle can be derived from the equation (2).

ϕ = Latitude of location

β = Wall Angle

γ = Azimuth angle

ω = Hour angle

Shading Analysis for four major cities in Andhra Pradesh State

Sun raising time differs daily depending on the latitude of the location and declination angle. The calculation of these sun raising time has been determined by the day light hours from the equation (4). Solar time of sun rise has been converted into the local standard time for the convenient application and understanding using equation (1). Tables 4,5,6 and 7 shows information of number of day light hours, sunrise solar time and local standard time.

$$N = \frac{2}{15}\cos^{-1}(-\tan\phi\ \tan\delta). \qquad (4)$$

Where

N = Number of Day light hours

ϕ = latitude of locations

δ = Angle of declination of sun

Table 3 Recommended Average Day for each month (from Klein, 1976) and values of n by months

Month	'n'th date of Month	Date	'n ', Day of Year	Solar Declination
Jan	i	17	17	-20.9
Feb	31 + i	16	47	-13.0
Mar	59 + i	16	75	-2.4
Apr	90 + i	15	105	9.4
May	120 + i	15	135	18.8
Jun	151 + i	11	162	23.1
Jul	181 + i	17	198	21.2
Aug	212 + i	16	228	13.5
Sep	243 + i	15	258	2.2
Oct	273 + i	15	288	-9.6
Nov	204 + i	14	318	-18.9
Dec	334 + i	10	344	-23.0

Table 4 Visakhapatnam 17.68N; 83.21E; Influence of Sun Angles with respect to time

Visakhapatnam 17.68N; 83.21E;				
Month	*Average day*	*day light hours*	*Sun rise - Solar time*	*Sun Rise - Local Std. Time*
Jan	**17**	11.067	5:32	5:44 AM
Feb	**16**	11.4094	5:42	5:59 AM
Mar	**16**	11.8972	5:57	6:09 AM
Apr	**15**	12.404	6:12	6:15 AM
May	**15**	12.8302	6:25	6:24 AM
Jun	**11**	13.0412	6:30	6:32 AM
Jul	**17**	12.9461	6:28	6:37 AM
Aug	**16**	12.5832	6:17	6:24 AM
Sep	**15**	12.0943	6:02	6:00 AM
Oct	**15**	11.588	5:47	5:35 AM
Nov	**14**	11.164	5:35	5:22 AM
Dec	**10**	10.9607	5:29	5:29 AM

Table 5 Vijayawada 16.5 N; 80.64 E; Influence of Sun Angles with respect to time

Vijayawada 16.5 N; 80.64 E;				
Month	***nth day***	***day light hrs***	***Sun rise Solar time***	***Sun Rise Local Std. time***
Jan	**17**	11.1333	5:34	6:09 AM
Feb	**16**	11.4512	5:44	6:34 AM
Mar	**16**	11.9045	5:57	6:55 AM
Apr	**15**	12.3754	6:11	6:14 AM
May	**15**	12.7713	6:23	6:34 AM
Jun	**11**	12.9671	6:28	6:47 AM
Jul	**17**	12.8789	6:26	6:50 AM
Aug	**16**	12.5418	6:32	7:01 AM
Sep	**15**	12.0876	6:02	5:52 AM
Oct	**15**	11.6171	5:48	6:14 AM
Nov	**14**	11.2234	5:36	5:49 AM
Dec	**10**	11.0346	5:31	5:52 AM

Table 6 Tirupat 13.4N; 79.2E; Influence of Sun Angles with respect to time

Tirupat 13.4N; 79.2E				
Month	*'n' th day*	*day light hours*	*Sun rise Solar time*	*Sun Rise Local Std. time*
Jan	**17**	11.3034	5:39	5:35 AM
Feb	**16**	11.5588	5:46	5:47 AM
Mar	**16**	11.9232	5:57	5:53 AM
Apr	**15**	12.3019	6:09	5:57 AM
May	**15**	12.62	6:18	6:01 AM
Jun	**11**	12.7771	6:22	6:08 AM
Jul	**17**	12.7063	6:21	6:14 AM
Aug	**16**	12.4357	6:12	6:08 AM
Sep	**15**	12.0705	6:02	5:45 AM
Oct	**15**	11.6921	5:50	6:23 AM
Nov	**14**	11.3758	5:40	5:12 AM
Dec	**10**	11.2243	5:36	5:21 AM

Table 7 Anatapur 14.4N; 77.39E; Influence of Sun Angles with respect to time

Anatapur 14.4N; 77.39E;				
Month	**Average** *day*	*day light hours*	*Sun rise Solar time*	*Sun Rise Local Std. time*
Jan	**17**	11.2491	5:37	5:26 AM
Feb	**16**	11.5244	5:45	5:39 AM
Mar	**16**	11.9172	5:57	5:46 AM
Apr	**15**	12.3253	6:09	5:49 AM
May	**15**	12.6683	6:20	5:56 AM
Jun	**11**	12.8377	6:24	6:03 AM
Jul	**17**	12.7614	6:23	6:09 AM
Aug	**16**	12.4696	6:14	5:59 AM
Sep	**15**	12.0759	6:02	5:37 AM
Oct	**15**	11.6682	5:50	5:16 AM
Nov	**14**	11.3271	5:39	5:04 AM
Dec	**10**	11.1637	5:35	5:13 AM

Results and Discussion

Extraterrestrial solar temperature average date for each month has been given in table3 by (Klein, 1977). Solar beam angles of every month has been analyzed using equation (3) of four major cities of Andhra Pradesh. Angle of beam radiation has been found using the corresponding azimuth angle. Further by the user friendly tables has been derived for four stations in Andhra Pradesh to workout shading devices quickly accurately by the architects and builders.From tables 8, 9, 10 and 11 standard dimensions of the shading device measurements has been derived and developed byConsidering the discomfort months of March to October. Tables will give the understanding regarding the sun angles in all the given average dates at the solar noon. Identifying the steepest solar angle shading devices can be designed accordingly.

Table 8 Results of sun angles using solar beam radiation equation in degrees – Visakhapatnam @12:00 pm Solar time

Visakhapatnam 17.68N; 83.21E; Angle of Surface 90^{O};									
Month	**Average date**	***Azimuth Angle***							
		0^{O} /90^{O}	***10^{O}***	***20^{O}***	***30^{O}***	***45^{O}***	***60^{O}***	***70^{O}***	***80^{O}***
Jan	**17th**	51.403	52.0945	54.1111	57.2987	63.8246	71.8251	77.6804	83.781
Feb	**16th**	58.7002	59.228	60.7786	63.2619	68.4475	74.9443	79.7651	84.8241
Mar	**16th**	69.9023	70.2204	71.1616	72.6873	75.9376	80.1069	83.2507	86.5792
Apr	**15th**	81.7349	81.8613	82.2365	82.8485	84.1659	85.8782	87.1818	88.5696
May	**15th**	91.1119	91.095	91.0449	90.9629	90.7862	90.5559	90.3803	90.1931
Jun	**11th**	95.4059	95.3235	95.079	94.6799	93.8197	92.6999	91.8465	90.9374
Jul	**17th**	93.5037	93.4504	93.2922	93.0338	92.4767	91.751	91.1977	90.608
Aug	**16th**	85.775	85.8393	86.0302	86.3418	87.0138	87.8889	88.5561	89.267
Sep	**15th**	74.5369	74.7775	75.4906	76.6501	79.1331	82.3392	84.768	87.3464
Oct	**15th**	62.7206	63.1686	64.4887	66.6139	71.0897	76.7521	80.9812	85.4351
Nov	**14th**	53.408	54.0516	55.933	58.9191	65.0697	72.6591	78.2359	84.0585
Dec	**10th**	49.2704	50.0157	52.1831	55.5926	62.5238	70.959	77.105	83.4942

Table 9 Results of sun angles using solar beam radiation equation in degrees – Vijayawada, @12:00 pm Solar time

Vijayawada 16.5; Angle of Surface 90^O;									
Month	**Average date**	***Azimuth Angle***							
		0^O /90^O	***10^O***	***20^O***	***30^O***	***45^O***	***60^O***	***70^O***	***80^O***
Jan	**17th**	52.583	53.246	55.1823	58.2505	64.5549	72.3137	78.0057	83.9434
Feb	**16th**	59.8802	60.3839	61.8653	64.2415	69.2168	75.469	80.1175	85.001
Mar	**16th**	71.0823	71.3803	72.2624	73.6936	76.747	80.6709	83.6336	86.7726
Apr	**15th**	82.9149	83.0231	83.3442	83.868	84.9965	86.4642	87.5822	88.7727
May	**15th**	92.2919	92.2571	92.1536	91.9847	91.6204	91.1457	90.7837	90.3979
Jun	**11th**	96.5859	96.4854	96.1871	95.7004	94.6518	93.2875	92.2481	91.1412
Jul	**17th**	94.6837	94.6124	94.4007	94.0551	93.31	92.3399	91.6003	90.8124
Aug	**16th**	86.955	87.0013	87.1388	87.3632	87.8473	88.478	88.959	89.4715
Sep	**15th**	75.7169	75.9384	76.5949	77.6631	79.9532	82.9141	85.1596	87.5446
Oct	**15th**	63.9006	64.3263	65.5815	67.605	71.8758	77.293	81.3461	85.6187
Nov	**14th**	54.588	55.2046	57.0091	59.8796	65.8119	73.1585	78.5692	84.2251
Dec	**10th**	50.4504	51.1655	53.2485	56.5342	63.2404	71.4354	77.4213	83.6518

Table 10 Results of sun angles using solar beam radiation equation in degrees – Tirupati @12:00 pm Solar time

Tirupati 13.4; Angle of Surface 90^O;									
Month	**Average date**	***Azimuth Angle***							
		0^O /90^O	***10^O***	***20^O***	***30^O***	***45^O***	***60^O***	***70^O***	***80^O***
Jan	**17th**	55.683	56.2751	58.01	58.01	66.5064	73.6272	78.8825	84.3819
Feb	**16th**	62.9802	63.4233	64.729	64.729	71.2622	76.8707	81.0612	85.4753
Mar	**16th**	74.1823	74.4287	75.1589	75.1589	78.8872	82.1668	84.6507	87.287
Apr	**15th**	86.0149	86.0755	86.2556	86.2556	87.1832	88.0087	88.638	89.3085
May	**15th**	95.3919	95.3098	95.0659	95.0659	93.8098	92.693	91.8417	90.935
Jun	**11th**	99.6859	99.5374	99.0967	99.0967	96.8326	94.8256	93.2988	91.6742
Jul	**17th**	97.7837	97.6647	97.3116	97.3116	95.4954	93.8829	92.6549	91.3476
Aug	**16th**	90.055	90.0541	90.0516	90.0516	90.0389	90.0275	90.0188	90.0095
Sep	**15th**	78.8169	78.9889	79.4992	79.4992	82.1176	84.4351	86.1966	88.07
Oct	**15th**	67.0006	67.3696	68.4595	68.4595	73.9616	78.7342	82.3203	86.1096
Nov	**14th**	57.688	58.2369	59.8482	59.8482	67.7921	74.4985	79.466	84.6741
Dec	**10th**	53.5504	54.1907	55.6982	56.0626	65.1589	72.719	78.2759	84.0784

Table 11 Results of sun angles using solar beam radiation equation in degrees – Anantapur @12:00 pm Solar time

Anantapur 14.4; Angle of Surface 90									
Month	**Average date**	***Azimuth Angle***							
		0/90^{o}	***10^{o}***	***20^{o}***	***30^{o}***	***45^{o}***	***60^{o}***	***70^{o}***	***80^{o}***
Jan	**17th**	54.683	55.2974	55.9679	59.9571	65.8719	73.1989	78.5962	84.2386
Feb	**16th**	61.9802	62.4425	62.7077	65.9936	70.5987	76.415	80.754	85.3209
Mar	**16th**	73.1823	73.4452	73.1754	75.489	78.1947	81.6822	84.3209	87.1202
Apr	**15th**	85.0149	85.0908	84.3185	85.6841	86.4772	87.5098	88.2969	89.1354
May	**15th**	94.3919	94.3251	93.1711	93.8026	93.104	92.1943	91.5008	90.7619
Jun	**11th**	98.6859	98.553	97.2234	97.515	96.1301	94.3305	92.9607	91.5027
Jul	**17th**	96.7837	96.6802	95.4286	95.8714	94.7912	93.3859	92.3154	91.1753
Aug	**16th**	89.055	89.0693	88.1321	89.1816	89.3318	89.5275	89.6768	89.8359
Sep	**15th**	77.8169	78.0048	77.5331	79.4693	81.418	83.943	85.8609	87.8999
Oct	**15th**	66.0006	66.3876	66.4511	69.3759	73.2857	78.2663	82.0037	85.95
Nov	**14th**	56.688	57.2582	57.8114	61.6004	67.1487	74.0619	79.1734	84.5276
Dec	**10th**	52.5504	53.2141	54.0153	58.2241	64.5346	72.3001	77.9966	83.9389

Chajja Projections

This is the most commonly used practice to cut off the solar radiation. The horizontal projection protrudes from the horizontal surface of the wall above the fenestration is known chajja. The length of the chajja is totally depending on the tangent of the angle

$$\text{Tan } A = \frac{x}{y} \qquad (5)$$

where ,

A = solar beam radiation angle from equation of solar beam radiation

y = length of the opening

x = the length of chajja.

Massing of Built form

Manipulating the building form by extruding the upper floor buildings to over shadow the entire wall of the ground floor. Can be done by using the same above mentioned equation. The length of the building projection can be determined.

Jali

This is a shading device which has been used in the indian style of architecture since many ages. This shading device consists of horizontal and vertical elements which cuts off the solar radiation from all the directions. Egg crate jail has rounded corner which avoids solar angles from rest of the direction.

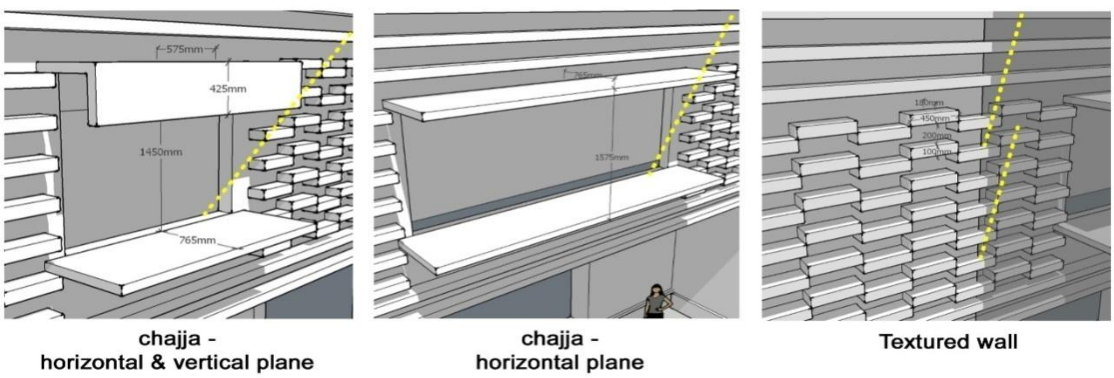


Figure 5 Building projections and shading devices and recommended sizes for the study area.

Textured Wall

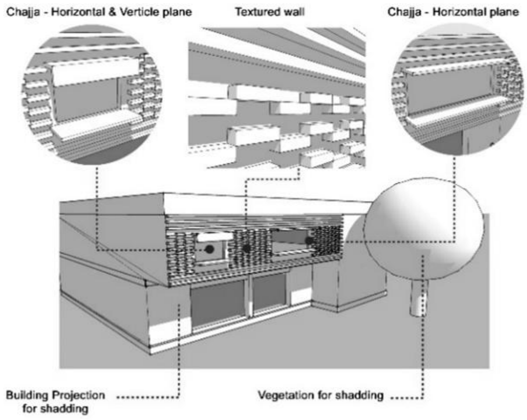
Wall having perpendicular projections as shown in the figure below is known as textured wall, texture will help in shading the whole wall which helps in the reduction of heat gain from outside.

Vegetation

Planting the trees with desired amount of foliage with required amount of helgt will result in the shading of whole adjacent wall.

Example

All the horizontal panes of shading devices derived from the equation (5) for the corresponding solar beam radiation. All the Solar beam angles has been taken from the Tables 6, 7, 8 and 9



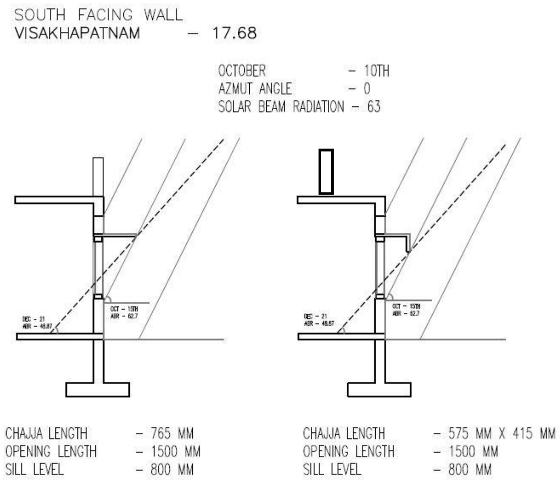


Figure 6 Derived Dimensions of Chajjas for Visakhapatnam – Oct 15th

Table 12Visakhapatnam; 17.68N 83.1N March 16th Sun Angle from Table 69.9O Hence corresponding design of Shading device;

Conclusion

Andhra Paradeshfalls under the region of warm and humid, region's latitude ranges from 13.4N degree to 18N degree latitude. Hence the discomfort months has been considered range from the month of March to the October. As the solar radiation ranges from the 31 to 48 degree within these months and in humid regions average relative humidity ranges from 70% to over 85%. Hence considering the sun angle within these months shading devices has been designed and recommended dimensions have been given. Chajjas, textured walls and Jali projections have been designed using the [equation (5)].Chajja minimum dimensions have been derived as 765mm perpendicular to the wall, Jali cell has been derived as 100mmX180mmX200mm, Building should projection should be minimum of 2630mm perpendicular to the built mass in order to attain the mutual shading through built mass.

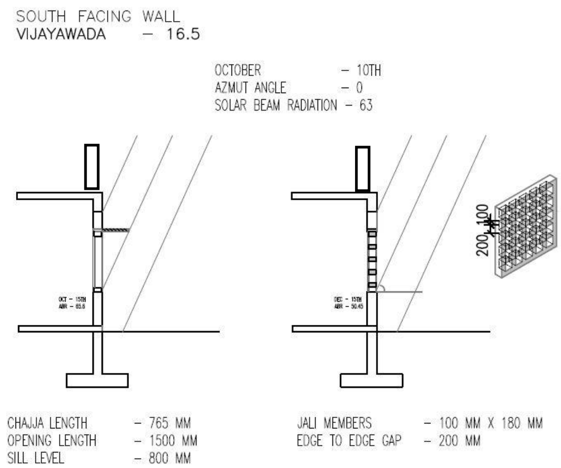


Figure 7 Derived Dimensions of Jali for Vijayawda – Oct 15th

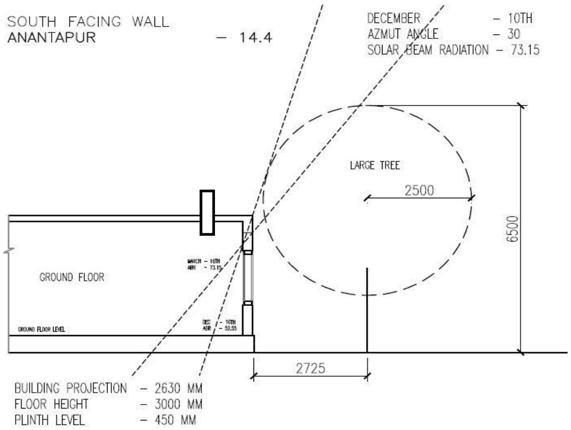


Figure 8 Derived Dimensions of Vegetative shading for Anantapur – March 16th

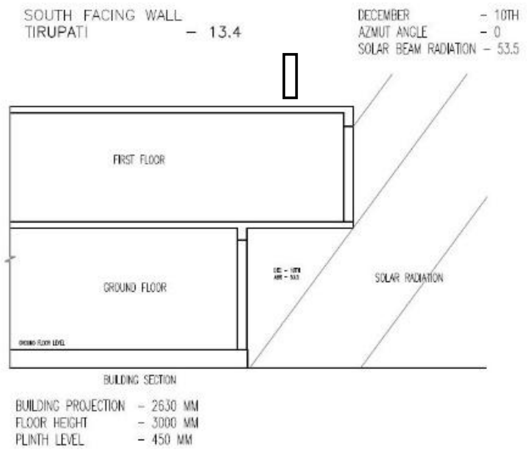


Figure 9 Derived Dimensions of Building Projections for Tirupati – Dec 10th

East and west walls with exceeding the azimuth angle of 30 degree should have an enclosed shading devices around the fenestration with a width of horizontal plane of its own.

Analyzing the sun angles by the given equations for the various geographical locations can be attained for the remaining regions of Andhra Pradesh. Similar study can be carried over for 31 cities with one lakh plus population within the state, the shading devices can be designed using the given formulae for gaining the indoor thermal comfort levels as a future scope of research.

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