A STUDY OF OPTIMIZATION OF THE LIGHT SHELF SYSTEM IN HOT AND ARID ZONES

Daich Safa Departement of architecture University of Biskra, Algeria BP (145) RP Biskra daichsafa@gmail.com Zemmouri Noureddine Departement of architecture University of Biskra, Algeria BP (145) RP Biskra zemmouri @bath.edu

Saadi Mohamed Yacine Departement of architecture University of Biskra, Algeria BP (145) RP Biskra saadiarchitecture @gmail.com

ABSTRACT

The objective of the present research is to choose the most appropriate configuration of light shelf system for the town of Biskra (South East of Algeria) optimized according to orientation position material and design. The determination of this configuration requires first of all knowledge of daylight climate of the city. This town is characterized by very large amount of daylight illuminance especially during summer season. NOOR1.1 program has been used for the evaluation of the exterior illuminance levels. This Fortran application has been developed specially for the evaluation of daylight illuminance under typical sky conditions. The results have been used then as an input for the evaluation of the light shelf impact on interior daylight levels and ambiances for a typical side-lit space using the well-known commercial software ECOTECT. The results have been then confirmed through a series of measures monitored on a scale model.

1. INTRODUCTION

From the point of view of sustainability, daylight is a natural resource, clean and inexhaustible. It is therefore, a key element in the architectural design especially during the sketching phase. During this phase, the architect has to make wise and appropriate decisions to ensure visual comfort, good working conditions, improve aesthetics and reduce energy consumption (Smiley, 1996). It has been proved that buildings do consume large amount of electricity for lighting and thus producing tones of CO2 (0r, 2002; Ihm, et al., 2009). Recently new architectural lighting strategies have been adopted to efficiently reduce the consumption of energy in buildings by introducing different systems in order to optimize the distribution of natural light inside buildings such as light pipes, light shelves and venetian blinds.

Light shelves systems has shown their ability to increase the depth of daylight penetration and to reduce significantly the risk of glare (Wiley, 2000). The reflectance of the light shelf surfaces has a large impact on the overall energy balance of the system. The upper surface needs to reflect a maximum of daylight inside the space and provide shade during hot and sunny days. On the contrary the lower surface of the system should absorb the maximum daylight to avoid glare from the window. However, it is believed that light shelves are not efficient in terms of light penetration under overcast sky conditions and reduce the amount of daylight reaching the interior space (Eagan et al., 2002; Littlefair, 1996; Christoffersen, 1995; Aizlewood, 1993). They are more efficient under clear sunny skies typical of hot and arid regions. The present research was carried out in order to demonstrate this fact under typical sky conditions of Biskra (Latitude 34.48 N, Longitude 5.44 N, Alt. 128 m above sea level). Biskra is a main town in Algeria situated in the south east on

the border of the Sahara desert with a large amount of solar potential 6 kwh/m²/day and 2190 kwh/m²/year according to ASA (ASA,2002). In addition the microclimate of Biskra is characterized with sunny skies, little rainfall and high air temperatures exceeding 30°C during nearly half of the year (from April to November). The design strategy adopted mainly in past and contemporary architecture is that of cooling reducing therefore external exposure of building's envelope and narrowing openings and windows. This design approach led unfortunately to an overuse of electricity for lighting especially during summer hot days.

2. MODELING DAYLIGHT CLIMAT OF BISKRA

In order to test the efficacy of using light shelves systems in town of Biskra we have first of all to assess the luminous environment and climatic conditions of the town through a series of indicators such as:

- Monthly average cloud cover.
- Hourly average cloud cover.

- Monthly average occurrence of overcast, partly cloudy and clear skies.

- Mean average horizontal illuminance levels calculated

through NOOR1.1 program (Zemmouri,2005).

- Figure 1 present monthly average cloud cover.
- Figure 2 show the time dependent cloud cover.

- Figure 3 gives the monthly frequency of occurrence of percentage of clear, partly and overcast skies at Biskra. All the represented data have been collated from the NASA SSE program website (www. eosweb. Larc. Nasa.gov/sse). This data set covers a large enough time period to evaluate the statistical properties of the regional analysis.



Fig. 1. Average monthly cloud cover in Biskra.



Fig. 2. Average hourly cloud cover in Biskra.

The horizontal illuminance data for Biskra have been calculated using NOOR1.1 code, the results are given in table 1. NOOR 1.1 is a daylight illuminance model developed as a desktop daylight calculation program under visual Fortran for analyzing daylight levels in urban outdoor spaces and investigating daylight availability over main urban agglomerations in Algeria under different sky conditions.



Fig. 3. Average monthly occurrence of overcast, partly cloudy and clear skies in Biskra.

TABLE 1 : CALCULATED AVERAGE HORIZONTAL ILLUMINANCE LEVELS FOR BISKRA IN LUX

Month Hour	9h	10h	11h	12h	13h	14h	15h	16h
January	17034	31515	43024	49039	48172	41384	29133	14559
February	25302	42701	55612	62349	62349	55612	42701	25302
March	40000	58839	70961	76821	76350	69511	56010	36528
April	54560	70430	79619	82560	81760	76387	63801	45272
May	62949	76806	82640	82912	83108	80028	69294	51563
June	57021	68314	72708	71585	72426	71533	63946	49583
July	40858	49980	54152	54266	54459	53409	47815	37418
August	40822	51960	57839	59578	59363	56573	48956	36635
September	39765	53157	61011	63863	62669	56693	45817	29963
October	39141	55626	65618	69353	66014	56349	40149	21167
November	26554	41879	51818	55252	52008	41130	27231	11419
December	17757	31121	40974	45205	43192	35361	22859	9504

3. <u>EVALUATION OF THE EFFECT OF LIGHT</u> <u>SHLEVES CHARACTERISTICS ON INTERIOR</u> <u>DAYLIGHT DISTRIBUTION</u>

Calculations were achieved according to time, light shelves configurations and horizontal illuminance. These conditions were chosen as they gave us the best chance to make sensible comparison. In each case a sequence of simulation was developed separately for, position, width, light shelf and ceilings tilt. An office room of 12m x 6m x3.2m has been considered, see Fig.4. & Fig.5. The fenestration and the light shelf are located in the shorter side. A grid system, sampled in Fig.6. is used for the reference points to determine the illuminance distribution on the working plane which taken at 0.9m from the ground plane.

From the results of simulations given in Fig.6. to Fig.10., it is obvious that using light shelves effectively influence interior daylight conditions. However, the effect of the light shelf tilt and orientation are more complicated. Illuminance distribution in the space is affected by materials, position (interior/exterior) and dimensions. It is clear also that the actual sky conditions vary considerably from the idealized overcast sky model. This is also expected, as we know that the overcast sky represents dark skies with heavy type clouds. Such skies are not typical of the bright partly cloudy skies experienced in Biskra.



Fig. 4. Section in the scale model



Fig. 5. Plane of the scale model



Fig. 6. Established grid system for the calculation procedure

500 Linx	30 Lux																			
5																				
388.95	377,68	381.47	389,18	391,32	420.76	427 24	435 76	457,80	495,35	531,80	558,68	638,34	689,31	824,49	968,12	1203 95	1498 20	1787	94 135	3.70
389.66	366 24	385,67	385 79	398,38	412,25	423 68	447,88	465,69	522,42	551 87	592 18	674,99	782,75	938,98	1174.97	1510 59	2082 54	2872	27 325	5.42
382_14	370.73	380_04	389 12	416,87	429.32	448 19	463,78	491,98	528 24	572,89	642.56	745,65	803,49	1080.28	1375.69	1875.87	2739.78	4018	15-428	8.77
373 <mark>.90</mark>	379.84	382 22	409,29	413.69	421.00	453 38	483,90	514.74	544 82	612,94	680.05	781.55	953_51	1159.39	1510.97	2043 12	3077 43	4400	10 10	9.07
375 <mark>.96</mark>	381 25	389.79	407_99	412,80	427_19	400 38	487 89	533_30	553_06	637 71	699.66	828_35	1031.88	1172.27	1587.52	2227 62	3285 01	14	34 450	8.55
	381_01	399_34	415_57	420,34	445,24	479 17	498 22	527_38	573_38	645 12	741.17	843_19	1031.40	1289.93	1680.62	2234 28	3384 00	+	\angle	5.25
385 <mark>.97</mark>	382_33	407_08	404_48	421 12	441.35	479.45	485,58	538 32	599,61	654 78	751.62	850,40	1045.82	1307.02	1681.43	2330 49	3500 77	5068	18 504	2.33
379.56	390,85	388_02	417,49	438_90	440_05	451.85	500,72	543_08	585,28	648 78	783.09	859.00	1087.89	1287.43	1735.24	2491 80	3499.77	10	18 81 8	9.95
379,10	391_21	394_13	419,22	428.07	447,17	481_06	499,01	542_37	582,53	639.07	734,94	800,68	1070.23	1343.12	1758.02	2401.71	3465.67	-	11 528	3.91
398 <mark>.80</mark>	388 69	398_97	424,55	447,32	445.01	458,93	501,21	522 20	561,58	640.30	714.20	891 29	1033.19	1298.39	1750.48	2357.93	3372.74		64 500	1.10
383_32	393_70	394_14	416 20	428_18	440 20	400 12	493,27	537,88	569_83	634.08	706 72	831,27	1025.59	1283.41	1728.73	2289 75	3365.17	403	4	5.11
388 <mark>.93</mark>	377_20	399_37	415_13	422_50	437_12	452 74	477,88	534,21	585_95	610_83	704_30	799_80	1003.73	1162.25	1643.98	2182 42	3177 47	• 10	23 (10	8.75
376_04	383_32	390_53	399_85	422_90	425.02	444_59	470.58	516 52	582 79	600_80	669_05	803_80	943_42	1177.31	1530 99	2074.45	3028 41	14	10 43	1.51
377 <mark>7</mark> 5	378_32	398_57	405 80	420,80	430,25	463_07	481,91	498_54	529,08	820 59	660 24	753,74	882,95	1054.84	1380 85	1982 98	2707.83	3985	37 400	8.73
			390 48	400 00	419 15	448 87	466 77	482.84	503.30	564,35	633.49	665.09	790.75	925.52	1178.92	1569.58	2127.08	3077	73 0.54	2.58

Fig. 7. Inside daylight distribution without light shelf.

IF Range: e of: 480	400-	543) Լս	X																																			
ECT v6																																							
	574	60	82	05	85.0	3 59	3.33	598	63	443	52	633	34 6	337	76 (858	57 (394.0	8 7	8.33	742	18	814	.08	858	01	977	33 1	134.1	39 13	33 0	1 162	4.09	191	2.61	152	5.25		
	572	81 :	189.1	9 5	95.60) 55	4.76	603	.40	620	32	627	46 E	356.1	39 (880.	82	718.8	8 74	2.95	781	.03	848	.38	944	.65 1	1080.	95 1	299.1	15 16	31.6	3 216	6.49	295	44	229	15	l,	
	584	79 :	181.4	4 5	88.18	3 55	7.60	623	98	633	99	652	89 E	365.	56 (891.	48	726.3	0 76	2.36	825	.33	910	.81	1013	.32 1	1209.	51 1	488.1	54 19	co.7	3 271	5.40	40	1.78	442	5.71		
	578	93 (187	5 5	89.10	0 61	6.07	616	.78	630	28	858	94 6	391.I	04 :	718	05 1	741.5	8 80	1.23	868	.58	950	.88	1092	25 1	1281.	29 1	614.5	93 21	22.9	1 305	5.04	444	1.31	496	2.55		
	592	52		1 8	01.24	. 87	1 02	821	88	812	15		82 6		10	720	74	755 2	2 01	10	071		992		1170	01.1	1201		899 /	22	<u>,</u>		1.7	7	7	502	07		
			Ť		Ť		Ť					Ť		Ť		Ť		Ť		1					Ť		Ť		Ť		Ť		ĨŤ	ť	1				
	.592	23 :	90.0	15 6	04.24	1 62	2.47	633	.84	650	.91	688	08 6	594.1	51	/35	45	(72.1	0 83	1.83	921	.80	1006	5.85	1167	.97 1	1401.	52 1	1124	38 23	09.9	1 340	0.06	fl	(.15	014	0.56.		
	595	67 :	196.1	02 6	16.3	5 61	6.17	630	.61	652	20	689	23 6	395.·	48 1	740.	34	788.7	5 8	1.88	932	.45	1019	9.41	1178	.50 1	1422	25 1	779.	26 23	95.3	5 349	3.82	508	.95	517	3,45		
	580	86 9	i99	7 5	97.6	3 62	7.70	646	.30	652	74	668	23 7	701.	57	737	29	777_B	9 83	8,13	942	.78	1023	.65	1198	20 1	1414.	63 1	825	11 25	41.8	1 349	<u>5.12</u>	508	.11	52í	0.16		
	402	88 (100	2 6	03,78	3 63	0.10	637	.81	655	13	687	38 E	399 :	31 1	738	02	777.5	9 83	1.34	930	.67	1024	.85	1193	.31 1	1453.	85 1	838.7	75 24	60.9	4 348	9.08	498	.64	520	.24		
	604	49 !	96.	9 6	07.31	7 62	8.68	661	.02	652	66	662.	11 7	703.:	22	721.	19	757.2	3 83	4,35	895	.86	1055	.24	1172	41 1	1405.	70 1	835 !	54 24	02.1	3 339	7.16	490	.12	513	3.72		
	587	16 :	i98.I	2 6	04.2	1 62	1.54	635	.76	653	.94	673	35 6	395.S	95 1	738	68	762.3	6 8	2.87	885	.56	1008		1168	.02 1	1389.	69 1	806.3	22 23	58.8	337	2.97	47	.60		8.04		
	596	93 (81.	8 6	07.70	0 62	3.85	630	.73	646	63	858	88 G	377	72	730.	46	760.9	8 8	8.53	881	.79	962	.84	1150	.87 1	1300.	871	735.	29 22	27.7	3 321	8.67	47	0.04	510	0.46		
	591	27				2 47	10.05	835	58	831	Q1	851	81 A			714		780 8	2 70		949	79	981	97	1093	94.1	1205	97.1	829 (7 21	40.2	1 204	1.09	Ţ.	N	505	7 05		
			Ť		t		1	0.00	Ĩ			Ť		Ť		Ť				Ť.							Ť	5	1		Ť.		Ť.	Ž	Ċ	1			
	283	70 :	-	4 0	48	5 01	2,01	023	44	033	94	004	82 0	-	40 (990	00	(28.9	4 8	4.28	834	.40	930	.00	1037	.08 1	11/4	12 1	483	14 20	53.4	2/0	02	1	12	+00	.49.		
	581	40 !	m_{i}	9 4	07,6:	2 60	6.31	615	.15	625	35	648	72 6	367	ŧ0 (884	43 (397,9	4 75	4,49	810	.92	841	88	948	78 1	1073.	98 1	315	11 16	79.6	4 222	3.36	31	0.55	320	0.70		

Fig. 8. Optimized daylight distribution with light shelf relative to position.

of: 480	Lux																															
	752.47	756	15	761,9	78	9,79	775,2	8 43	9.91	809	13 81	3,96	829	.96	868,46	90	.88	907,1	7 970	48	1015.9	0 112	3.13	1268.	70 14	42.25	9 169	7,48 1	983.7	0 153	0,45	
	748.05	385	89	769.0		2,29	780.2	8 79	.91	803	31 83	7.98	833	.57	887.15	5 901	.63	943.6	7 101	1.90	1089.4	8 121	2.88	1420	97 17	10.5	1 219	2.88.2	870.E	0.310	9.80	
	761.43	755	.24	762,3		15	798.3	7 80	.19	824	02 83	9,43	863	.54	895.49	92	.19	990,54	108	4.29	1159.8	9 134	2,47	1596.	52 20	123.12	2 278	7.82 3	889.4	0.400	4.35	
	754.34	761	.70	766.2	5 79	2,80	794.0	4 80	.27	834	93 86	0,16	886	65	908.98	970	.45 1	034.2	3 110	6.53	1243.8	1 142	1.52	1718	91 21	73.4	8 307	.04 4	227.5	0.448	3.70	
	759.87	763	81	779,1	79	5,48	797.8	8 80	.09	840.	43 80	7.34	904	20	923.03	3 98	.16 1	031.0	7 114	3.89	1321.9	7 143	8.15	1790	45 23	42.98	3 323	8,17/4	s A s	13 447	2.69	
	785 88	765	.64	782 1	5 79	9.27	807.1	4 82	.98	858	32 87	0.12	906	45	937.76	99	.58 1	084.9	3 115	7.38	1310.6	1 152	8.35	1871	34 23	48.46	3 333	8.15 4	688.7		8.04	
	773.17	771	.60	795.4	78	98. E	807.2	2 83	2.02	888	45 88	3,79	910	.96	983.08	3 101	4.87 1	087.7	2 110	9.06	1313.5	9 154	6.85	1874.:	25 24	130.92	2 344	.28 4	a de	0 455	6.53	
	759.44	m	.30	777.0	8 80	3.42	819.5	4 82	.38	840	24 81	6.80	915	.08	948.53	2 100	2.49 1	105.7	2 118	9.75	1335.3	154	0.68	1906	80 2	80.65	9 343	7.73 4	754.8	8 484	7.46	
	401.87	775	40	ms	80	8.96	811.1	8 83	12	865	72 81	84	909	82	952,18	5 996	.15 1	091.0	9 118	1.28	1345.3	31 158	7.55	1927	53 24	82.6	7 340	4.93 4	est.	1 457	7.08	
	780.65	770	16	782.4	5 80	1.17	837.2	3 82	.25	839.	17 81	7 32	900	28	925.21	99	.24 1	057.8	8 120	4.35	1309.0	0 153	1.69	1925 :	24 24	47.17	333	.05 4	621.5	1 454	2.13	
	763.00	m	13	775.1	3 79	4.02	814.5	3 82	18	845	33 81	277	909	.33	934,12	98	.57 1	042.6	2 115	0.63	1306.3	9 152	1.63	1896 :	82 23	87.4	2 333	.44 4	602 S	12 451	9.59	
	774.25	757	.21	784.1	79	5.95	802.8	9 82	.33	833.	58 85	2.67	901	.75	930,80	98	.77 1	043.9	2 111	9.67	1285.3	8 141	8.38	1834.)	61 22	184.31	2 317	.74 4	407.1	3 454	7.35	
	758.07	762	.62	773.8	3 78	5.33	805.7	4 80	.30	826	05 84	5,19	887	.89	927.8	966	.03 1	004.9	6 111	5.94	1227.1	0 143	6.37	1728	81 21	97.28	5 302	.28 4	333.3	4 451	9.19	
	780 25	757	.53	778.4	2 79	2.48	801.1	7 80	.60	838.	74 83	4.01	882	29	897.33	2 98	.39 1	000.3	1 108	3.31	1180.9	132	8,00	1575.	22 20	180.01	1 274	5.20.3	77.5	18 412	0.44	
	767.08	753	.12	407.6	2 78	0.65	789.0	4 79	.03	821	31 83	8.78	857	.54	885.81	3 92	.41	973.1	5 100	1.05	1103.3	121	1.28	1423.	18 17	54.95	9 222	.58-3	084.6	7-296	4.56	
	761.37	748	.59	760.0	78	1.28	797.5	7 80	03	809.	38 80	1,45	839	.69	874.4	903	.70	957.0	9 936	.17	1047.2	2 110	3.79	1278	22 14	130.44	4 175	2,98 1	989.8	8 154	8.70	

Fig. 9. Optimized daylight distribution with light shelf relative to dimension.

aylight Ana ylighting Levels tour Range: 400 - 5430	lysis	•																																	
teps of: 480 Eux																																			
	705.54	708.	18 7	15,08	5 72	2,88	725	55	756,4	0 75	9,00	76	1.87	785	.20	824.	30	856.6	5 8	13.65	943	58 3	ag 1	3 10	85.40	127	.91	1490	99 TI	<u>101</u>	25 18	510	148	.93	
	700 <mark>.82</mark>	698.	31 7	18,19	9 71	.75	731	82	745,1	1 75	6.83	776	.12	785	.14	841	30	881,1	7_9	92,92	983	19 1	074.0	04 12	09.57	148	.70	1766	84 21	170.:	28 28	15.43	310	8.47	
	711 <mark>.58</mark>	708.	52 7	11,7	7 72	0.80	745	.87	758.5	5 77	5,50	793	.47	812	.67	843	39	879.9	4 9	16.23	103	.82 1	158.5	6 13	55,94	162	.47	2100	88 21	156.:	99 38	34.81	400	9.86	
	706,49	712.	00 7	17.6	4 74	2.01	745	.93	753.6	5 78	5.85	808	.86	839	.07	861	51 /	921.7	8 9	39,99	106	3.57 1	227.8	88 14	21.35	177	.64 :	2281	04 30	<u>163.</u>	72 41	78.15	497	9.24	
	710.59	714,	80 7	26.8	2 74	2.41	748	.68	760.8	0 79	1.93	815	.19	853	.94	874	28	940,2	8 9	90.62	1118	3.71.1	308.8	37 14	50.44	1796	33	2396	98 33	122	88 44	2	450	5.24	
	720.52	718.	92 7 18 7	41.00	3 74	1.61	757	97 32	775 0	4 80 2 81	3,83	824	1.01	807	.01	917	38 81	901.U	s 10 5 10	45.03	112	80.1	302.0	4 15	94.83 89.74	188	40	2546	29.34		11		Ľ,	7 25	
	711.59	726.	08 7	24.4	1 75	.00	768	.59	778.6	3 79	3.71	825	.20	800	35	900	09	981.5	4 10	63.99	115	.38 1	329.5	33 15	55.70	201	.77	2718.	12 33	199	88 47	10.07	489	8.53	
	715.71	725.	17 7	29.7	3 75	.89	761	39	781.7	1 81	3.72	822	.53	856	.65	905	03	949.7	5 10	48.72	1150	.46 1	345.9	97 15	88.70	1934	.06	2531.	62 34	100.	08 48	37.47	482	0,7801	
	731 <mark>.81</mark>	720.	58 7	31.3	1 75	59	783	31	778,4	9 79	3 45	825	32	844	.37	877	53	952,4	D 10	12.69	117	.13 1	280.8	4 15	24.92	200	.83	2591.	40 32	260.:	93 40	30.35	450	4.53	
	713 <mark>.85</mark>	729.	59 7	30,4	3 74	8.05	764	43	779.2	8 79	7,31	817	20	859	.17	889	61	936,9	7 10	11.28	111	.61 1	294.8	8 14	9 <u>5</u> .30	1928	.99	2534	04 33	32	70 44	57.50	455	1.70	
	720 <mark>.41</mark>	710.0	53 7	29,1	7 74	93	753	.94	769.3	7 78	2 34	803	2.57	854	.73	884	08	934.7	0 10	05.45	108	.57 1	271.7	7 14	31.62	187	1.32	2350	64 31	108	37 44	10 <u>.08</u>	456	7.23	
	709.27	712.1	04 7 10 7	22.7	9 73 1 72	2,48	755	.73	759.3	1 77 5 70	7.31	801	87	843	.03	883	55 22	919,6 921 2	4 91 9 91	54,34	110	.65 1	180.7	27 14	52.49 10.56	180	. 17	2297	47 3	764	38 42 70 28			0.92 8 01	
	706.65	705.	05 7	15.5	3 73	21	737	.47	752.4	0 77	6.63	787	28	804	.92	821	89	873.9	0 90	31.31	972	.33 1	078.4	18 12	30.91	148	.85	1748	18 22	224	23 29			8.39	
	711.08	704	47 7	11.8	1 73	19	747	.53	757.7	8 76	1 60	77	.38	789	.89	825	25	854.3	9, 91	38.06	892	78 1	016.2	10	93, 16	131	.14	1482	38 17	707.	58 19	36 66	148	1.58	
		-									+			-			-			-			÷			-						-		_	
- 1																																			

Fig. 10. Optimized daylight distribution with light shelf relative to tilt.

4. VALIDATION

In order to validate the simulation results, a scale model has been constructed and tested under typical partly cloudy sky. The effect of each parameter on the interior illuminance is evaluated individually and the results are presented in Fig.11. It can be observed that results are with a range $\pm 5\%$ of Ecotect results, which suggests a good correlation with the reality, considering predefined daylight external conditions.



Fig. 11. Validation through measurements in scale model

5. CONCLUSIONS

According to the results of the simulations and measurements, it is possible to conclude that different tilting angles, configuration and a position of light shelves can contribute effectively to better results in naturel lighting design in hot and arid regions. Better naturel daylight contribution is understood as a condition that establishes good illuminance levels in the inner spaces without creating glare or large luminance and illuminance contrast levels.

To prove the applicability usefulness of the light shelf system, a case study was completed for a hypothetical small space under the specific sky conditions of Biskra. This study highlighted the limitations of using arbitrarily light shelves on building' facades and showed the benefit of integrated systems that take into account actual daylight conditions and distributions.

REFERENCE

(1) Aizlewood, M.E., Innovative Daylighting Systems: An Experimental Evaluation, Lighting Research & Technology, 1993

(2) Christoffersen, J., Daylight Utilisation in Office Buildings, Danish Building Research Institute, 1995

(3) Egan, M.D., Olgyay, V. W., Architectural Lighting, McGrow-Hill Company, New York, 2002

(4) Ihm P, Nemri A, Krarti M., Estimation of Lighting Energy Savings from Daylighting. Building and Environment, Vol. 44, pp. 509–14, 2009

(5) Littlefare, P.J., Designing With Innovative Daylighting, Building Research Establishment report, Construction research Communications Ltd, Herts, UK, 1996.

(6) NASA SSE program(http://www.eosweb.larc.nasa.gov/sse/)

(7) 0r, M., Global Energy Savings in Offices Buildings by the Use of Daylighting, Energy and Buildings, Vol. 34, pp. 421–429, 2002

(8) Smiley, F., Students Delight in Daylight, International Association for Energy Efficient Lighting Newslatter, 1996

(9) Wiley, J., Sons., Architectural Graphic Standards : A.G.S, Inc, New York, 2000

(10) Zemmouri, N., Daylight Availability Integrated Modelling and Evaluation: A Fuzzy Logic Based Approach, Doctorate Thesis, 2005.