Development of form proportions configurations in office building skins in order to improve daylight levels using "Parametric Design Methods"

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Abstract: Natural daylight inside space is one of the most important affairs because of its importance in caving energy consumption and its ability to provide a comfort environment inside space for occupants. The research aims to improve daylight levels for office space in hot arid by optimizing the best skin configuration proportions with multi-functional layers that work for resolving multi objectives problem to daylight.

The implementation of the simulation process is carries out by using grasshopper software which supports simulation parametric model process and DIVA as a simulation engine to space with southern orientation in Cairo, Egypt. The simulation process performed by using "sDA" and "ASE" metrics with integration of "LEED v4" criteria.

The research optimized skin configuration which achieve best daylight levels that achieved (100% SDA) and (3% AS).

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Key words: Skin façade proportions- Daylight simulation- parametric design- illuminance levels.

1.0 Introduction.

Escalating of energy crisis in recent times in Arab Republic of Egypt is the important motive for saving of energy consumption and attention to a new and renewable energy, especially in case of resources available abundance in Egypt.

This research aims to saving energy consumption by achieving the desired daylight levels in administrative spaces through dependence on daylight sources which be more helpful that Egypt characterized by abundant of day light sources. Egypt occupied the second world wide place after USA in order of most sunshiny countries in the world which has the longest sunshine period throughout the year.

More of previous studies attended to studying the proportions of louvers and shading devices that achieve the best daylight levels inside space during the year. These studies also interested in development of old shading devices strategies, such as development of "mashrabya" and "shading devices development" such as "blinds" and its effect on day light in space. But the studiousness of those studies was to develop skins that covers the traditional openings on wall with window to wall ratio (WWR) not encroach (10-15 %) from the total of area wall of case study, but did not care about study the buildings with glassy curtain walls in hot arid, which have the (WWR) reach to (90:100 %) from the total wall measurement of studied case.

This research aims to study the development of form proportions of office buildings skins, which cover the glassy curtain walls that improve daylight levels in spaces which support saving energy , in addition to achieve visual and psychological relief for users all that through using "Parametric Design Methods".

The research supposed that using a group of consecutive functional levels of skin cover supports daylight levels perfection in space specially in hot arid , that in comparison with using one level of shading device as blinds or any other daylight shading devices.

The research tries to find the best form proportion to the building skin cover in order to protect glassy curtain walls of office buildings in hot arid. The skin increases required daylight rate in space, and protect user from the negative effect of direct sunlight exposure which creates a visual and psychological uncomfortable environment, besides that it reduce production rate. As a result to this saving of electricity energy consumption whether in artificial lightening or cooling, we find the heat gain a result of penetrating a huge amount of direct solar radiation through the space.

Middle East is one of the most important areas that noticed with strategies of negative environmental remediation which supports the principle of adopt with the surrounding environment changes without needing to external energy.

One of this important remediation is "mashrabya" or "Roshan" which is a forming of module network of wooden cylinder different in its sizes and diameters, which collected through a convergence points that introduce plates with different sizes holes. This treatment proved efficiency in use but it still in its traditional form for along time without any development.

Research studies one of developed models for "mashrabya" and its ability of skin to control glassy curtain walls and dealing with the multi objective case which specialize the hot arid. Although these areas characterized with a clear sky with sun climate, but also have direct solar radiation which affects visual environment relief and increase heat gains rate in the same time.

So the importance of this research comes from trying to create a skin form proportions able to improve a piercing daylight levels.

2.0 Skin configuration.

The climate features of Arab Rebuplic of Egypt which sorted as a "Hot desert arid climate" to climatological sortihg "KOPPN" which characteries with clear sky and high direct solar radiation that needs a speicial type of treatment. The research tryies to find a new idea to askin configuration from a consecutive gtoup of functional levels,which support controlling to daylight levels and direct solar radiation through the space.

The skin consist of three main levels from inside to outside:

2.1 Glass skin.

Support gaining mush amount of daylight in space , whereas the height of window's opening effects on lights division in space depth, but that leads to increase heat gain rate.

2.2 Horizontal shading device.

It has a strong effect on improving daylight levels, and direct solar radiation controlling in southern facades of studied case. The research studies the effect of depth change of this horizontal shading device and its effect on improving daylight levels in space.

2.3 Complicated skin cover for bay forming.

Skin configuration works for dispersion of direct solar radiation and prevent it from interring in space, also works repetition of solar radiation directing in space which rise day light levels in space depth. This skin forms from triangular principle unit contains six units rolling around axis with different directions which repeat inside a hexagonal module.

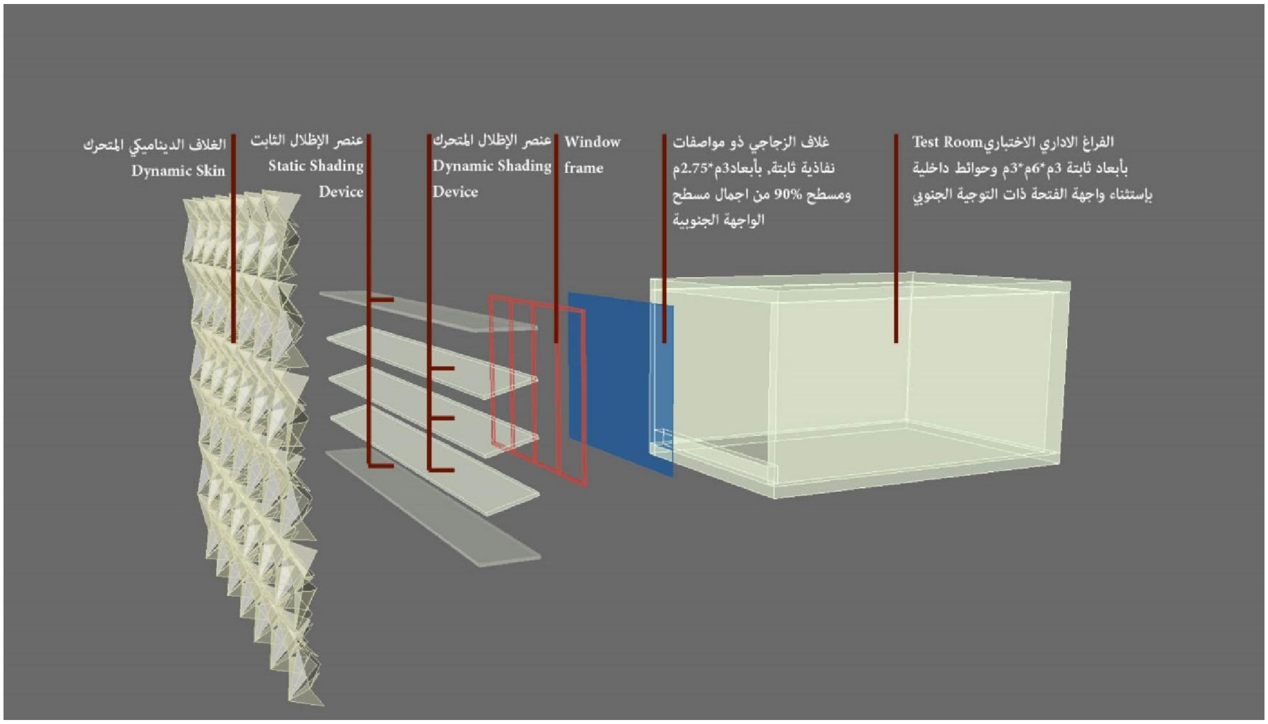


Fig. 1 Skin facade configuration

These units are responsible for controlling daylight levels inside space. The research aims to define best configuration proportions which support daylight performance inside space by using a group of variables such as angles of rotated skin units and its sizes.

The research change variables by using parametric design methods, each time variables changed daylight levels measured by daylight metric, till reach the optimum proportions of skin measures that achieve the best desired daylight level inside spaces which achieve best day light levels in space.

Parametric Design methods supports establishing an electronic model contains many variables connected with each other's in relationships which are defined through mathematical calculations and variables with different values, these relationships produce an matrix of different forms appears automatically with no need to create a new model. One of important programs that support parametric design processes is "Grasshopper" program which is a visual programming language also "GH" program that support "Rhino 3D" program and used it as an "Interface" in showing visible images of simulation model.

This research aims to develop form proportions and measures for office buildings skin in order to improve daylight levels inside space by using "Parametric Design Methods".

3.0 Methodology.

The research methodology is carried out through two main steps, first one concentrate on daylight levels analysis which resulting from variables change of building skin units, this step uses DIVA for Rhino (a plugin for rhinoceros modeling software) and DIVA uses RADIANCE and DAYSIM and its basic daylight as a simulation engine. The second step is evaluating daylight levels to optimize the best skin configurations which achieve the best Illuminance of daylight levels inside space.

DIVA setting was determined as follows, in table 1.0

Table (1.0) DIVA setting.

simulation type	Climate-Based
occupancy schedule	9 a.m. to 5 p.m.
Minimum Illumination	300 LUX

And "Radiance parameters" appears in following table, table (2).

Table (2.0) shows Radiance Parameters.

Ambient Bounces (-ab).	6
Ambient Division (-ad).	1000
Ambient super samples (-as).	20

3.1 Skin variables.

Skin variables aims to improve the daylight illuminance levels inside space, some of this variables belong to main shading device that appears in "Depth", and others variables are belong to complicated skin cover variables that appears in "Unit radius of Rotation angle", and the following table shows the variable, its number and cheangable values,table)3).

The following table shows the geometrical configurations of skin variables, figure 2.0

Fig.2: the geometrical configurations of skin variables.

Table (3.0) Main skin variables

Variable category	Variable name	Cases										Total number of cases
main shading device	Depth (meter)	0.75	0.9	1.05	1.20							4
Complicated skin cover	Unit radius (meter)	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1			8
	Rotation angle (degree)	0.0	10	20	30	40	50	60	70	80	90	10

3.2 Constants variables.

Is a group of variables affect directly on quality of daylight Illuminance levels in space, but it is constant through out the research, it is represented in space direction to follow southern orientation, in addtion to space dimensions such as length, width, and height are) 4.0 m width × 6.0 m.length × 3.0 m height (. the simulation model space is on a 6.0 m height from the ground surface which so it was considered the reflections from the ground surface.

The glass window area is constant it is (4m.width × 2,75m. height) about (90%) of total of wall area which facing the southern faced, accordingly we find that space depth reach to double distance of glass window height (1 : 2), where the window height is (3.0 m.).That is one of this research targets is to reach at great daylight distribution inside space depth in a ratio (1:2) which prescribed in "IESNA". Figure 4.0

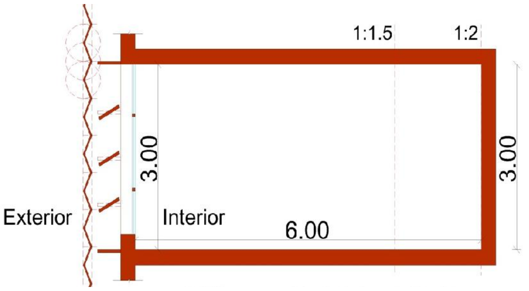


Fig. 3 Relation between depth and window height ratio

Reflectance of space external walls, skin and internal finishing materials is constant also floor, walls and ceilings materials are fixed material and reflectance ratio, shown through table 4.0 , and this values are certified from (IESLM 83- 12. 2012).

Table (4.0) shows Material Properties

Floors	20% – Generic Floor – Diffuse Reflectance
Walls	50% - Generic Interior wall
Ceiling	80% - Generic ceiling – Diffuse Reflectance.
Window Glass	80% Glazing – Double panel- clear- Transmit
Window Mullions	Metal Diffuse
Outside Ground Floor	20%- outside Ground- Diffuse Reflectance
main shading Device	35% Diffuse Reflectance – outside Façade
secondary shading Device	35% - outside Facade – Diffuse Reflectance
Dynamic skin	35% outside- facade – Diffuse Reflectance
Window Frame	Metal Diffuse

3.3 Metrics

The daylight illuminance levels were measured using a group of dynamic metrics as follow.

3.3.1 Spatial Daylight Autonomy (sDA 300/50%).

Describes the sufficiency of daylight illuminance levels incised space, or be defined as it a ratio of space area which achieves a daylight level not less (300 lux) for total time not less (50%) of space occupation hours throughout the year so it known as (sDA 300/50%).

3.3.2 Annual sunlight exposure (ASE 1000/250).

Describes the expected visual discomfort inside work environment which defined as a ratio of area of space that the direct illumination level rises over a (1000 lux) in zero bounces case, for total time more than (250 hours) of the total occupancy hours so it is known as (ASE 1000/250).

4.0 Analysis results.

The simulation study in this research is parametric for (320) different studied cases, which shows the effect of skin configuration proportions changes on the daylight performance inside space. The evaluation of simulation results is important for understanding the daylight performance through variables change such as depth of main shading devices, and the rotation angles of the skin units, In addition to skin unit radius, which be taken in consideration that the climate is specified by weather data file for Cairo and occupation hours to space is determinate.

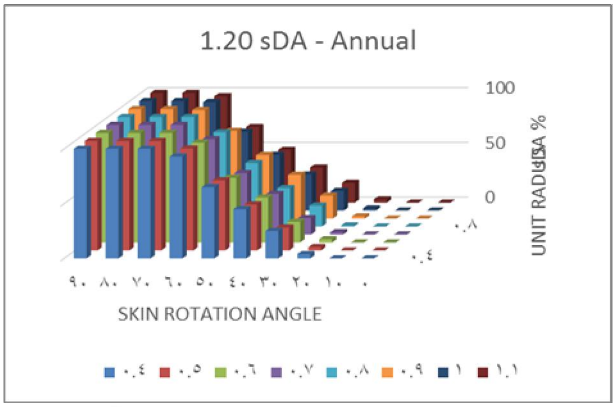
The results divided into four main sections according to main shading devices depth. It shows each case of variables effect on daylight performance in addition to definition and choosing the best solutions which support the required daylight levels in space.

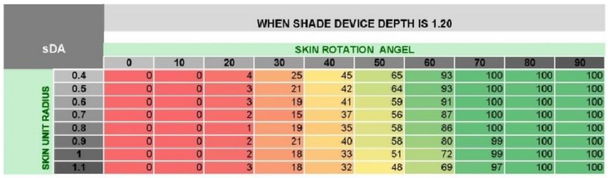
4.1 Results

The following part shows three sections of four which describes the variation results.

4.1.1 Depth of main shading device (1.20 m).

Illuminance levels starts to achieve the required level of illumination starting from skin rotation angle (50°) that gives a range of illuminance values between (48% : 66%) which the required Illumination levels in (LEEDv4) starts from (55%) whereas Illumination levels reach to (100%) in rotation angles range between (70°: 90°). rotation angles effects on Illumination levels is clear which the Illumination levels have analogy relationship with rotation angels, whenever the rotation angles increase, the illumination rate increase too, figure 5.0. Also the illuminance levels at angles (zero - 10°-20°-30°) do not match the required levels in all cases. Skin unit radius has a contrary effect on illumination levels, whereas the unit radius increases, the illumination levels decrease when rotation angles are fixed. The rate of daylight change according to radius changes between (25%: 30%).

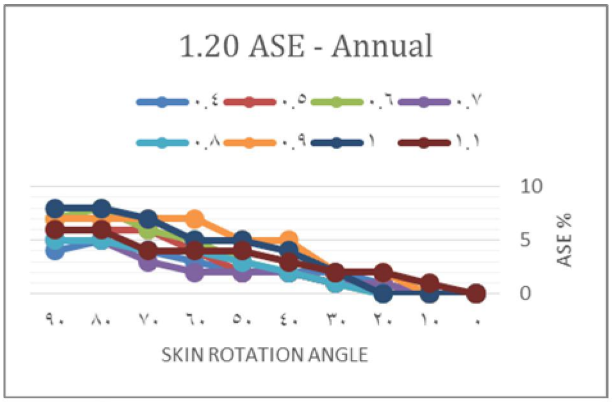


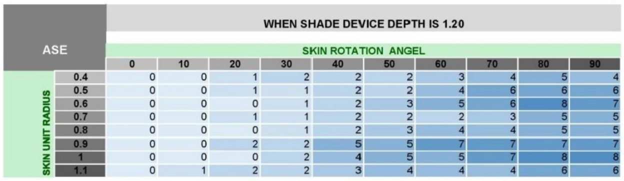


sDA	WHEN SHADE DEVICE DEPTH IS 1.20									
	SKIN ROTATION ANGEL									
SKIN UNIT RADIUS	0	10	20	30	40	50	60	70	80	90
0.4	0	0	4	25	45	65	93	100	100	100
0.5	0	0	3	21	42	64	93	100	100	100
0.6	0	0	3	19	41	59	91	100	100	100
0.7	0	0	2	15	37	56	87	100	100	100
0.8	0	0	1	19	35	58	86	100	100	100
0.9	0	0	2	21	40	58	80	99	100	100
1	0	0	2	18	33	51	72	99	100	100
1.1	0	0	3	18	32	48	69	97	100	100

Fig. 4 (sDA 300 ⁄ 50%) results of (1.20 m) depth.

The direct sunlight exposure results appear through figure 7.0, all values of (ASE) not overpass (8%) and maximum value not over reach (5%) and it's an acceptable level.



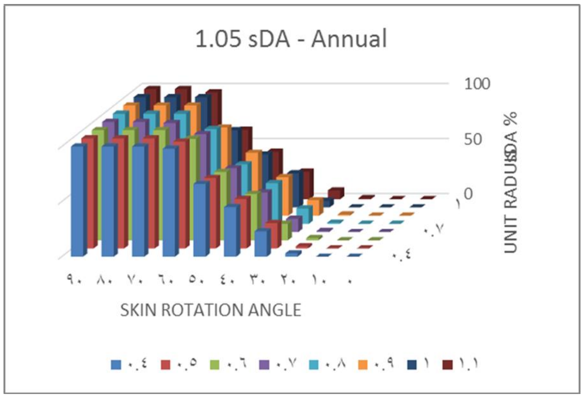


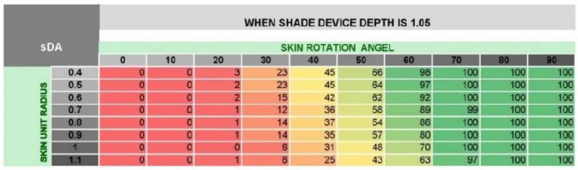
ASE	WHEN SHADE DEVICE DEPTH IS 1.20									
	SKIN ROTATION ANGEL									
SKIN UNIT RADIUS	0	10	20	30	40	50	60	70	80	90
0.4	0	0	1	2	2	2	3	4	5	4
0.5	0	0	1	1	2	2	4	6	6	6
0.6	0	0	0	1	2	3	5	6	8	7
0.7	0	0	1	1	2	2	2	3	5	5
0.8	0	0	0	1	2	3	4	4	5	5
0.9	0	0	2	2	5	5	7	7	7	7
1	0	0	0	2	4	5	5	7	8	8
1.1	0	1	2	2	3	4	4	4	6	6

Fig. 5: (ASE 1000/250) results of (1.20 m) depth.

4.1.2 Depth of main shading device (1.05 m).

A clear stability of illumination levels values in all cases at depth (1.05 m.) in comparison with depth (1.20 m.) with the exception of individual cases which increase the illumination levels with small rates in illuminance levels, figure (8).

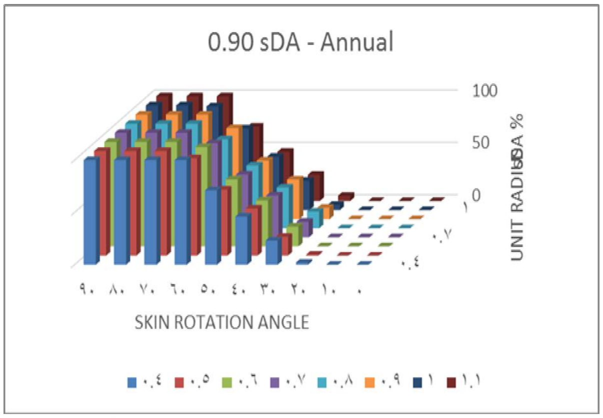


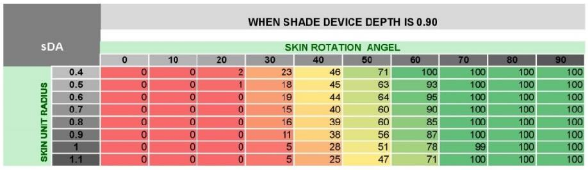


sDA	WHEN SHADE DEVICE DEPTH IS 1.05									
	SKIN ROTATION ANGEL									
SKIN UNIT RADIUS	0	10	20	30	40	50	60	70	80	90
0.4	0	0	3	23	45	66	98	100	100	100
0.5	0	0	2	23	45	64	97	100	100	100
0.6	0	0	2	15	42	62	92	100	100	100
0.7	0	0	1	12	36	58	89	99	100	100
0.8	0	0	1	14	37	54	86	100	100	100
0.9	0	0	1	14	35	57	80	100	100	100
1	0	0	0	6	31	48	70	100	100	100
1.1	0	0	1	8	25	43	63	97	100	100

Fig. 6: (sDA 300 ⁄ 50%) results of (1.05 m) depth.

In comparative (1.05m) case with (1.20m.) depth, we find the same (ASE) values in direct sunlight exposure, with the exception of individual case that appears through figure (9). There is no difference between (SDA) and (ASE) values.



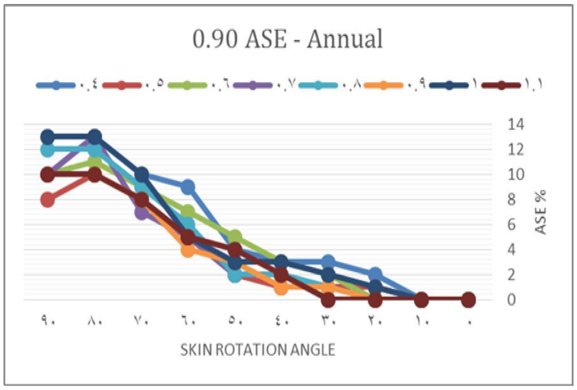


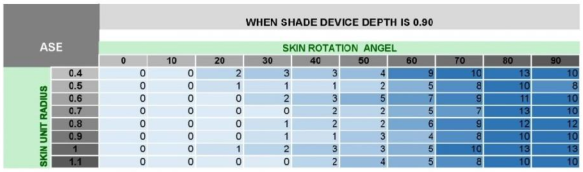
WHEN SHADE DEVICE DEPTH IS 0.90

sDA	SKIN ROTATION ANGEL									
SKIN UNIT RADIUS	0	10	20	30	40	50	60	70	80	90
0.4	0	0	2	23	46	71	100	100	100	100
0.5	0	0	1	18	45	63	93	100	100	100
0.6	0	0	0	19	44	64	95	100	100	100
0.7	0	0	0	15	40	60	90	100	100	100
0.8	0	0	0	16	39	60	85	100	100	100
0.9	0	0	0	11	38	56	87	100	100	100
1	0	0	0	5	28	51	78	99	100	100
1.1	0	0	0	5	25	47	71	100	100	100

Fig. 7 (sDA 300/50%) results of (0.90 m) depth.

Results of (ASE) in depth (0.90 m.) shows a noticeable rise in (ASE) values as a result of shading element depth decreasing, which not accepted in (LEED-v4) at angles (80°-90°). Unit radius has no major effect on (ASE) except in some individual cases a reducing is happened to (ASE) with unit radius increasing, figure (12).





WHEN SHADE DEVICE DEPTH IS 0.90

ASE	SKIN ROTATION ANGEL									
SKIN UNIT RADIUS	0	10	20	30	40	50	60	70	80	90
0.4	0	0	2	3	3	4	9	10	13	10
0.5	0	0	1	1	1	2	5	8	10	8
0.6	0	0	0	2	3	5	7	9	11	10
0.7	0	0	0	0	2	2	5	7	13	10
0.8	0	0	0	1	2	2	6	9	12	12
0.9	0	0	0	1	1	3	4	8	10	10
1	0	0	1	2	3	3	5	10	13	13
1.1	0	0	0	0	2	4	5	8	10	10

Fig. 8: (ASE 1000/250) results of (1.05 m) depth.

5.0 The optimum solution.

Evaluation of simulation results figure out that case number (107) between (320) total case has a configuration proportions makes it the optimum solution to achieve the maximum illumination levels inside space which results (100% sDA) and (3% ASE), so (107) case is the optimum solution, the optimum solution skin configuration showed in table 5.0.

Table (5.0) shows optimum solution skin configurations.

1	Skin unit rotation	70°
2	Skin unit radius	0.6 Meter
3	main shading device depth	1.05 Meter
4	secondary shading Device depth	0.75 Meter

The following figure no.8 shows Illumination Analysis Grid to "DA","ASE" and "SDA" OF (case 107), whereas figure 9 shows a perspective of case configuration case.

Conclusion.

The research shows the effect of multi-functional layer skin to improve the daylight levels in office space by using parametric simulation tools to examine a building skin to develop the daylight strategies in hot arid in Middle East. The case study facade is southern orientation and simulation was carried out in Cairo, Egypt. The skin is controlled by a group of variables which affects the illuminance performance inside space this variables is (skin unit rotation angles, skin unit radius and main shading device depth). And it results some of general indicators of variables effect on illuminance performance, as an example;

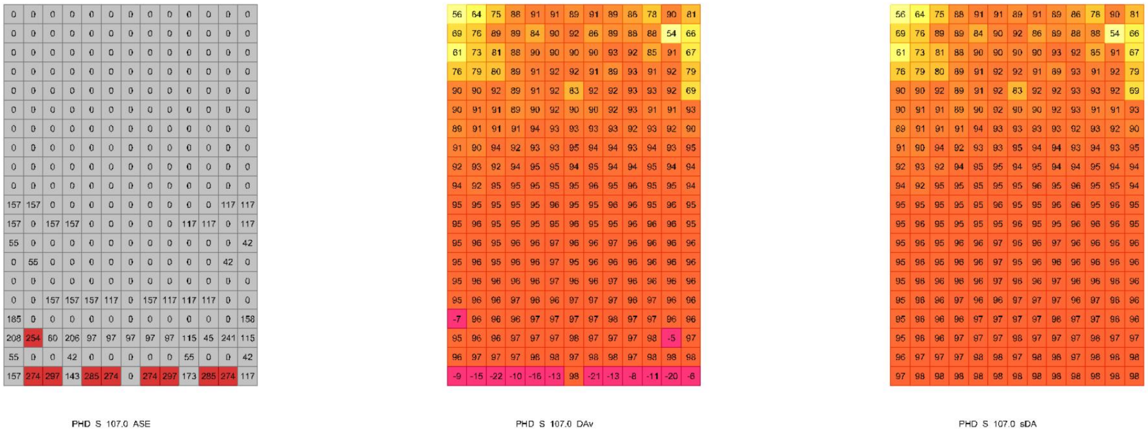
Main shading devices depth Affect strongly on illuminance quality inside spaces, depth increasing leads to a little decreasing in illumination levels, but it has a strong effect on reducing the impact of direct sunlight exposure. Research figured out that the good range of depth is between (1.05m. to 1.20m.), it control the values of (ASE) that not overpass (10%) the acceptable range by (LEEDv4).

unit rotation angles affects illuminanace levels, illuminance levels reach the required levels between (50° : 90°) in analogy relationship with illuminance levels, whereas the Illumination levels value increases with increasing of rotation angels, but the best range of the Illumination levels values is at angles (60°:80°), whereas rotation angles increasing leads to rising the values of (ASE), and stability of (sDA) values which reach to maximum value (100%) starting from (70°) angles, while angles between (80°-90°) the values of (sDA) reach to stability, but the values of (ASE) are increasing and that not desirable.

Skin unit radius has a contrary effect on the illumination levels, whereas the radius increases, the illumination levels decrease and (ASE) ratio increases in irregular way with radius rising, and the best range of radius between (0.4 m. to 0.7m.).

The research reached to the optimum of skin configurations which achieves the maximum levels of day light performance in office space and it is skin unit radius is (0.6m.), main shading devices depth (1.05m.), secondary shading devices depth (0.75m.)it is a constant value during simulation process, and (70°) to skin unit rotation angle, the skin reached to (100% SDA) and (3% ASE).

The research aims to achieve the integration between using of daylight simulation tools and parametric design methods to improve daylight levels in space in hot areas.



0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
157	157	0	0	0	0	0	0	0	0	0	117	117
157	0	157	157	0	0	0	0	0	117	117	0	117
55	0	0	0	0	0	0	0	0	0	0	0	42
0	55	0	0	0	0	0	0	0	0	0	42	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	157	157	157	117	0	157	117	117	117	0	0
185	0	0	0	0	0	0	0	0	0	0	0	158
208	254	60	206	97	97	97	97	97	115	45	241	115
55	0	0	42	0	0	0	0	0	55	0	0	42
157	274	297	143	285	274	0	274	297	173	285	274	117

PHD S 107.0 ASE

56	64	75	88	91	91	89	91	89	86	78	90	81
69	76	89	89	84	90	92	86	89	88	88	54	66
61	73	81	88	90	90	90	90	93	92	85	91	67
76	79	80	89	91	92	92	91	89	93	91	92	79
90	90	92	89	91	92	83	92	92	93	93	92	69
90	91	91	89	90	92	90	90	92	93	91	91	93
89	91	91	91	94	93	93	93	93	92	93	92	90
91	90	94	92	93	93	95	94	94	93	94	93	95
92	93	92	94	95	95	94	95	94	94	95	94	94
94	92	95	95	95	95	95	96	95	96	95	95	94
95	95	95	95	95	96	95	95	96	96	95	96	95
95	96	95	95	95	95	96	95	95	96	96	96	95
95	96	95	96	96	97	96	96	97	96	96	96	96
95	96	95	96	96	97	95	96	96	96	96	96	96
95	96	96	96	96	97	96	96	97	96	96	96	96
95	96	96	97	96	96	97	97	97	96	97	96	96
-7	96	96	96	97	97	97	97	98	97	97	96	96
95	96	96	97	97	97	98	97	97	97	98	-5	97
96	97	97	97	98	98	97	98	98	97	98	98	98
-9	-15	-22	-10	-16	-13	98	-21	-13	-8	-11	-20	-6

PHD S 107.0 DAv

56	64	75	88	91	91	89	91	89	86	78	90	81
69	76	89	89	84	90	92	86	89	88	88	54	66
61	73	81	88	90	90	90	90	93	92	85	91	67
76	79	80	89	91	92	92	91	89	93	91	92	79
90	90	92	89	91	92	83	92	92	93	93	92	69
90	91	91	89	90	92	90	90	92	93	91	91	93
89	91	91	91	94	93	93	93	93	92	93	92	90
91	90	94	92	93	93	95	94	94	93	94	93	95
92	93	92	94	95	95	94	95	94	94	95	94	94
94	92	95	95	95	95	95	96	95	96	95	95	94
95	95	95	95	95	96	95	95	96	96	95	96	95
95	96	95	95	95	95	96	95	95	96	96	96	95
95	96	95	96	96	97	96	96	97	96	96	96	96
95	96	95	96	96	97	95	96	96	96	96	96	96
95	96	96	96	96	97	96	96	97	96	96	96	96
95	96	96	97	96	96	97	97	97	96	97	96	96
95	96	96	96	97	97	97	97	98	97	97	96	96
95	96	96	97	97	97	98	97	97	97	98	97	97
96	97	97	97	98	98	97	98	98	97	98	98	98
97	98	98	98	98	98	98	98	98	98	98	98	98

PHD S 107.0 sDA

Fig. 9: Illumination Analysis Grid for optimum solution.

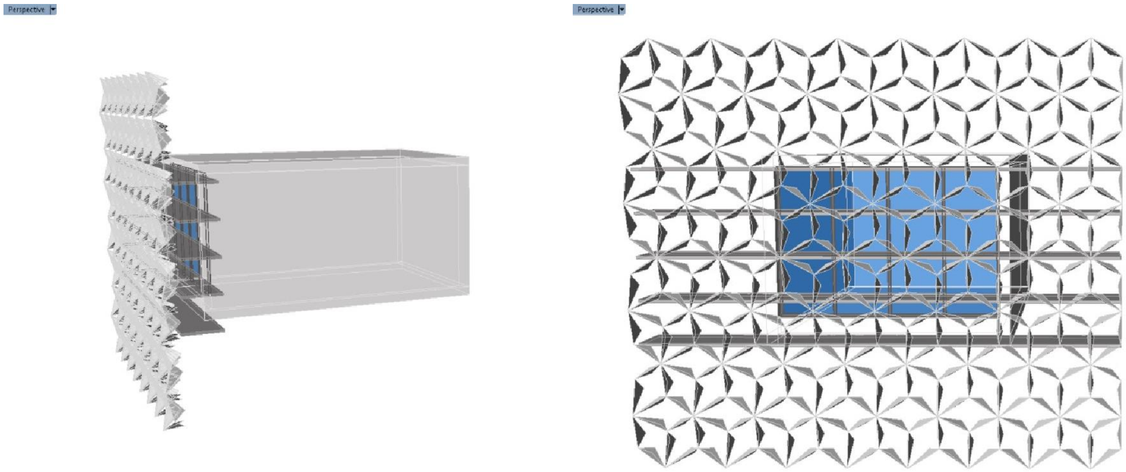


Fig. 10: Perspective for optimum solution-case 107.

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