GLAZING DESIGN FOR BILATERAL DAYLIGHTING IN PUBLIC SCHOOL CLASSROOMS IN NORTHERN PART OF ALGERIA

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To my beloved parents, wife, sisters and friends

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ABSTRACT

Daylight quality and quantity in Algerian schools display a serious condition in ensuring the visual comfort of students and teachers. Some problems arise due to poor window design and excessive amounts of daylight penetration into the classrooms as well as non-uniform daylight distribution, which may cause glare and heat gain. This study aimed at choosing an ideal window size and glazing pattern to maximise daylight effectiveness and occupant comfort in Algerian schools. Field measurements of selected classrooms were carried out in selected schools in Algeria during the summer and winter seasons. The data were analysed and used to develop a model design for simulation. Seven patterns of glazing window design was used for an extensive simulation exercise. The results of the investigation from the site measurements show that WWR was more than 40%; the WPI was found to be within the range of 300lux to 500lux and the DF of 4%, which exceeded reference value, except the southeast orientation which recorded 2.98%. Results from the simulation using IES <VE> by comparing three different glazing types (tint, clear and reflective) and using different glazing size from 25% to 75% in winter (under overcast sky condition) and summer (under intermediate sky condition). The evidence from this study suggests that tinted windows in both winter and summer is ideal as the simulation's result shows that significant usable area (31.22% - 41.74%) is achievable in a bilateral window opening with a DF<2 by increasing the percentage of the tinted glass from 25% to 75%. From the results this research suggests that a 30% WWR with a tinted glass of 50% VT in a bilateral school design would be ideal for public schools in Algeria as it yielded a WPI within the range of 300lux to 500lux. The use of different glazing configurations during the experiment had a significant impact in the improvement of the quantity and quality of daylighting.

ABSTRAK

Kualiti dan kuantiti cahaya siang sekolah di Algeria menunjukkan keadaan mendesak dalam memastikan keselesaan visual bagi pelajar dan guru. Beberapa masalah timbul disebabkan oleh reka bentuk tingkap yang lemah dan penembusan cahaya siang ke dalam bilik darjah yang berlebihan dan tidak seragam, yang boleh menyebabkan silau dan pertambahan haba. Kajian ini bertujuan untuk memilih saiz tetingkap yang ideal dan kaca berpaten untuk memaksimumkan keberkesanan cahaya siang dan keselesaan penghuni di sekolah Algeria. Ukuran tapak bagi kelas yang dipilih telah dijalankan ke atas sekolah terpilih di Algeria semasa musim panas dan musim sejuk. Data tersebut telah dianalisis dan digunakan untuk membangunkan reka bentuk model simulasi. Tujuh corak reka bentuk tingkap kaca telah digunakan untuk latihan simulasi terperinci. Hasil siasatan dari ukuran tapak menunjukkan bahawa tetingkap kepada nisbah dinding (WWR) adalah lebih daripada 40%; pencahayaan ruang kerja (WPI) didapati dalam julat 300lux ke 500lux dan DF sebanyak 4%, melebihi nilai rujukan kecuali orientasi tenggara iaitu sebanyak 2.98% pada waktu pagi dan 2.29% pada sebelah petang. Keputusan daripada simulasi menggunakan IES <VE> dengan membandingkan tiga jenis kaca yang berbeza (warna, kejelasan dan reflektif) dan menggunakan saiz kaca yang berbeza dari 25% sehingga 75% ketika musim sejuk (di bawah keadaan langit mendung) dan musim panas (di bawah keadaan langit perantara) . Bukti daripada kajian ini menunjukkan bahawa tingkap gelap di kedua-dua musim sejuk dan musim panas adalah paling sesuai, kerana hasil simulasi menunjukkan bahawa kawasan yang boleh digunakan adalah dari (31,22% - 41,74%) boleh dicapai dalam bukaan tingkap dwisisi dengan (DF <2), dengan meningkatkan peratusan kaca berwarna dari 25% kepada 75%. Dari keputusannya, penyelidikan ini mencadangkan bahawa tetingkap kepada nisbah dinding (WWR) 30% dengan kaca yang berwarna 50% VT dalam reka bentuk sekolah dua hala adalah ideal untuk sekolah-sekolah awam di Algeria kerana ia menghasilkan pencahayaan ruang kerja (WPI) dalam lingkungan 300lux ke 500lux. Penggunaan variasi konfigurasi kaca yang berbeza semasa eksperimen mempunyai kesan yang nyata dalam meningkatkan kualiti pencahayaan waktu siang.

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LIST OF ABBREVIATIONS

WPI	-	WorkPlane Illuminance
DF		Daylight Factor
IES-VE	-	Integrated Environment Solution Virtual Environment
T	-	temperature (^{o}C)
AFE	-	The French Association of Lighting
MW	-	Megawatt
Lux	-	unit of illuminance
UV	-	ultraviolet
IR	-	Infrared
ICE	-	International Commission on Illumination
CEN/TC	-	The European Committee for Standardization
FC	-	Foot-Candle
Ei	-	Exterior illuminance
ii	-	interior illuminance
m	-	meter
Sq. mi	-	Square mill
km	-	Kilometre
klx	-	kilolux
°N		North
WWR	-	Windows Wall Ratio
WFR	-	Windows Floor Ratio
SBR	-	Sustainable Building Research
VT	-	Visible Transmittance
VR	-	Visible Reflectance
SHGC	-	Solar Heat Gain Coefficient
°E		East
IEA	-	International Energy Agency
ISIRI		The national lighting committee of standard and industrial organisation of Iran
CIBSE		Chartered Institution of Building Services Engineers
G1	-	Clear glass
G2	-	Tint glass
G3	-	Reflective glass

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CHAPTER 1

INTRODUCTION

1.1 Background

Sun is the authentic source of light defined in Latin as luminary "flambeau". It is an essential source of energy for every creature on Earth. The activities of scientists such as astronomers and engineers, among others, have proved that the sun is a source of energy. Currently, solar energy is an important global resource that scientists continue to explore and make use of in many human endeavours including architecture.

The past decade has proved to be a turning point in the quest for educational attainment in Algeria, many of the 8 million estimated students spend quality time schooling. The study of the architecture of comfort, building conditions, and environmental needs of the society has become paramount. This provides the opportunity for proper environmental monitoring of in-depth analysis of thermal, acoustic and luminal science that influences societal wellbeing explain that in recent years (Mohd-Zin, K.2005). There has been an increasing interest in sustainable issue and that environmental consciousness and energy saving methods (green energy) have become a popular subject, which has improved knowledge on the need to sustain

resources for present and future generations without impairing the environment. This is known as sustainable architecture.

The importance of daylighting in our educational buildings has dominated research in recent years. There has been a positive correlation between the positive effects, considerable capacity to the performance by the students, and the promotion of better health by proper lighting of schools (Wu & Ng, 2003). It has been proved that daylighting affords the best quality of light available to mankind, classroom, and corridors. It has also been proved that daylighting eliminates noise pollution and flickering from electric light sources (Edwards & Torcellini, 2002).

Student comfort while learning is imperative and therefore requires a building that will provide such comfort highly influence their learning ability. The school building must therefore meet such criteria. One of the fascinating developmental needs of students is lighting. Students at various stages of their development require a motivational component of education which is lighting, which shapes the ability of the student to identify and differentiate colours, the scale of their surroundings, and ability to navigate their school premises unaided.

The manner in which a student reacts to daylighting can be either positive or negative. In the case of adverse conditions, daylighting can cause negative reactions to schooling. Excessive lighting to the classroom can also have an adverse effect on student learning. The level of concentration of daylighting and penetration of large amounts of light into a classroom can cause visual discomfort. Difficulty seeing or glare is one of the most common problems suffered by students in schools.

1.2 Problem Statement

The current state of schools in Algeria is such that there is an urgent need for building new schools to meet the needs of increasing school standards in accordance

with the times. Few of these schools meet the minimum norms on the basis of the design criteria for effective learning. In schools built and reconstructed after 50 years of independence, there is little significant improvement in terms of quality of construction. There is a need for urgent improvements to remedy the many problems constantly suffered by school children. These problems are caused by poor environmental learning conditions (irrational sunlight) through a large amount of daylight penetration inside the classroom known as glare and non-uniform daylight (Saffidine-Rouag)

Regarding educational institutions in Algeria, the guide published by the Ministry of Education concerning the regulations for school building construction only considers the geometric characteristics and classroom orientation. No indication is given on the requirements of daylighting, window design, and glazing systems such as glass type and size for each zone (Ibrahim, 2002; Ibrahim, 2009; Ibrahim, Hayman & Hyde, 2008). The application of daylight through the window requires more comprehensive recommendations and guidelines to be used during early stages of design. All these emanate as a result of a lack of standard guidelines which serve as a vital pillar and provision of a standard structure that will stand the test of time. The proposed typologies and window would be beneficial to the designers in Algeria and the health of students.

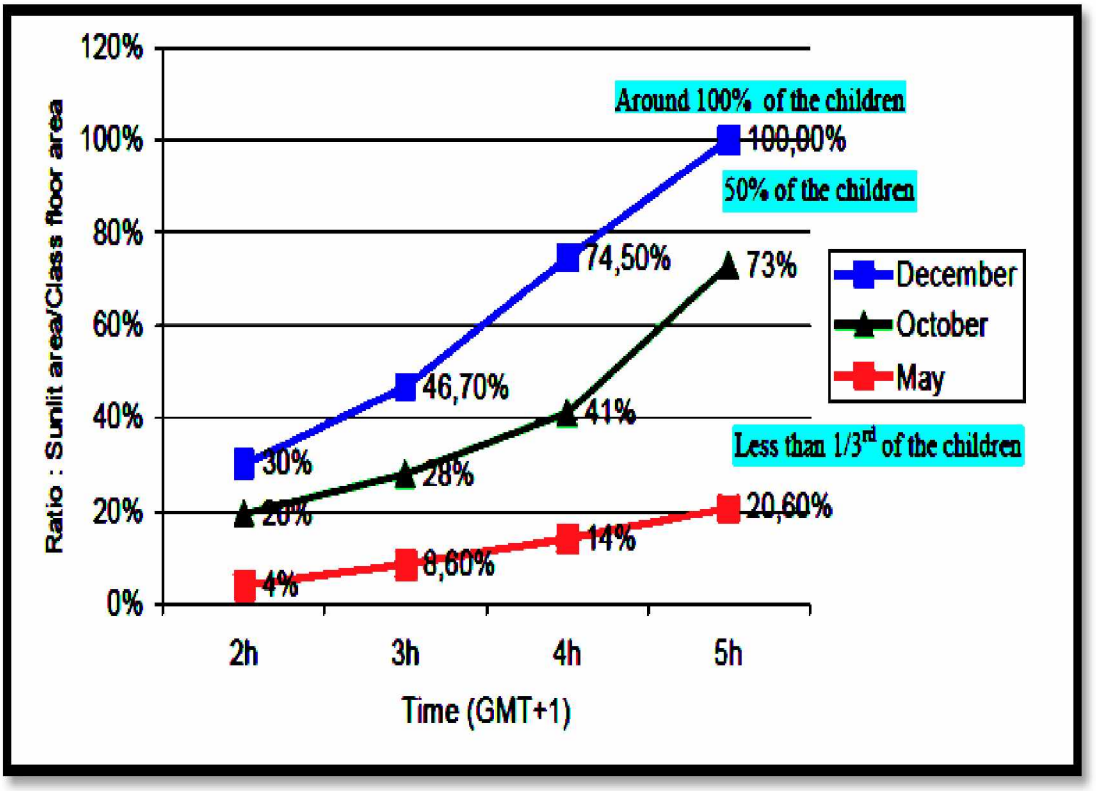

Figure 0-1: Variation of Sunlit Areas and Percentage of Children Exposed to Sunlight throughout the Academic Year in Algerian Classrooms (orientation=230° from North) (Saffidine-Rouag, 2013).

1.3 Research Aims

This research investigates the current daylighting consideration in existing school buildings in Algeria and determines the best glazing pattern to maximise daylight, effectiveness on window glazing patterns, and occupant comfort in order to recommend appropriate daylighting strategies for Algerian school design.

1.4 Research Objectives

1. To investigate daylighting performance of typical classrooms in Northern Algerian public schools.
2. To investigate good daylight quantity and quality for pupils' visual comfort through classroom windows glazing configurations.
3. To determine and recommend an appropriate design of window glazing pattern that responds to the bilateral daylighting requirements.

1.5 Research Questions

After reviewing the past literature, and in line with the above mentioned objectives, this study will seek answers to the following research questions:

1. Does the daylighting in Algerian public schools (typical classroom) comply with the international standards?
2. Is the quality of illuminance within classrooms ideal for students' visual comfort?
3. Is there a special design for the windows in public schools in Algeria proposed by the concerned authorities?
4. Does modifying the configuration of window glazing types affect the improvement of the quantity and quality of daylighting within the classroom?
5. What are the appropriate window glazing types for different façade orientations for Algerian schools?

1.6 Scope and Limitation

School structures contain many spaces such as classrooms, laboratories, meeting rooms, and teacher rooms. An individual classroom was chosen for this study

because it is considered the most important element in schools. Algeria is a large country with four different climatic zones. This study limits its daylighting analysis to northern Algeria where the majority of schools are concentrated (the region are located between latitude 34°-36° with a Mediterranean climate with an overcast sky).

There are many techniques used to illuminate spaces in classrooms which include: side lighting, skylight, and roof monitors. The current designs of Algerian public schools usually have side windows (side lighting) which can be surveyed by quantitative or qualitative approaches. This thesis focuses on daylight factor (DF) and WPI for quantitative analyses and distribution of daylight by using different glazing configurations, types, and sizes not provided in Algerian school guidelines for qualitative analyses. It ignores the reflectance value of the surrounding environmental in the simulation. The IES-VE (Integration Environment Solution Virtual Environment) simulation software was chosen among several simulation software including Ecotec, Velux, and Revit. The reason behind the choice of IES-VE lies in the availability of many properties and accurate rendered images and WPI and DF data. (IES, 1993; IES <VE>. 2006; Reinhart & Breton, 2009).

1.7 Significance of the Research

There is no specific design of windows in Algerian school buildings in relation to its orientation, sunlight permissible in classroom, and comfort of student learning through regulations to achieve the maximum environmental needs of the students. The government of Algeria has not put in place a proper design procedure for public building daylighting. Therefore, this research aims to generate significant information to serve as a platform for daylighting requirements for classroom building design. Subsequently, the requirements would form a basis for future daylighting recommendations for Algerian public school design.

1.8 Organisation of thesis

Chapter One introduces the research by stating the research problem, the objectives, scope, and limitations of this study. The chapter concludes with the significance of the study.

Chapter Two reviews the definition of daylighting and its performances in school buildings. This is followed by an explication on the concept of side lighting, modes (unilateral, bilateral, and multilateral), and presentation of the technical requirements of the guidelines and the types of glazing provided in Algerian markets. It also provides an explanation of the French international standards (A.F.E). Furthermore, this chapter presents the parameters for visual comfort within the classroom and analyses school buildings in Algeria. It concludes with an examination of the relevant research on this topic.

Chapter Three explains the research methodology which is a combination of two methods. First is site visitation and experimental measurements in selected Algerian schools, followed by computer daylight simulation experiment by IES Integrated Environment Solution VE.

Chapter Four presents the results of the field measurement in selected public schools in Algeria during two critical time periods, and compares these results with the international standard (A.F.E). This chapter also presents the results from a simulated model of a typical classroom in order to determine the daylight factor (DF) in winter, absolute WorkPlane Illuminance (WPI) in summer, in addition to the uniformity of daylight.

Chapter Five reviews the research objectives highlighted in Chapter One and examines the impact of the findings revealed through the outlined objectives. The practical implication and recommendations are highlighted, and the limitations of the study are discussed, with suggestions offered for further research.

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APPENDICES

I Daylighting glazing window patterns Analysis of (EAST-WEST) with corridor facing Classrooms

J Annual Weather (Temperature, Average sunlight, Sunshine hours) Averages of Algiers city

K Pictures show the problem of glare (direct sunlight) and the use of coating on windows in addition to Curtains within classrooms in Algeria public schools