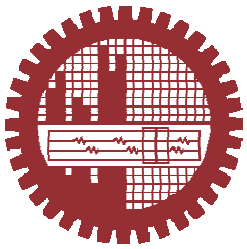
STUDY OF DAYLIGHT CONDITION IN CLASSROOMS OF URBAN PRIMARY SCHOOL BUILDINGS IN SYLHET WITH RESPECT TO VISUAL PERFORMANCE.

MOHAMMAD SAIFUZZAMAN



DEPARTMENT OF ARCHITECTURE
BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY

MASTER OF ARCHITECTURE

FEBRUARY, 2016

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DEDICATED TO MY PARENTS

COL (RETD) MD. SAFOR ALI MOLLAH AND BEGUM AFIA TOHFA

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Abstract

In the primary schools of Sylhet, artificial light is found the main contributor to the visual environment, even though there is a large quantity of daylight and the entire study period is enclosed within daylight hours. Studies show that, there are significant impacts of using daylight on human health and the visual performance in terms of efficiency and productivity. This research primarily concentrates on visual performance of the students, under daylight condition, at urban primary schools of Sylhet, where the skies are generally overcast throughout the year, unlike other divisional cities of Bangladesh. The research also aimed to investigate the relationship of the physical parameters of the classrooms spaces with daylight condition. In Bangladesh, there are no studies incorporating human interaction with the visual environment, in the divisional town of Sylhet. An intensive literature study provided the knowledge base for this research. The problem was identified first, by a survey of existing primary schools, in Sylhet City Corporation area, aimed at an understanding of their luminous environment. A detailed field survey was initiated to determine the visual performance of the students which, was derived through a intensive visual performance test. The field investigation also encompasses the physical parameters of the classroom spaces, which can influence the overall distribution of daylight, and compared to international standards. The findings of the study clearly show the interrelationship of daylight and students visual performance. It is clearly demonstrated that, visual performance, measured by time taken to complete the visual test and errors made during the test, are directly related to the amount of daylight available. The possible measures and scopes for further investigation are followed from the discussion on the research findings.

KEY WORDS:

Visual environment, Daylight, Visual performance, Students, Urban primary schools, Physical parameters, Classroom spaces.

CHAPTER: ONE

PREAMBLE

1.1. INTRODUCTION

The architect's task of creating a favorable environment, for living and working demands a study of the response of the human being to this environment, and of their requirements from the building which they inhabit.

A building may be intended for a particular use, and may not necessarily be occupied continuously. A school building, particularly a primary school building, is only in use during the part of the day known as "school hours", which can be divided into two segments: "morning shift" and "afternoon shift". It is observed from the physical survey, though daylight is available for nearly the entire occupancy period of school hours, artificial light is used as the main contributor during the physical survey, to the overall luminous environment of primary school buildings in Sylhet**.** However, studies show that, reducing reliance on artificial lighting, by daylight, can be an effective means of saving on lighting energy **[1],** and creating a better visual environment for the students. The study is limited to investigate the relationship between visual performances of the students, under different daylight situations and also encompasses the physical parameters, which can affect the overall daylight condition of the classroom spaces.

In a primary school building, particularly in the classroom spaces, the environmental parameters become more important, because of their attributes to the performance and efficiency of the students. Minimal quantitative differences accumulate, to a vast qualitative difference because of the sheer number of users, and the hours of usage of the classroom spaces. Figure 1.1 shows the Khasdobir Government Primary School, which is located near Amberkhana, Sylhet, which represents a common scenario of the typical classrooms of urban primary schools in Sylhet.

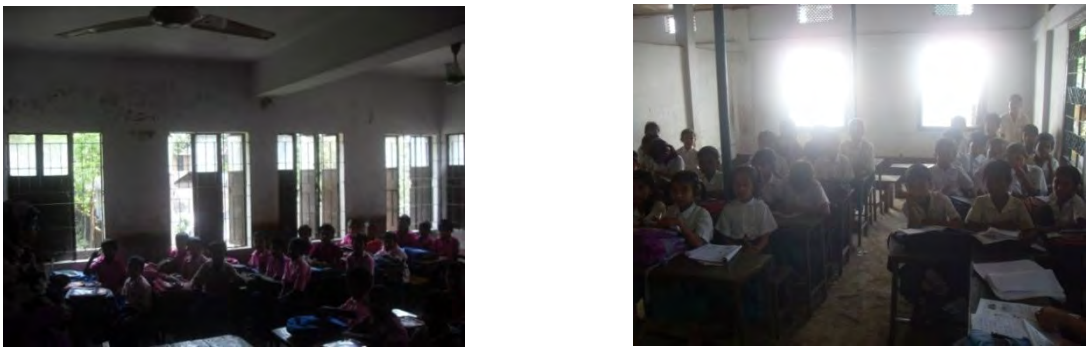

Figure 1.1 Existing Indoor Illumination Conditions of Classroom Spaces at KHASDOBIR GOVERNMENT PRIMARY SCHOOL.

There are many environmental parameters, such as physical, climatic, thermal and luminous. This study is limited to identifying the visual performance, under daylight conditions, inside the classroom spaces, of urban primary school buildings in Sylhet. At the same time the research will progress to understand how daylight impacts on the luminous environment for primary level students.

The lighting of a space, both natural and artificial, is a fundamental part of its design. However, with a few exceptions, it receives little attention from practicing architects, during the design of a building. Daylight has always been an important part of Architecture. In a brief history of day lighting in

architecture, Evans states, those structural concepts, through the ages, were shaped by the availability of the sun, which was the predominant source of daytime light, before the invention of electric lighting. Daylight is described as diffused sunlight. The primary means of allowing daylight into a building is through windows. In early times, window design was controlled, by physical limitations of material and construction techniques. Now with advances in building technology, it is possible to have a window as large, or as small as desired. With the development of artificial lighting, in the mid-twentieth century, daylight received less attention as a functional element and, dependence on artificial lighting became dominant, particularly in the design of classroom spaces.

The selected illumination level, should be sufficient to satisfy the requirements of people who occupy that environment, when performing a given task. The desirable illumination level, required by different people, is dependent on the degree of complexity of the function, the level of concentration and overall skills, required on the task to be performed. It will also be affected by surrounding climatic conditions, of the immediate vicinity, and also the age and background of the user. The quantity of light provided, should match the optimum amount of light required to efficiently perform a specific task. Similarly, the quality of light also needs to be such, that it is free from glare, while having good color rendering properties.

Many of the developed countries have adopted the practice of progressively increasing task luminance recommendations **[2],** based on visual performance**.** In Bangladesh, there have been a few preliminary studies **[3],** incorporating human interaction with the visual environment **[4],** but none specifically in the divisional town of Sylhet.

Urban schools are often situated in dense conditions, where daylight penetration is restricted by neighboring structures. This study addresses the visual performance of the primary level students, with respect to the quality and quantity of daylight, within the classroom spaces, at urban primary school buildings in Sylhet.

1.2. BACKGROUND OF THE STUDY

Daylight has received importance in determining the form of buildings historically, together with the effects of climate and location, and daylight availability was fundamental to design **[5]**. The history of architecture, is synonymous with the history of the window, and of day lighting. From the initial crude openings, letting in light and air, heat and cold, the window was the vehicle for the introduction of daylight, in to the interiors of many historical buildings.

For centuries, day light was the only efficient source of light, available prior to the invention of electricity. Architecture was dominated by the goal of spanning wide spaces, and creating openings, large enough to distribute daylight, to building interiors. Efficient artificial light sources and fully glazed facades, along with innovative structural possibilities, have liberated designers from these constraints of the past. Advanced day lighting systems and control strategies, are another step forward in providing day lit, user friendly, and energy efficient building environments. The systems need to be integrated into a building, to become part of the overall architectural strategy of the design process from its earliest stage **[6]**. Daylighting remained the primary means of lighting, in all types of building until the early 20^{th} century, when for various reasons, not least the greater efficiency in the development of electric sources, the primary role of day lighting was beginning to be questioned.**[7].**

The pressure to increase the levels of light in buildings, comes from the utility companies, who saw this as a means of increasing the sale of electricity, and for the manufacturers the sale of lamps and equipments. By the 1960s, artificial or electric lighting had gradually supplanted natural light, as the primary source of light, during the day in the work situation **[8].**

The role and historic advantage of daylight was not insignificant, the human factors demanding a closer look at this source. The historic result of this was that buildings, analyzed as the greatest cause of the problem, came under intense scrutiny, the words "passive building" and "sustainable architecture" started assuming greater importance **[9].**

Daylighting is extremely important, requiring a holistic approach to design, in which the human factors can also be placed in to the correct order of priority. It is no longer true that daylight is a luxury, concerned with the view out of the window, although the view out of the window is an essential part of the effect of providing daylight.

There are many reasons for renewed interest in day lighting-

A) The cost of fossil fuels has increased steadily.

B) The source of electricity has a finite life. Excessive use of the natural resources will severely affect the coming generations to conserve energy sources.

C) The less tangible aspects, which relate more to the human spirit, i.e. change and variety modeling, orientation, sunlight effect, colors and all effects of daylight are required to improve human health and happiness.

1.3. PROBLEM STATEMENT

There are several reasons which are responsible, for creating the problems regarding daylight penetration, inside the classroom spaces, which introduces the extreme dependency on electrical lighting, even on a sunny day. Some of those problems are created due to lack of understanding on daylight benefits, and its impact on student's ultimate visual performance.

Crowded classrooms, beyond the capacity it can hold, create shadows, visual annoyance, thermal and other physical discomfort situations. Figure 1.2 shows the examples of crowed situations at Lamabazar Government Primary School and Khasdobir Government Primary School in Sylhet.

Figure 1.2 Crowed situations at LAMABAZAR GOVERNMENT PRIMARY SCHOOL AND KASDOBIR GOVERNMENT PRIMARY SCHOOL.

Using paint on the window glazing (Figure1.3), to preserve privacy, creates daylight obstructions and darkness, and stands as a barrier for uninterrupted daylight penetration, which also increases the dependency on electric lighting. This condition is especially observed, in the corridor side windows, aiming to impose concentration, on the lecture by restricting student's vision within the classroom. This is one very unacceptable way to cut off enormous day light, though there remain scope and availability, particularly in the upper levels of the school buildings, where the surrounding visual obstructions are less, than the luminous situation at ground floors. Figure 1.3 shows the painted glazing, which are creating darkness in the indoor spaces.

Figure 1.3 Painting the glazing creates darkness at MADHUSHAHID GOVERNMENT PRIMARY SCHOOL)

Improper direction of day light penetration, often causes glare, and is responsible for visual disturbance, instead of creating a favorable daylit visual environment. Figure 1.4 shows the inappropriate route of daylight, which causes an inappropriate luminous situation in the classroom.

Figure 1.4 Improper direction of daylight causes an unfavorable luminous condition in the classroom at KASDOBIR GOVERNMENT PRIMARY SCHOOL)

The introduction of daylight inside the classrooms, can increase the quality of visual environment, and this research, will evaluate how it impacts on the student's visual performance. But the day light penetration needs to be considered in a controlled way because of associated heat, which can increase the internal temperature, and cause thermal discomfort in tropical situations. A good answer to overheating problems is controlling solar radiation incident on the building **[10]**. Using solar protective glazing is one simple solution, which can be easily integrated in to the building design **[11],** which can only applicable for air conditioned buildings. Glazing always stops ventilation, which also conflicts with thermal needs.

One major drawback of solar protective glass is, that it reduces solar gains in the building, even during winter time. Therefore, in the winter time a movable device is a better solution **[12].** But manual control of movable shading device is not reliable, and may cause constant disruption for the occupants, and most of the schools of our country cannot afford the system of dynamic control of motorized shading devices.

Shading provision should be considered as an integral part of fenestration system design, especially for facades with high solar gain. It may control solar gains, block direct sunlight, and transmit diffused sunlight in to the room, eliminating glare and high contrast and creating a pleasing luminous environment **[13].** Moreover; shades are also needed for rain protection. Sylhet has a high rainfall in comparison to other cities in Bangladesh. This makes shading an integral part of buildings in Sylhet.

In the context of Sylhet, which is predominantly overcast (Chapter four), there is no tested rule for the size of the openings, or of the shading devices. According to the building construction act, it is said that there must be provision for daylight, without being specific about the lighting standards for different purposes. Here it is also said that, maximum depth of shading device will not exceed 0.5 m, over compulsory setback areas. But this rule, which is for all orientations, is unlikely to come from any investigation, or analysis, of luminous performance, nor from any comparative study, or evaluation for different climatic situations. Therefore, buildings are being constructed without proper attention to the performance of openings, used materials and shading devices. This unawareness on the potential of daylighting in a school building, is being addressed in this study.

Studies on lighting relate daylight to performance (Chapter Two). Such studies are context specific. It is important to test the particular subjects of this region to determine relevance of daylight and performance.

1.4. TESTING VISUAL PERFORMANCE

A child needs many abilities to succeed in school. Good vision is a key. It has been estimated that as much as 80% of the learning a child, occurs through his/ her eyes **[14].** Reading, writing, chalkboard work, and using computers are among the visual tasks students perform daily. A child's eyes are constantly in use, in the classroom, and at play. As children progress in school, they face increasing demands on their visual abilities.

When certain visual skills have not developed, or are poorly developed, due to problems in the eye, or due to the poor quality of the visual environment, learning becomes difficult and stressful, and children will typically:

- Avoid reading and other near visual work as much as possible.

- Attempt to do the work anyway, but with a lowered level of comprehension or efficiency.
- Experience discomfort, fatigue and a short attention span.

Vision is more than just the ability to see clearly, or having 20/20 eyesight. It is also the ability to understand, and respond to, what is seen within the visual environment. The indicators of visual performance tests include the following aspects **[15].**

- **Recognition** (the ability to tell the difference between letters like "b" and "d"),
- **Comprehension** (to "picture" in the mind what is happening in a story being read), and
- **Retention** (to be able to remember and recall details of is read).

Visual environment should ensure the following vision skills, for effective reading and learning:

- **Visual acuity** — the ability to see clearly in the distance for viewing the chalkboard, at an intermediate distances for the computer, and up close for reading a book.

- **Eye focusing** — the ability to quickly and accurately maintain clear vision as the distance from objects change, such as when looking from the chalkboard to a paper on the desk and back. Eye focusing allows the child to easily maintain clear vision, over time, like when reading a book, or writing a report.

- **Eye tracking** — the ability to keep the eyes on target, when looking from one object to another, moving the eyes along a printed page, or following a moving object like a thrown ball.

- **Eye teaming** — the ability to coordinate and use both eyes together, when moving the eyes along a printed page, and to be able to judge distances, and see depth for class work and sports.

- **Eye-hand coordination** — the ability to use visual information to monitor and direct the hands, when drawing a picture or trying to hit a ball.

- **Visual perception** — the ability to organize images on a printed page into letters, words and ideas, and to understand and remember, what is read.

If any of these visual skills are lacking or not functioning properly, a child will have to work harder, and will take more time than otherwise required. This can also lead to headaches, fatigue, and eye strain problems, and will resulting a poor score during visual performance tests **[16].**

In this study, the environment of the visual performance test of the children has addressed the number of errors and required time for completion of a specific visual task, which will come up with a performance result, as to how the visual environment impacts on students' visual task.

1.5. VISUAL PERFORMANCE TEST UNDER DAYLIGHT CONDITION

In 1999, a rigorously documented study looking at the effect of day lighting on human performance was made public **[17].** The study, conducted by the Heschong Mahone Group, looked at the effect of day lighting on human performance. Mathematics and reading test scores were analyzed for over 21,000 students from elementary schools in different regions of the western United States.

Students with the most day lighting in their classrooms progressed 20% faster in math and 26% in reading in one year, than those with the least. And students with a well-designed roof light in their room (one that diffused the daylight throughout the room and which allowed teachers to control the amount of daylight), also improved 20% faster than those without a roof light. **[18].**

The required amount of light can be ensured by daylight, along with electrical lighting as supplement. At the same time, it is also possible to adjust the overall amount of light within the classroom spaces, only using electrical lights, but still daylight has some extraordinary benefits for human physiology and psychology, which is mentioned in more details in section 2.3.2.

This study focuses on visual performance only under daylight situation, to establish the relationship between the students' visual performance with daylit visual environment.

1.6. AIM OF THE STUDY

The aim of the study is to observe how daylight impacts on student's visual performance and also address the physical parameters which impact on the overall daylight condition, within the classroom spaces of urban primary schools in Sylhet.

1.7. OBJECTIVE OF THE STUDY

The study explores the interrelation of student's visual performance, with the amount of day light penetration inside of classroom spaces, and the parameters that influence the latter, determining relationships between these.

The principle aims of the study are:

1) To evaluate visual performance of primary level students under daylight condition.
2) To relate physical parameters of classroom spaces with daylight condition.

The study has explored the interrelation of student's visual performance, with the amount of day light penetration, inside of classroom spaces, and the parameters that influence the latter, determining relationships between these.

1.8. METHODOLOGY

1.8.1 RESEARCH STRATEGY

Primarily the strategy of the research would be observational. It will be necessary to identify and define independent variables, dependent variables, unit of the assignment, control group and system of measurements for this research.

Here the major possible independent variables would be:

- Illumination level at the top the desk
- Location of the student during the visual performance test.

The possible dependent variables are:

- Number of errors during the visual performance test
- Time for completion of test.
- Visual performance parameters (adequacy of day light penetration, brightness, contrast, glare, eye problems etc.

Unit of the assignment will be classrooms, with dissimilarity of daylight penetration at different depths of the space.

1.8.2 LITERATURE REVIEW

Extensive relevant literature has been conducted from published and unpublished sources such as books, national and international journals, reports, previous thesis works and web documents, to develop the concept of the research, and to assist in the design of the experiment, to evaluate visual performance under daylight condition. International standards for classroom spaces were also gathered, and criteria were set for the visual performance testing.

1.8.3 DATA COLLECTION

1) Designed government recognized schools set within Sylhet City Corporation, were selected based on the criteria established from the literature review. A physical survey of the study areas to determine physical parameters of the selected classroom spaces has also been conducted.

2) An extensive questionnaire survey and accompanying visual performance test, prepared on the basis of international standards, was conducted in the selected classrooms, on primary level students selected in accordance with established criteria. The procedure has observed, the required time, number of errors in a given task, and related them to different amounts of measured day light that was available during these tests.

1.8.4 ANALYSIS OF RESULTS

The results were related to daylight measurements, to estimate change of visual performance with change of daylight amount. Daylight measurements were also related to the classroom and surrounding conditions, to relate these with daylight penetration, in order to establish relationships with physical parameters of daylight inclusion in the classroom spaces.

1.9. SCOPE AND LIMITATIONS

The research work presented in this study, concentrates on day light inclusion in urban school buildings in Sylhet. Though in the tropics, with the daylight may enter unwanted heat, and too much or unguided daylight may cause glare, the study is limited to evaluating the visual performance of the students, under different daylight conditions. Recommendations are made regarding the existing building, which can be applied easily to other school buildings in the Sylhet context. The different

technical solutions like changing the properties of glass, movable shading devices, automatic controlling system, BEMS (Building Energy Management System) etc. were not considered in this research, but they may form the basis of further research from these initial findings.

Besides evaluating visual performance of the students, daylight inclusion is also related to energy consumption (electric lighting, mechanical heating and cooling), aesthetics, heat loss and gain, sound transmission, glare control, economics, ventilation, safety, security and subjective concerns of privacy and view. During the investigation, the consequences of daylight inclusion on energy savings, ventilation, view and comfort were however, beyond the scope of this research.

Moreover, participation of a vast number of students could have increase the accuracy of this research, but, the present work, within the given time and resources, compacted within a small sample size of 24 students. However, the method established for this small group of students, for assessing visual performance under daylight conditions, can be applied at a larger scale in further investigations.

The focus mainly lay on relating the physical parameters of classroom spaces, with different daylight condition and its impact on student's visual performance, with special reference to overcast conditions of Sylhet city.

1.10. INSTRUMENTATION

Digital light meter and stop watches were used during the visual performance test. Light meter was used for the measurement of illumination during the physical survey. Light meters are commercially available, that are color and cosine corrected, and suitable for measuring both indoor and outdoor lighting conditions. To measure illumination levels, readings were taken simultaneously using such a light meter: the TES 1332 Digital Lux meter (for detailed specifications, see Appendix A)

The research used Microsoft Excel data spread sheets to prepare the analysis of the student's visual performance test, and to produce necessary graphs, to determine the relationships between the amount of daylight penetration inside of the classroom spaces, and the student's visual performance under these different lighting situations.

1.11. THE STRUCTURE OF THIS THESIS

Chapter 1 provides a brief introduction of the subjects that are felt necessary for understanding this research. Understanding of visual environment, daylight, vision and visual performance is discussed in the chapter 2, based on established research and published sources, to provide a knowledge base for this research, which will help to be selective of the issues on which the experimentation and evaluation procedure is conducted later. Chapter 3 reports the findings in the physical survey of existing government primary school buildings in Sylhet city, aimed at an understanding the problems of luminous environments under the given context and in selecting the 'case schools' for further detailed investigation, and experimentation on students visual performance. Analysis of the student's visual performance tests, and relation with the amount of daylight penetration inside the classroom spaces, is discussed in chapter 4. Finally chapter 5 summarizes the findings of the entire research, recommending the possible guidelines, and identifying the research areas that need further investigation, subsequent to this study.

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CHAPTER: TWO

LITERATURE REVIEW

CHAPTER: TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Among all of our senses, vision provides us more information in a working environment, or any other context, in the world. Majority of jobs involve the use of visually displayed information, and as a consequence, environmental conditions necessary to optimize the eye's performance are of paramount importance **[1]**. It has always been an important aspect, to design the interior lighting, and to bring daylight inside.

Daylight is one of the most important natural forces available to architects, in their quest to enhance the visual quality of interior spaces. It is an abundant resource in the tropics, indispensable both as a primary source of illumination, as well as an ingredient of drama, excitement and dynamism, in the architecture and aesthetics of the spaces **[2]**.

Daylight can be defined as a conscious usage of glare free natural light, to illuminate a building's interior. Daylight advocates claim, that it yields significant benefits for a building, and its occupants, ranging from productivity gains, to an enhanced architectural design quality, and energy savings **[3]**.

Among the advantages of daylight, are physiological, as well as psychological benefits, for users **[4]**.Not only does daylight allow one to save on electricity consumption, but studies show that people actually perform better, when exposed to daylight **[5]**. Daylight is often used for ambient lighting, but may be used for critical visual tasks as well, in each case supplemented with electrical light, as needed **[6]**.

This chapter presents information on visual environment, particularly dealing with daylight, and its related terminologies and units. This chapter also discusses the basic information about the understanding of visual performance and its evaluation procedures. The different considerations for design with daylight are also discussed in this chapter.

2.2 VISUAL ENVIRONMENT

The visual environment is composed of three indispensable ingredients; firstly, a light source, secondly, an object, or surface, to be viewed, i.e. a task, and thirdly, an observer, i.e. an eye. The relationship between these three, is critical in designing a proper visual environment, and can be explained as source – observer – task relationship. The source of light, when considering daylight, is primarily the sun, but since the sun is hardly ever visible in properly designed buildings in the tropics, to avoid heat, the sun's light only enters as reflected light, from the sky, clouds, the ground and surrounding surfaces. Once it enters a space, the light is again reflected by the room surfaces, along with all furniture, and even the occupants, before it finally impinges on the task at hand. All these surfaces are, therefore, considered secondary sources of light, while the light entering through doors and windows into the interior, is considered as the primary source of light, and includes sunlight as well as reflected skylight, and the light reflected off external and ground surfaces **[7]**.

Of the sun's radiation, only a small fraction can be perceived by humans, through their senses. A narrow band, approximately composed of radiation of wavelength between 380 and 720 nm, is known as the visible range **[8]**.

Table 2.1 Wavelengths of sunlight with its color impressions and percentage of sunlight. (Source: http://www.solarpoweristhefuture.com/what-light-wave-do-solar-panels-use.shtml)

	Wavelength	Percentage of sunlight
Ultraviolet	10 nm – 380 nm	46%
Violet	380 nm – 450 nm	7%
Blue	450 nm – 495 nm	
Green	495 nm – 570 nm	
Yellow	570 nm – 590 nm	
Orange	590 nm – 620 nm	
Red	620 nm – 750 nm	
Infrared	750 nm – 10,00,000 nm	47%

Similar to all electromagnetic radiation, this range has the velocity of 3 x 10^8 m/sec in vacuum, and can be identified by its wavelength and frequency, which are inversely proportional. It gives two chief impressions, of the sense of sight as perceived by the eye, that of light, and of color, each associated with the characteristics of the wave. The impression of brightness is created by the amplitude of the wave, whiles the impression of color, is created by the wavelength of the radiation **[9]**.

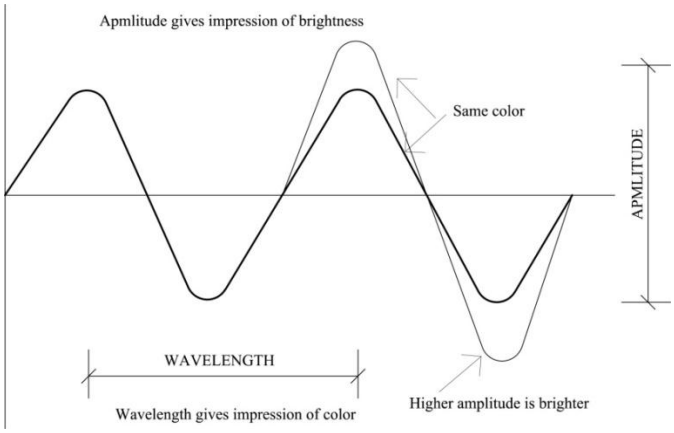

Figure 2.1 Impressions on human sight. (Source: AHMED, Z.N., (2014) *Letting in the Light: Architectural Implications of Day lighting*; First Edition, published by DAERS, BUET, Dhaka, p.73*)*

In addition, other impressions of color radiation are created by a slightly higher band of wavelengths, called the infra-red band. This range gives the sensation of heat, and is perceived, not by the eye, but by the skin. It is the associated radiation, and inevitable input with the visible band, that can be disturbing in tropical areas **[10]**.

The ultra-violet range, which is slightly shorter than the visible range of radiation, cannot be directly sensed by humans. This range however has the capacity to affect us much. It is known that, the ancient Egyptians worshipped the sun for its healing powers and used sunlight as medicine **[11]**.

2.3 DAYLIGHT:

The building envelope is thought of as a barrier between the internal, controlled environment, and the external, perhaps undesirable conditions. It must be realized that it should be a selective barrier, or rather a filter, which excludes the unwanted influences, whilst admiting those which are desirable. One such desirable effect is 'daylight' **[12]**.

Perhaps the most important communication channel of man with his environment is vision. The eye is stimulated by light, reflected from objects, which light is a prerequisite of seeing. Light can be produced artificially (e.g. electric light), but if it is available -as it is 'free of charge'- it should be utilized **[13]**.

2.3.1 SOURCES OF DAYLIGHT:

The ultimate source of daylight is the sun. When in bright sunshine, the illumination is around 1, 00,000 lux. The light arriving from the sun, may be partly diffused by the atmosphere, and locality prevailing atmosphere conditions, will determine how this light will reach a building.

If we consider a point inside a building, light may reach it from the sun in following ways (figure 2.2):

a) Diffused or skylight, through a window or opening
b) Externally reflected light (by the ground or other building), through the same windows.
c) Internally reflected light from walls, ceiling or other internal surfaces
d) Direct sunlight, along a straight path from the sun, through a window to the given point **[14]**.

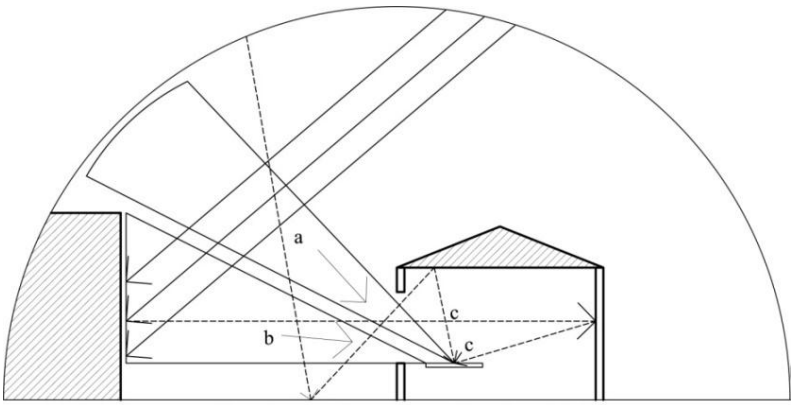

Figure 2.2 Daylight entering a building. (Source: KOENIGSBERGER, O.H., INGERSOLL, T.G., MAYHEW, A., SZOKOLAY, S.V., (1975) *Manual of Tropical Housing and Building;* p.141*.)*

CIE standard sky: The CIE sky is a standard overcast sky in which the luminance steadily increases, above the horizon (Figure: 2.3). The sky is defined, by the Commission Internationaled'Eclairage, by the formula **[15]**:

$L_z = L_h (1+2 \sin z)$

Where, L_z = Luminance at z altitude angle

L_h = Luminance at horizon

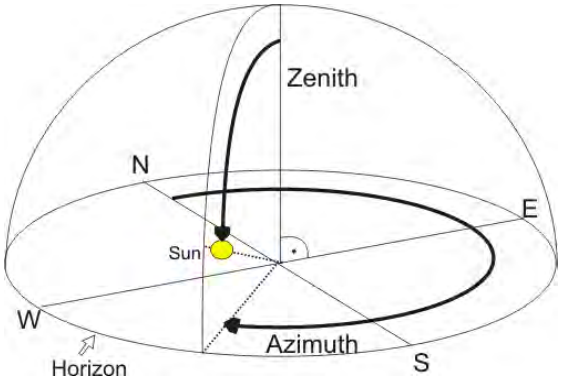

Figure 2.3 The Sun's Position in terms of Solar Altitude and Azimuth. (Source: http://infosys.beckhoff.com/content/1033/tf3900_tc3_solar_position_algorithm/Images/SPA_Angles.png, Date of Access: 04.11.2014.*)*

2.3.2 BENEFITS OF DAYLIGHT

Daylight in a building is not only about energy savings, and research **[16]** shows that it is difficult to justify the cost of extensive daylighting, on that basis alone. Rather the beneficial financial justification, of the widespread use of daylight in buildings, are related to its impact on human performance and workplace productivity, on human health, and on financial returns on investment **[17].**Physiologically daylight provides impetus, to both the visual, as well as the circadian system of human beings, while psychologically, day light offers much in terms of effects and views. The result of recent research attempting to quantify the benefits of daylight show that there is enough evidence that daylit spaces provide superior conditions, compared to those where daylight doesn't feature. Owing to the quality of daylight, research shows that only 35% as much light is needed for visual performance of specific tasks, than that required if the same task were to be performed, using artificial sources **[18].**At the same time, it must also be recognized that all the effects of daylight, may not be beneficial for the users. In the tropics, with the daylight may enter unwanted heat. Too much or unguided day light may cause glare **[19].** However, care needs to be exercised, when designing with daylight as it can cause visual discomfort, through glare and distraction, produced by veiling reflections, or by shadows **[20]**.

The three ways in which lighting conditions affect individual performance, are through the visual system, through the circadian system, and through the perceptual system **[21]**.The visual system functions as a very quick remote-sensing mechanism, that alerts us to environmental changes, and enables us to identify nearby threats and opportunities. The circadian system establishes an internal biological rhythm, by which humans set a daily cycle of dark – light within the 24 hour diurnal cycle. Research suggests that the sensitivity of the circadian system to light exposure, varies significantly over the 24 hour day **[22]**.Lack of daylight during the day can phase-shift the circadian rhythm, as can excessive electric light during the night. The basic reason for this is that the cycle production of many hormones and enzymes, are related to the cycles of daylight **[23]**. The most common disorder, due to lack of daylight exposure, is called 'Seasonal Affective Disorder' (SAD). The healing effects of sunlight, were recognized in the early 20th century, when patients were treated through exposure to sunlight in a practice known as 'heliotherapy' **[24]**.The impact of lighting conditions, on the perceptual system, deals with the ways in which individuals change moods, for different conditions. The basic problem in researching these mood swings is that mood is subject to so many external influences, that the impact of lighting alone is hard to isolate, and can be masked by uncontrolled

variations in other influences. However, research clearly shows **[25]** that daylight is preferred over electric lighting, and that windows are valued for the added benefit to the view they provide.

Daylight has strong influence on child psychology, and it applies more strongly on children, because of its changing nature throughout the day, and in different seasons, which has the capacity to create drama in spaces. Depending on the weather, daylight can create low-contrast (during overcast days) or high- contrast environments (during bright sunny days). Even the spaces where spirituality is not the main requirement, light can create a feeling of repose and calm. In such spaces, the daylight is allowed to diffuse in, and create a general ambiance, rather than sharp focal points. When there is the danger of heat associated with daylight, it can be filtered through foliage and vegetation, providing cooler, shadier daylight, thus breaking the monotony of artificially lit interiors.

Studies show that day light has specific influences on the human body, other than that normally associated with vision **[26].** It seems that ultra-violet rays are essential to children, and when most of the daylight hours have to be spent indoors, provision must be made to supply the ultra-violet rays indoors. Ultra-violet light, at the lower fringes of the visible range from the sun, is not sensed by humans, but its effect on humans is found to be beneficial, making daylight indispensable for mental and physical well-being. Ultra-violet of a certain range, can also be the cause for skin cancer, but at the lower latitude, that range is largely screened out from sunlight, by the outer atmosphere. Other studies **[27],** indicate that, monotonous lighting, while producing visual efficiency, is often associated with mental fatigue**[28]**.In recognition of the importance of daylight for human health, in the Netherlands, health regulations forbid buildings where staff sit further than 6m away from a window **[29].**Table 2.2 is shows the direct and indirect effects of daylight on child health.

Table 2.2 Direct and indirect effects of daylight on child health. **[30]**

Effect	**Direct**	**Indirect**
Physiologic	1.Erythema	1. Vision
	2.Pigmentation	2. Entrainment of Rhythms
	3.Epidermal Thickening	3. Reproductive Activation
	4. Vitamin - D Synthesis	4,. Entrainment & Suppression of Melatonin Synthesis
	5. Blood Levels of Amino Acids	
	6. Immune Systems	
Pathologic	1. Photo Sensitization Porphyries	1. Characterized Behavioral and Medical Effects.
	2. Ocular Damage	
	3. Carcinogenesis	
Therapeutic	1. Hiperbilirubinemia	1. Depression: Seasonal Affective Disorder (SAD)
	2. Rickets	
	3. Light Drug Interactions (Psoriasis, Leukemia)	

In spaces which are not very large, where daylight penetration can reach the deepest parts, artificial lights can be completely avoidable, with proper placement of functions and windows. This can allow considerable energy savings. Though this research is not attempting to identify energy saving issues, but as all the school buildings were found to operate their programs during the day, the proper utilization of daylight can limit energy consumption**.**

Daylight enters buildings through windows. Other functions of a window include ventilation and view, which are indirect benefits of daylight **[31]**. The need of privacy, however, conflicts with the need for daylight, and thus, these needs are to be treated carefully during daylight design considerations. Privacy and view are subjective matters, almost impossible to quantify scientifically. **[32]**

Figure 2.4 Daylight entering a classroom and view open to the outside. (Source: http://denverlibrary.org/files/LargeClassroomWindowView_0.JPG, Date of Access: 03.11.2014)

An additional indirect benefit of windows, like ventilation, can be determined objectively, but its preciseness is dependent on the accuracy of prediction of initial conditions. In the urban setting, this is a very complex variable, because of the proximity of buildings, which tend to cut off breezes, and also because of the hard surfaces, used in urban built forms, which tend to modify the urban micro climate, often forming heat traps. The BS (British Standard) daylight code recommends the inclusion of daylight, relating the added psychological benefits of relaxation.

All occupants of a building, should have the opportunity for the refreshment and relaxing, offered by changes of scene and focus. Unless an activity requires the exclusion of daylight, a view out of doors should be provided irrespective of its quality **[33].**

2.3.3 LIGHTING NEEDS FOR EDUCATIONAL BUILDING

An educational building is an expensive long-term resource. The design of its individual spaces, needs to be flexible, to accommodate both current, and evolving pedagogies, future-proofed to enable space to be re-allocated and reconfigured, bold to look beyond tried and tested technologies and pedagogies, creative to energies and inspire learners and tutors, supportive to develop the potential of all learners, enterprising to make each space capable of supporting different purposes **[34]**. This study will be concentrating only on classroom spaces.

Classrooms are mainly day use spaces, and energy considerations make it important to aim for using daylight, as much as possible. Classrooms need to make use of side lighting, preferable from the left, as a majority of the children are right handed. The main lighting challenges in classrooms, are the avoidance of glare on blackboards, minimizing the disturbances created by having side windows,

which normally face the access corridors, and minimizing the heat associated with natural light **[35]**. In this research, the orientation of the windows will be observed, to deal with the glare issues, but the primary concern of this study is to understand the illumination condition, at the top of the desk.

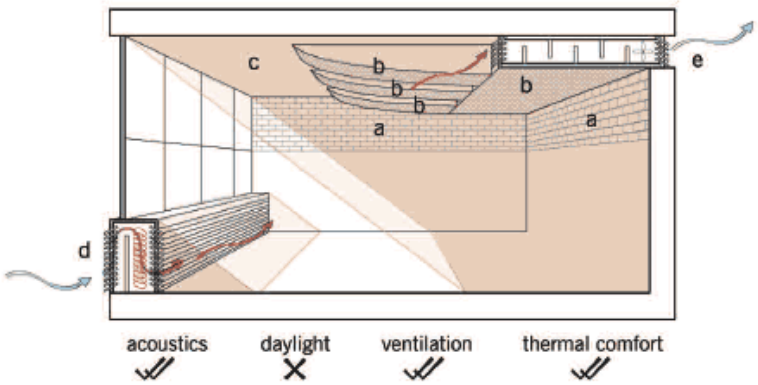

Figure 2.5 Glare on the board wall (Source: http://www.scotland.gov.uk/Resource/Img/167966/0050195.gif, date of access: 15.02.2015).

Experts suggest, that the light from windows should best come from over the pupils left shoulder, and that the teacher shouldn't be required to face windows, when addressing the class from the normal teaching position**[36]**. For lecture rooms **[37]**, the focus platform for the teacher and demonstrations, should be placed at a proper distance from the seating, and within viewing angles adequate for the purpose. Seating should be placed within a distance from the focus area, not less than twice, nor more than six times, the width of the chalk board screen to be viewed, and not more than 400 times the smallest letter to be viewed. Also the angle of elevation from the eye, to the upper part of the screen chalk board, should not exceed 30°. Light, whether from natural or artificial sources, should fall on the focus area and not on the audience.

Before the energy crunch of the 70s, lighting standards required that classrooms have a minimum daylight factor of 2%. But later studies showed that, to provide such levels, the windows were so large, that glare and overheating was inevitable. Studies relating window size to daylighting requirements were conducted. Based on these, the 1981 UK guidelines classroom window size was specified as 20% of the area of the window wall **[38]**.

2.3.4 QUANTITY OF LIGHT AND PHOTOMETRIC TERMS

Before proceeding to the analysis regarding the visual environment, it is a essential to introduce some of the basic technical lighting or photometric terms, that are used frequently in the lighting literature, and their conceptual understanding **[39]**. The terms and units used in this work are defined below in terms of the System International (SI units)

Illumination, symbolized by E, is the incident luminous flux (lumen) per unit area (m^2) and has a unit of lumens/m^2, more commonly known as 'lux' and is independent of direction. Illumination refers to the light falling on a body, or surface, and is not connected to its reflection coefficient, i.e. the amount of light it is capable of reflecting. From a point source, illumination reduces with the square of its distance, following the inverse square law. Thus a point source of unit intensity (I = 1 cd), has a flux of $\Phi = 4\pi l$ lumens, distributed around an area $4\pi d^2$ square meters at a distance d:

Illumination $E = 4\pi l / 4\pi d^2$ or $E = I/d^2$ lux.

Luminance, symbolized by L, is the incident luminous intensity (candela) per unit of apparent area (m^2), and has the unit candela/m^2or cd/m^2.Due to the largeness of the unit, it is often expressed by cd/cm^2, where each cd/m^2 equals 10000 cd/cm^2. Luminance is closest to the common English term 'Brightness', and the previous units of stilb and nit of brightness are not now in common use **[40]**.

2.4 VISION:

2.4.1 THE HUMAN EYE

The human eye is the organ through which human being sense radiation from the sun within the visual range, i.e. 380- 720 nm. Light enters the eye through the pupil passes through a lens and strikes the retina where an image is formed. This image is transferred to the optic nerve directly to the brain for interpretation, completing the process of vision **[41]**.

2.4.2 VISUAL ACUITY:

Visual acuity, or sharpness of vision, is defined as the reciprocal of the visual angle, subtended by the list perceptible detail form the center of the eye **[42]**. In any given situation visual acuity is dependent on individuals and is influenced by the following:

1) The quality of the eye
2) Luminance of the field of vision
3) Contrast between the object and the background
4) The presence or absence of disturbing factors, e.g. if there are strong background contrasts or glare.
5) The time available for the perception, i.e. whether there is adequate time for recognition.

The quality of any eye is found to deteriorate with age, making it necessary to have higher levels of lighting for the aged to perform the same task that a younger person can accomplish at lower lighting levels. **[43]**

2.4.3 CONSTANCY:

In addition, the eye also has powers of constancy, which enables the observer to intelligently weigh up what is seen and to perceive surfaces as having the same color, even when differential lighting makes different parts of the surface appear to be of different shades. This power of constancy fails in dim lighting, creating the impression of gloom, the four effects associated with which are:

1) The blackening of grays
2) Harsher modeling
3) Loss of vividness
4) The impression of coldness**[44]**

2.4.4 THE VISUAL FIELD:

The entire range of vision that one can see keeping the eyes stationary without moving the head is known as the visual field or field of vision. For the average eye this field extends 180° horizontally and 120° vertically. The vertical extent is not equally symmetrical about the horizontal (i.e. the line perpendicular to vision), being about 80° below it and only 40° above this (Figure 2.6).

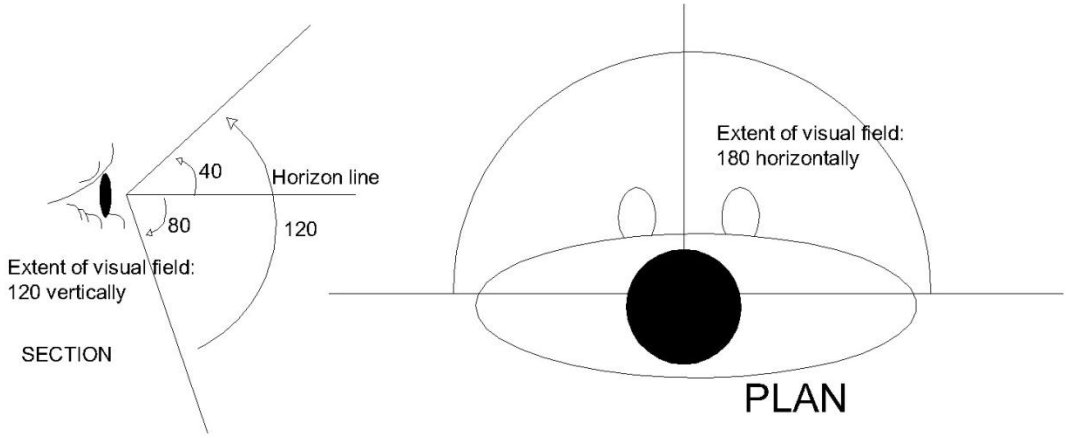

Figure 2.6 Physical extent of the visual field (Source: AHMED, Z.N., *Letting in the Light: Architectural Implications of Day lighting*; First Edition, published by DAERS, BUET, Dhaka; March 2014, p.88.)

The visual field can be divided into three distinct parts; the central field of vision, the immediate surround or background and the far surround or environment. **[45]**

2.4.5 EXTERNAL VISION FACTORS

The human eye, one of the three principal ingredients of the visual environment, during the process of viewing, is subjected to external limits set by the physical environment. These limits act on the eye, regardless of the eye's own powers, i.e. its visual acuity. These limits or conditions imposed on light energy in order to see are called external vision factors. The most important of these are: brightness, contrast/glare, color, size and time and they are all interconnected **[46]**.

A) BRIGHTNESS

Adequate brightness is essential for efficient viewing which is determined by the amount of light falling on any object and on its capacity to reflect this. Generally, visual performance increases with the level of brightness, but only up to a certain limit. Moreover, equal increments of increase in brightness will not produce equal increments of improved visual performance. Thus performance improvement drops until a certain optimum brightness level has been reached **[47]**.

B) CONTRAST AND GLARE

Contrast, the element of external vision factor, is a measure of brightness (illumination or lighting) differences between different areas of the visual environment. When the brightness difference between the various areas of a visual environment is too insignificant, there is no visual focus in the environment and the effect is a monotonous, uninteresting environment **[48]**. Too much of contrast may create glare.

C) COLOR

Color is a result of selective reflection from material surfaces and is the manifestation of the effect of wavelength on human vision. It is an extremely important external vision factor, having the ability to attract the focus of one's vision. Colors of the same wavelength may also appear different to the human eye because of differences in lighting, reflection factors and contrasts. Moreover, the human eye is not sensitive to all the wavelengths of light equally **[49]**.

D) SIZE AND TIME

Size and time are intimately related for visual activities. Any visual task needs some time for successful completion. The more complex the task and the smaller it's detailing, the more is the time needed to complete it. The amount of time required is also related to the state of adaptation of the eye **[50]**.

E) INTER-RELATIONSHIP OF THE EXTERNAL VISION FACTORS

When working with very fine detailing involving very small visual tasks as the visual performance test, more time is needed and an increase in brightness and contrast may do wonders in easing the visual task and improving performance. These relationships have been tested by researchers using visual performance exercises. Increasing time for the assigned task reveals relationships with the other factors and on the visual efficiency achieved. One of the objectives of this research is to establish performance through tests, and to relate them to the time of completion.

2.5VISUAL PERFORMANCE:

2.5.1 LIGHTING AND HUMAN PERFORMANCE

For purposes of learning, performance, and productivity, lighting in a school building should allow people to see to read, to see others with whom they are communicating, and to perform other visual tasks associated with learning, teaching, and school administration. Lighting can be provided by electric systems or by daylight through windows, clerestories, and skylights **[51]**. Typically, school buildings in Sylhet use a combination of electric lighting and daylight.

When evaluating the performance of any lighting system, electric or daylight, its impact on two biological systems—the visual and the circadian—may be considered, together with the physical attributes of light that differentially affect these systems. However, this study will focus on the visual system.

2.5.2VISUAL PERFORMANCE

Visual performance is defined in terms of the speed and accuracy of processing visual information. A model of visual performance should be independent of the influence of non-visual factors, as they influence **speed and accuracy**. It is also important to have practical application tools, that can measure the salient aspects of the visual environment, and compute (predict) visual performance for real tasks **[52]**.

Visual performance can be affected by several factors. Those which are inherent in the task (largely independent of lighting) are discussed below:

Contrast refers to the luminance difference between the critical detail of a task, and its immediate background. As the contrast of a task increases, performance will also increase **[53]**.

The **size** of the visual task is also important. A task with an infinitesimally small size will be invisible, with visibility increasing as size increases.

The **time** a visual task is presented also affects visual performance. For visual tasks which are visible for only very brief periods of time (less than 0.1 sec), the intensity and time are traded off, such that a signal which appears for half the time of a second signal, would need to be twice as intense to be as visible as the second signal.

Therefore, in a visual performance test, contrast and size can be kept constant. For different illumination levels, the time taken to complete the tasks can be all accurate indicator of the individual's visual performance.

2.5.3 LIGHTING FOR VISUAL PERFORMANCE

There is a complete model of visual performance tests available for predicting the impact of background luminance (light level), target contrast, target size, and observer age **[54].** In general, given the characteristics of the visual response functions, it can probably be concluded that most lighting and task conditions are adequate for most students **[55].** Going the next step of performance and productivity, however, is more questionable, because there is no evidence that the quality or quantity of light directly affects student learning **[56].**

It is assumed from the behavior of the students that, for a large majority of the students in buildings, lighting for vision during the day is quite adequate. Laboratory experiments show that young people with normal eyesight will systematically adjust the eye-to-task spacing to maintain good task visibility, either by moving closer to the visual task, or by shifting posture to avoid reflected glare **[57].**

2.5.4 LIGHTING FOR VISUAL PERFORMANCE FOR STUDENTS

A significant portion of the primary school-age population may not have properly corrected eyesight, however, and may not be able to take full advantage of adaptive strategies, to see educational materials in the classroom. In a large study using the 1996-1997 National Health Interview Survey, **[58]** it was determined that, approximately 25 percent of U.S. school-age children, have corrective lenses (eyeglasses or contact lenses). No such study was found for Bangladesh conditions.

It could be hypothesized that for those students who need, but do not have, corrective lenses, supplemental daylight may offer a significant advantage, by providing higher light levels, and better distribution of light (side light), to minimize shadows than would be provided by electric lighting alone. However, the potential for daylight in classrooms, to improve the visual performance of children, with, or without, properly corrected eyesight, has not been systematically studied.

2.5.5 GLARE AND VISUAL PERFORMANCE

There is much less certainty in predicting visual comfort in regard to glare, even in children and adults, than in predicting visual performance **[59]**. A clear distinction is made between glare, that reduces visual performance (disability glare), and glare that does *not* (discomfort glare). As would be expected, disability glare becomes more problematic with age, owing to physical changes of the eye, particularly from the scattering of light within the eye, by the crystalline lens **[60]**.

Formulas exist for calculating discomfort glare, and these are often used to characterize the lighting layout for a space, using commonly available lighting software. However, collective understanding of the mechanisms underlying discomfort glare, is rather poor **[61]**. Osterhaus (2006), Luckiesh (1944) were one of the first to propose the use of "brightness (luminance) ratios as a basis for ensuring lighting quality". For prolonged critical seeing,

- Brightness ratios smaller than 1:5 are desirable.
- Brightness ratios greater than 1:10 should be avoided if reasonably possible.
- Brightness ratios of greater than 1:100 should not be tolerated.

The calculations of these ratios are fairly straight forward, as they only involve measurements of lighting levels, at the brightest and darkest points of any space.

2.5.6 DAYLIGHTING AND STUDENT VISUAL PERFORMANCE TEST

In a recent study in Sri Lanka **[62]**, it could be seen that the required optimum lighting levels are generally lower in comparison to specified standard levels, and the researchers felt that the scenario is likely to be similar in other developing countries too. In Bangladesh there have only been a few preliminary studies **[63]**, incorporating human interaction with the visual environment **[64]**.

The visual environment of a classroom space can be evaluated, based on three aspects: Visual Performance, Visual Comfort and Visual Ambience, though it is difficult to quantify the latter two. The three aspects are summarized as:

- **Visual performance** – degree of efficiency with which the eye can function, related to the speed and accuracy required, for the visual task to be performed. This is the focus of this particular study.
- **Visual comfort** – optimizes the conditions in which the eyes have to function, reducing fatigue and thus increasing students' performance and satisfaction.
- **Visual ambience** – the general way students feel about their surroundings; the effect of the total school or classroom environment, on their state of mind.

This study will be limited on visual performance aspects, due to the limitations of time. Visual performance can be affected by a number of factors, which can be grouped in four broad based categories, and will be consciously maintained as constant in this research:

- **Age of the users:** In general, increasing age results in declining visual efficiency. This is predominant after 40 years of age, mainly due to the reduction of clarity of the vitreous humor and changes in the retina **[65]**. This study will focus only on primary school children.

- **Socio-economic background:** It is a general understanding that people who are used to living or working under certain conditions are adapted to those conditions **[66]**. Therefore standards can vary depending on expectations and habits. The subjects considered in this study, come from the contextual background of Sylhet, and it is assumed that, they are adapted to very similar backgrounds.
- **Nature of the task:** The complexity and nature of the task may require different lux levels, with all other conditions remaining the same. A performance test requiring the same amount of illumination is being set for this study.
- **Internal and external conditions:** Varying internal and external conditions give rise to varying illuminance requirement. Daylight may be obstructed or unobstructed externally, by neighboring structures or internally by office furniture, co-workers or even by the user himself. Other conditions such as; incident daylight on the window plane, transmittance of glass, reflectance of the room surface, room dimensions and work-top may affect the luminous requirements and the degree of performance efficiency. It is the purpose of the test in this research, to examine, whether changes of illumination affect the visual performance of the students.

2.5.7 STUDIES ON STUDENT'S VISUAL PERFORMANCE TEST

Several studies, investigating the effect of day lighting on student performance, were conducted by the Heschong-Mahone Group, between 1999 and 2003. In the 1999 study, data were obtained from elementary school districts, in three locations, having different daylight conditions **[67].** The study looked for a correlation between the amount of daylight provided by a student's classroom environment, and test scores. Test results for more than 21,000 students and 2000 classrooms in these districts were analyzed.

This study found that, the large magnitude of the increases in scores, sometimes exceeding 20%, was related to lighting to lighting levels. Another study in a different school district was conducted in 2003 **[68].** The amount of daylight was measured—by measuring light levels with electric lighting turned on and off. However, student performance was also found higher in classrooms with a better, primarily larger, view to outdoors. The effects of various parameters, linked to the presence of windows, other than the various daylighting environment, were also clear from this study.

Among the authors' conclusions were that sources of glare negatively affect student learning; direct sun penetration into classrooms, especially through unshaded east or south-facing windows, negatively affects student performance, likely causing both glare and thermal discomfort. Blinds or curtains allow teachers to control the intermittent sources of glare or visual distraction through the windows; absence of teacher control of windows negatively affects student performance **[69]**.

2.5.8 IMPACT OF WINDOWS ON STUDENTS VISUAL PERFORMANCE TEST

Windows can be a major source of light in school buildings, which also provide a view to the outside. Windows can also provide high light levels, and, when properly located, they can provide ideal distribution of light, for performing visual tasks, that do not involve self-luminous displays, such as computer screens, or audiovisual presentations. Skylights and clerestories can also be good sources of illumination, even though they do not provide a view. However, this advantage can only be taken for classrooms in the top floors of building.

Studies conducted using subjective ratings from adults, show that people like views from windows **[70],** and that those architectural spaces, with views from windows, command higher prices **[71]**. Although these findings for adult populations are interesting, the relationship between view and performance of students remains largely undocumented, and is also kept out of the scope of this research.

2.5.9 VISUAL PERFORMANCE TESTING OPTIONS

Study shows that, there are different visual performance testing options, under different situations and for different purposes. Among the different methods of taking visual performance tests, some are described here:

1) Computer based display use by B.V. Nagy in 2012 **[72].** They studied, Visual performance under different artificial illumination, including LED. They investigated the ambience with similar photometric and colorimetric parameters, but spectrally different light sources, in human visual performance. Their study was limited to the effects of photometric and colorimetric ambience on human visual performance, within two age groups, 20-35 years old and 55-70 years old.

2) VA chart, VSF chart used by J.Qu and others in 2003, for patients **[73].** They studied, corrected Visual Performance and Visual Quality, using VA chart (visual Acuity chart), observing the patients' corrected visual performance.
3) Stoffregen and others used counting the frequency of letters, on a block of text, to assess visual performance, in 2000 **[74].** They explored relations between visual performance and postural control. Variability in postural sways was analyzed, in the context of variations in supra-postural visual tasks. They varied target distance (near vs. far) and visual task (inspecting a blank target vs. counting the frequency of letters in a block of text). The search task placed more restrictive constraints on the visual system, and also that postural sway was reduced, to facilitate visual search. The experiment was carried out in accordance with ethical guidelines laid down by the West Campus Human Subjects Committee of the University of Cincinnati. Twenty-four undergraduates at the University of Cincinnati (mean age of 20, ranging in age from 18 to 44) participated in their test.
4) Several studies investigating the effect of day lighting on student performance were conducted by the Heschong-Mahone Group between 1999 and 2003, where they used math and reading scores of the children, to assess visual performance. **[75].** They investigated the effect of daylighting on student performance, between 1999 and 2003. In the 1999 study, data were obtained from elementary school districts, in three locations having different daylight conditions**.** The study looked for a correlation between the amount of daylight provided by a student's classroom environment, and scores of math and reading test. Test results for more than 21,000 students and 2000 classrooms in these districts were analyzed. This study found that, the large magnitude of the increases in scores, sometimes exceeding 20%, could be related to daylighting increases.
5) Mueller and others, tested visual performance for children, with attention deficit hyperactivity disorder in 2015 **[76].** They used the King-Devick (K-D) test; a vision-based test of rapid number naming, that requires saccades and visual processing. They investigated whether children with Attention Deficit Disorder (ADHD) had worse scores, compared to similar aged matched controls.
6) Yu Chen and His Lai experimented on visual performance testing, on computer keyboard legends and color for school children, using the effect of alphabetic character and color of the letters. **[77].**

Their study investigated, the best color combination sample of computer keyboards, for school children. 15 boys and 15 girls, having normal color vision, were recruited to participate in this experiment. All subjects in the experiment are 4^{th} to 6^{th} grade elementary school students, who have compulsory course in computer and English in school.

7) Tapio Jokinen and others studied visual performance deficits by sleep loss in 1999 **[78].** This study performed to detect the visual performance deficits caused by sleep loss. Six pediatric residents volunteered for the study, all having certain common physiological characteristics. It was a computerized performance test of 30 minutes. Stimuli were presented to the subjects on the display screen of an IBM-compatible PC. The target was displayed at random intervals (10-20 sec) randomly in one of eight possible locations on a 34-cm-diameter screen. The subject reacted by moving the cursor from the center of the screen to the target using a pointing device (Microsoft Mouse).
8) A questionnaire based visual activity test was studied by Sloane and others for assessing performing visual activities of everyday life. They identified the target areas of visual functioning such as visual processing speed, visual search, acuity, depth perception, light and dark adaptation, to be assessed by questionnaire. But, this study was limited to testing elderly people and drivers **[79].**
9) Wang,T.Y., Huang, H.C., Huang,H.S., studied computer assisted cancellation test system (CACTS) to understand the visual attention performance and visual search strategies in school children in 2004. They demonstrated some ways in which computer techniques can allow the educator, not only to obtain more detailed information of visual search strategies, but also to identify the problems of visual attention in school children. Their results show that there were no significant deference in correctness between sex, test layouts, and search patterns, except for the performance on different test forms (symbol vs. Chinese radical).The related factors that affect visual search behavior were also discussed. **[80].**
10) Sinan Hopcan, Elif Polat, Metehan Irak and Tufan Adiguzel studied the design, development and validation of computerized version of the Cancellation Test in 2013, the paper-pencil version of which was first developed by Weintraub and Mesulam (1985). This computerized version consists of four sub-tests (organized letters, random letters, organized shapes and random shapes) and administration panel where only researchers can access. The test was formatively evaluated by administering to a small group of university students and was accordingly revised. The final version of the test was validated on 52 university students. **[81].**

It is observed from the above list that, many researchers investigated visual performance with different methodologies for various circumstances, which are not similar to each other. Moreover, some researchers investigated visual performance with different age groups, with patients, with ambience of similar photometric and colorimetric parameters, with hyperactive disorders, and so on. There are also some studies, which investigated visual performance with the effect of drug and alcohol, visual performance for basketball players, visual performance in military tasks and so on.

It is obvious form the different case studies, that, visual performance tests are highly contextual rather than being universal. It is important to have a detailed understanding, of the circumstances, for the respective visual performance test. So, it is essential to justify the testing conditions, and the criteria for preparing the questionnaire, for specific visual performance tests to be conducted. In this research, the criteria for the testing conditions are discussed in the Table 2.3, and the preparation of the method for the test along with the visual performance test questionnaire is shown in table 2.4.

It is clear that, different testing methods are used under different circumstances, for taking a comprehensive visual performance test. In this study, the visual performance test addressed the local context of the primary schools, where the following aspects were considered:

1) Computer based visual performance test was not taken, due to the difficulties of arranging the computers and screens in the classrooms spaces. This can also cause unfamiliarity to the students of government primary schools in that area.
2) Heschong-Mahone group studied with math and reading score, to assess student's performance. To be more specific towards the visual performance analysis, the questionnaire used in this study, addressed the identification of symbols, rather than using math and reading scores, due to unavailability of such data on a regular basis.
3) Methods used for detecting specific factors, which can affect the visual performance, such as sleep loss, hyperactivity disorder were not considered in this research.
4) Methods used for taking visual performance test considering elderly people, drivers, players and so on, were not considered in this research.

Visual performance tests, conducted in this research, have several justifications related to the testing conditions and questionnaire pattern, which is described in the section 2.5.10.

2.5.10 CRITERIA FOR TESTING CONDITIONS OF STUDENT'S VISUAL PERFORMANCE TESTS AND TEST SHEET DESIGN:

A variety of tests are available for the evaluation of visual performance. Many tests are applicable for adults, and some are for children. It is essential to ensure appropriate testing conditions in the classroom space, where the visual performance is going to take place. The testing condition for a visual performance test, and preparation of test sheets to be used in the test for this research, are described below with necessary justifications.

2.5.10.1 TESTING CONDITIONS:

The overall testing condition should encompass the physiological and psychological state of the children, during the test and the physical settings of the classrooms. Table 2.3 shows the testing conditions in detail:

Table 2.3 Testing condition for visual performance test of the children with its rationale.

NO	TESTING CONDITION	RATIONALE FOR THE CRITERIA
01	The overall physical and psychological environment should be friendly and fearless for the children	This is a prerequisite, which should be ensured before taking any visual performance test. The children will naturally intend to take it as a regular academic examination. The researcher will have to motivate them about the purpose of this test, and to convince them, that, they are not going to appear for any

		academic examination. If the fear works in the mind of the children, they will not be able to perform naturally and to the best of their ability, which will distort the outcome of test, in terms of, increasing time to perform the task and increasing errors also.
02	The examinee should be allowed time to become comfortable and familiar with the room setting.	For any visual test, it is obligatory to give the examinees enough time to be comfortable and familiar with the luminous environment and also with the other physical settings of the classroom, so as not to negatively affect the visual performance test and increase the error percentage and required time for completion of the task. Though the dark adaptation depends on intensity and duration of the pre-adapting light, size and position of the retina, wavelength distribution of the light used, Rhodopsin regeneration etc, but studies show that, sensitivity of eye had increased 35 times after time in the dark, and Aubert (1865) introduce the term "adaptation". **[82]**. In this research, it is considered that, some of the examinee had been sitting in the classroom from long before the test starts, but some may join in the classroom from outdoor play areas, where the difference of illumination level are quite high. So, it is required to allow time to adjust with the luminous setting of the classroom for all examinees.
03	The examiner must take some time for describing testing materials.	Before the test starts, the testing materials and what exactly the participants need to do during the test, should be clearly and if necessary, repeatedly spelled out to ensure their understanding of the test. As the main objective of this test is to evaluate the visual performance, any ambiguity regarding the test may distort the results.
04	Pens are preferred to pencils if writing instruments are necessary.	if pencils are used as writing materials, a few types of problems may generate: a) If wood pencils are used, it may require sharpening again during the test, which will take unexpected extra time, and will affect the relationship between required times of a given task under daylight. b) If lead pencils are used, there are also possibilities for refilling the lead, which will also take unwanted time and distort the key findings. c) The research needs to preserve the testing materials for further analysis. The pencil writings may fade in course of time where, instead of which, pen is a good choice as writing material, in this type of test.
05	Sitting arrangement must ensure the three	Sitting arrangement will ensure that, each performing student will appear in the visual performance test under three different types of daylight condition; firstly window side, where the daylight measures highest among

	types of daylight condition for each performing student.	all other spaces in the classroom, then corridor side, where the daylight amount is found poor, and in the middle row of the classroom, where the amount of daylight measured lower than the other two situations. This is how; the research will evaluate a comparative study of individual student's visual performance indicators (error and time) under three different types of day lighting.
06	Breaks should be allowed whenever the examinee feels fatigue and between two tests	It is necessary to give time in between two tests, which will help to prevent monotony and fatigue in the testing process. This break will also allow students to change their sitting positions, according to the instruction, distribution of new question sets, and slight conversations between examiner and the examinee, will keep the students lively for the next test to be performed. It is necessary to consider that, boredom of repeated exams may cause adverse psychological impacts on the children's mind, which will certainly affect the visual performance test results.

2.5.10.2 CRITERIA FOR TEST SHEET DESIGN FOR STUDENT'S VISUAL PERFORMANCE TEST AND IT'S RATIONALE:

The test sheets should be prepared, on the basis of aspects that, validate the visual performance test sheets, and prevent bias or influences by other factors, that can affect the result of the visual performance test. The possible aspects along with their justification are described in the table 2.4.

Table 2.4 *Criteria for test sheet design for visual performance test of the children with its rationale.*

NO	CRITERIA FOR TEST SHEET DESIGN	RATIONALE OF THE CRITERIA
01	Typed materials should be represented in large print.	The size and shapes are crucial factors determining the legibility of print. It has a key role in understanding reading performance, which will lead to the ultimate visual performance assessment. **[83]**. The contents in the testing material, it should be in a sufficient size, so that, the eye can process the visual information, without hampering visual acuity, which may affect the visual performance. Thus, the result will be free from the influences of stress in eyes of the examinees.

02	Avoiding the contents for a merit test or intelligent test	The primary focus of the test sheet design is to identify the visual performance rather than identifying the merit or intelligence of the student. Intelligence tests are psychological tests, that are designed to measure a variety of mental functions, such as reasoning, comprehension, and judgment, **[84]** ability to form concepts, solve problems, acquire information, reason, and performs other intellectual operations **[85].** On the other hand, merit tests measure general sharpness of memory, skill on mathematics, skill on language, design quality etc. But, in the visual performance test, all the items discussed above, to measure intelligence and merit, should be avoided. If the test sheet of the visual performance test, incorporates the intelligence and merit issue, the finding of the test will be distorted. Primarily and principally, the test sheet concept for visual performance test for this research should be limited to identifying only those aspects, which can fluctuate with changes of illumination levels.
03	The question pattern should not generate fear to the students.	The elements used in the questionnaire should not incorporate any items or images that can generate fear in to the children mind, and which will affect the visual performance test.
04	Counting elements within a frame and identifying numeric figures are suitable for such tests**.**	It is obvious, that, the amount of illumination will affect the result of counting elements in terms of accuracy and required time. So, counting elements within a given frame will also justify the result of students' visual performance test.

2.5.10.3 TEST SHEET DESIGN FOR THIS VISUAL PERFORMANCE TEST:

Based on the literature survey, three sets of the test sheets were prepared for the visual performance test for the students. Three sets were required, as the test will be conducted under three daylight situations individually. There are a total of 500 randomly placed different symbols, in the each set of questionnaire, where there are total 100 specific symbols, which the subjects were asked to cross out.

Every set of test sheet is unique, in terms of the arrangements or placements of the symbols. One sample test sheet is shown in the figure 2.7, where the details of this test sheets are included in appendix D.

QUESTION SET: A
SAMPLE NO:
SITTING POSITION OF THE STUDENT:
(BESIDE WINDOW/ MIDDLE ROW/ BESIDE CORRIDOR)

Error percentage:
Score:
Time required:
Score:

Name of the student:(/ নাম) :

Find out the symbol 'π '

€ π β μ β π ± μ ÷ € π ∑
± Ω ¥ π ÷ ¥ π € ≠ ∑ © μ
π £ ≥ € μ ≤ π α π α Ω

≤ π ≥ μ ≥ π Ω © Ω ± β ¥ α
π Ω ¥ π £ α £ ± ≤ Ω ± μ
β α μ β μ ¥ π ¥ μ ¥ π ¥
∑ ± ± ∑ Ω α Ω ∑ ± α μ €
β ± ± β £ ∑ ¥ μ α ¥ α μ β
μ α Ω π £ ¥ μ ¥ £ π ∑
± Ω ¥ Ω ± ∑ α π £® ± μ
Ω π ≤ © Ω β μ £ € ≤ π
€ © α ¥ ∑ Ω π € β ≤ μ ∑ ± π €
£ ≤ € α ≥ α € ∞ ± × α ® £ ®
π ≤ π Ω β ≠ ∑ € © ∞ ☺ π ∑ ± € π ∞ π ©
× Ω ® ≠ ∞ π ≠ ¥ ∑ ≥ ∑ ± ≤ Ω π ≥ ±
∑ ± β ≤ ¥ π ≥ ± β ∑ α π α Ω μ π ≤
€ © ≤ π Ω Ω π α ± © € μ π
β £ α € α Ω β ¥ £ π € Ω ≥ ± ± ¥
≥ π ≤ £ ± Ω ≥ π © ≤ α ± ∑
≤ £ ☺ α ® £ α ∞ μ ¥ π Ω π α π £ π ≤ ≥ © ∑ α © ≥
£ π ± β ® α π Ω β β μ π ± £ π μ ∑ π
¥ β π © © μ ≥ £ ± π β α Ω β
π ® ¥ ≠ € β β Ω © π £ ≠ ¥ π ¥ ≥
α ¥ π © π ® ± μ ≥ ± μ π β ® ® β © ± Ω €
± β π μ μ π β β £ Ω £ α β π μ ± €
¥ ≥ ≤ π ± μ ± ¥ ± μ π β Ω ¥
Ω β π © μ ± μ © π £ € β
€ £ π α © μ © α π ± € μ £ β © μ π ©
π μ π μ ± π € α Ω π ≤ ≤ π μ β
π ≤ © α ≤ π Ω ® μ © ® Ω μ π ® ¥
π £ β μ π ≤ π μ ® Ω ©
μ π ± € α α ± π μ ¥ π μ π ±
£ ± π β ¥ π ¥ ¥ β μ μ β
¥ π © ± π μ μ π ± β α π β π β
α ± μ ¥ £ € Ω ± ± Ω
€ £ ¥ α ± μ β π ± π μ β π
β β π μ π μ ¥ £ π β β €
€ β π ± β ± ± β π μ £ Ω μ π
≤ π £ ≤ β © Ω π μ ≥ £
β Ω © ≤ π £ ≥ ¥ € © ≤ Ω β π μ
∑ α © ≤ ¥ ± ∑ μ ® ¥ α € £
€ α ∑ μ Ω £ π ∑ Ω μ α ±

Figure 2.7 Sample test sheet used for Visual Performance Test.

2.6 LIGHTING CRITERIA FOR SCHOOLS

From literature survey, we know that performance of students increases, in a good visual environment **[86]**. Besides that, energy use by electric lighting is one of the important energy costs for schools **[87]**. These are reasons to research the design possibilities for an optimum use of daylight. However, a classroom is a difficult space to light with daylight, because of the depth of the classroom and the different tasks which must be performed in it. At the University of Delft, research has been done in order to optimize the daylight access by the design of classrooms.

Light levels in school buildings, are strongly influenced by the expected visual performance requirements for a given task. In general, higher illuminance levels are recommended for specialized tasks, such as reading and writing, than for less demanding visual tasks, such as eating or walking. Lower illuminance levels are also recommended for public spaces where reading and visual inspection are only occasionally performed or where there is no time pressure to complete the task. The recommended illuminance levels are given here **[88]** for specific tasks in classrooms.

- Desks (300-500 lux on a desktop),
- Chalkboard (500 lux on a vertical surface),
- Corridors (100 lux on the floor), and
- Art rooms (500 lux on a desktop, 300 lux in the vertical plane)

These values have been compared with the illumination conditions of the classrooms in this research, taken for the case studies in Sylhet, which is described in Chapter Three.

2.7 PHYSICAL PARAMETERS OF A CLASSROOM RELATED TO DAYLIGHT

There are many physical parameters, that can be considered in the detailed design process of a classroom but this study is only addressing the factors which are related to daylight inclusion within the classroom spaces. In this research, these factors were identified in the case studies (Chapter Three), as they have strong influence on the overall daylight condition of the classroom.
The different physical parameters, which can affect the penetration of daylight inside of the classroom spaces, can influence the overall luminous condition of the classroom. Though this study aims primarily to find out the relationship between the daylight conditions with the student's visual performance, it is also important to understand the physical factors, which affect the daylight condition within the classroom spaces. The physical parameters, which affect the distribution of daylight within the spaces, are named and described below:

A) THE SIZE AND ORIENTATION OF THE CLASSROOM (LENGTH AND BREADTH).

The size of the room must be designed, to accommodate the programmed number of occupants, as well as, to provide for additional support space. The support space must take into consideration, the setup, the use of audio-visual equipment, access for disabled, layout of the instructor's materials, circulation space, and empty floor space, which acts as setback, to keep students from being seated too close to a chalkboard, and also accommodating projection screen, or video monitor.

Studies show that, the area of each Classroom shall be **70 -76 sqm (**an average of **2.33 sqm – 2.53 sqm/** pupil**)** minimum, with a class capacity of **30 pupils**. The geometry of the classroom can differ, with the various architectural considerations. However, there should be one Classroom of 91m², which can act as a combined classroom/general purpose room in each school **[89].** A floor area of **7.5 sqm** per Classroom shall be designated as Storage, within the classroom itself. The required classroom size according to the number of pupils, is shown in the Table 2.5**.**

Table 2.5 Space requirements for students in different classrooms. **[90]**

Setup Style	Space per Person	Notes
Type I Classroom: General	1.57 – 2.04 sqm	Allows for use of rectangular tables that are 1.8 or 2.4 m long and .45 m wide, with 0.6 m per person and 1.05 m between tables as the minimum for comfortable set.
Type II Classroom: 60 People or less	2.04 to 2.14 sqm	As noted above.
Type III Classroom: Practical Skills Classroom	2.32 Sqm	Variables must be considered dependent upon what types of skills are being taught and the amount of student participation at any one time.
Type IV Classroom: Computer and/or Distance Learning Classroom	2.8 to 3.7 Sqm (dependant on use)	For use of individualized computer or laptop workstations, 2.8 to 3.7 sqm is required. For use as distance learning for generalized lectures, all requirements for types I and II must be followed.

In existing school buildings without Classroom Storage, and where there is no suitable adjacent space, which can be designated as Storage, additional Storage may be allocated, subject to a maximum area of **7.5 sqm** per Classroom or **35 sqm** total area, whichever is the lower **[91].** The orientation of Classrooms and their location relative to the development of the external environments, i.e. natural ventilation and provision for natural light penetration, must be considered by the Design Team, in the planning of the building.

B) CEILING HEIGHT OF THE CLASSROOM.

Ceiling heights should be considered, in the context of the size and function of the space, and should take into account the physical environment, within that space. A minimum finished floor to ceiling height of **3.150 m** should be provided in all Classrooms, corridors, and administrative areas. In larger

rooms, such as assembly areas, the height should be in proportion to the size, and take into account the function and any specialist requirements, such as day light inclusion and natural ventilation. **[92].**

C) LOCATION OF THE CLASSROOM, PRIMARILY IN WHICH FLOOR

The location of the classroom at different floors, can allow different amounts of daylight inclusion, particularly in the dense urban situation. Ground floor has the lowest day light access, due to the highest obstructions for daylight inclusion. So, this aspect should be considered during the design process, to ensure desired amount of daylight, within the classroom spaces in the ground and lower levels of the school building, allowing larger or more number of windows in the lower floors.

D) SIZE AND ORIENTATION OF THE OPENINGS

The position and size of opening window sashes, must take ease of operation into account, and maintain an adequate level of safety, i.e. sashes should not open dangerously over adjacent paths at ground floor level. **[93].**

E) MATERIAL AND TEXTURE OF THE OPENINGS

Windows should be easy to clean and maintain, and have permanent ventilation louvers, in addition to high and low level opening sashes. Vents should contain baffles for noise, wind and rain. Permanent vents and opening sashes, should exceed the current guidelines set out in the technical guidance documents to the Building Regulations, and should be designed to suit the class environment having regard to the high levels of humidity generally in Classrooms **[94].** There are no such stipulations in the Bangladesh National Building Code.

F) MATERIAL, COLOR AND TEXTURE OF WALLS, FLOOR AND CEILING

The material used in floor, ceiling and wall, should appear in light colors, as it can have a better reflectance, than the dark colors **[95]**.

G) THE RATIO OF WINDOW AREA AND FLOOR AREA

Until detail daylighting analysis is conducted, the following basic rules of thumb can be taken to determine the right amount of daylight **[96].** The situations are for the US context in general, which also includes low latitude areas.

a) South facing window area: 8% - 11% of the floor area
b) South facing window with lightshelfs: 8% - 11% of the floor area
c) South facing window with lightshelfs and blinds between glazing: 15% - 20% of the floor area
d) North facing window area: 12% - 15% of the floor area

Classrooms windows should address the following features: **[97]**

a) Natural Lighting from left of Children (considering most of the children are right handed.)
b) Blackboard position should not be just opposite to the window side.
c) Area of windows: **20% of floor area (1:5)**

H) NATURE OF THE SHADING

The nature of the shading device can strongly affect the luminous environment, under daylit conditions. Addressing the following design considerations, during the design procedure of shading devices or light shelves, can improve the daylight inclusion in classroom spaces **[98]**.

a) Recognizing the limitations of side daylighting.
b) Bouncing light into deeper spaces.
c) Selecting durable but reflective light shelf materials.
d) Shading lower view glasses.
e) Restricting direct beam with directional blinds.
f) Using horizontal blinds between glazings.
g) Elongating rooms to maximize glazing opportunities.
h) Sloping ceiling from top of light shelf down to back of room.
i) Avoiding the use of light shelf in north walls.

I) PATTERN OF THE SITTING ARRANGEMENT

Pattern of the sitting arrangement can also impact on the effectiveness of daylight, received in the classroom. The arrangement of the children sitting, will be more efficient if the day light enters from the left hand side, considering the right handed students are in majority **[99]**.

J) SURROUNDINGS OF THE CLASSROOM

Surrounding obstructions, affect the daylight penetration severely. Trees and other buildings create shadows, and restrict the access of daylight, within the classroom spaces. So, it is important to develop the layout plan of the school building, considering adequate distance from neighboring structures.

2.8 CONCLUSION

The question of daylight inclusion in school buildings is important, because being day-use buildings a significant portion of the period of use of these buildings, coincides with time when outdoor lighting is substantial. Using this light, dependence on artificial lighting source can be minimized, affecting students' performance and the energy efficiency of the building.

To improve the index of visual performance, daylighting requires the integration of all major building systems. Early planning is essential, since it may be difficult and costly, to add features later in the design development. This chapter also included a review of criteria for visual tests, which helped to design the test for the study area and sample group.

As the primary focus of this research is visual performance testing, a field investigation was performed for this study. From the initial study, 'case schools' have been selected, representative of Sylhet's trend in urban Government primary school buildings (Chapter Three). The condition of these schools, with respect to the standards mentioned in this chapter (section 2.7), has been included in chapter 3. The student samples from these schools have been involved in the visual performance test under daylight conditions, to evolve a relationship between the light levels and visual performance. (Chapter Four).

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CHAPTER: THREE

FIELD STUDY

3.1 Introduction and objective of the field study

3.2 Criteria for selection of study area and case studies

3.3 Pre survey works

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3.5 Findings of the pilot survey

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CHAPTER: THREE

FIELD STUDY

3.1 INTRODUCTION AND OBJECTIVE OF THE FIELD STUDY

This chapter presents a study of urban primary school buildings, located in different places of Sylhet City Corporation area, to set up a picture of the current situation of the luminous environment in classrooms, and to determine the key issues, where daylight could largely enhance the luminous environment, and have an effect on the student's visual performance. A pre survey work was conducted on the school buildings within in the Sylhet City Corporation area to explore the different features, and to select the classroom that will be used for the visual performance testing, in this research. The findings of this investigation, helped to identify some specific problems, and led to select for the detailed investigation conducted in the next phase of the field study, considering existing daylight condition, and its effect on the student's visual performance.

3.2 CRITERIA FOR SELECTION OF STUDY AREA AND CASE STUDIES

3.2.1 REASONS FOR STUDYING WITHIN THE URBAN CONTEXT OF SYLHET

Currently, Sylhet is one of the most important divisional cities in Bangladesh, regarding economy, education and exploration of architecture practice. It has a dominant warm-humid climate, where heat is accompanied with high humidity, and higher rainfall in comparison to other cities of Bangladesh. Due to the high physical density in urban areas, the penetration of daylight within classroom spaces is lower, than in a school in a rural setting. Therefore it is challenging for architects, to maximize the use of daylight, in urban school buildings.

Sylhet is located in north-east corner of Bangladesh, and has a characteristics climatic condition in terms of sky condition, rainfall, humidity and precipitation. In Bangladesh there have been a few preliminary studies **[1]** incorporating human interaction with the visual environment**[2],** but none specifically in the divisional town of Sylhet, where skies are generally overcast, throughout the year **[3],** unlike other divisional cities in Bangladesh.

3.2.2 REASONS FOR STUDYING WITH PRIMARY LEVEL STUDENTS

In most of the cases, children are generally found good in vision, rather having eye problem like Myopia (short sightedness vision) and Hypermetropia (long sightedness vision), which are predominant contexts for visual performance tests. These two visual problems can significantly influence the visual performance test with respect to day light condition inside of the classroom spaces. Studies show that luminous performance of elderly people is lower than that of younger people. Therefore, inaccuracy in eye may distort the results of any visual performance test. Though it is difficult to initiate concentration on primary level students, but once it is achieved, the result of any visual performance test should be

considerably free from other influencing factors, like individual intelligence, intention and difference in visual aspects.

3.3 PRE SURVEY WORKS

For this field investigation, a pre survey work was conducted, to prepare the survey strategy in primary schools in Sylhet city. Students were asked to provide their responses, along with their teachers, about the visual performance test. Students were given the understanding, that they would be appearing in the visual performance test, which is dissimilar to the other regular academic examinations. This helped to get rid of their fear about the test.

During this period, a clear indication about this visual performance test, the purpose of the test, what exactly they need to do during test, and how much time they will be able to take, etc, was instructed to the students. An important issue emerged in the pre survey period, that the students were difficult to control, in the absence of their teachers. Therefore, from the pre survey, it was decided that the teachers of the respective classes would have to be informed and requested to be the part of the testing, before the actual survey, so that, the students could have a familiar feeling within the classroom, during their actual visual performance test.

3.4 PILOT SURVEY

Sylhet district divided in to 13 sub districts or upozilas **[4].**Among these, Sylhet City Corporation (S.C.C.) area comprises of the following upozilas:

a) Sadar upozila (Part)
b) Dakkhin Shurma Upozila (Part)

Highlighted part in the figure 3.1 shows the Sylhet City Corporation area.

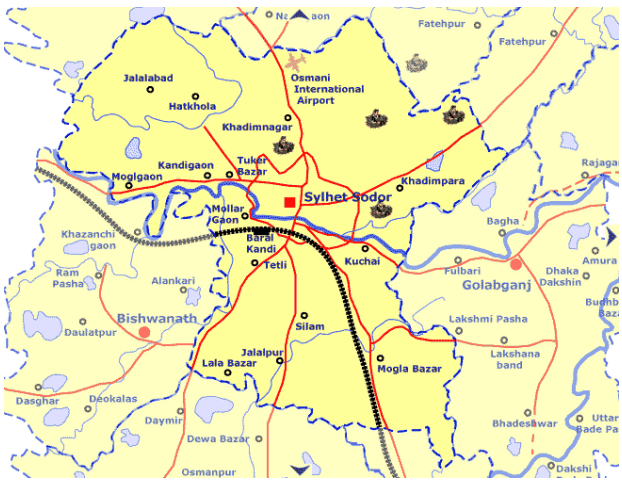


Figure 3.1 Sylhet City Corporation map (highlighted part) (Source: Sylhet City Corporation)

There are total 121 primary schools located in different areas of these two upozilas. Among these, the types of schools are:

a) Government Primary school: 97
b) Registered Primary School : 18
c) Community Primary school: 06

Figure 3.2 is showing the proportion of government, registered and community schools in Sadar Upozila and Dakkhin Shurma Upozila.

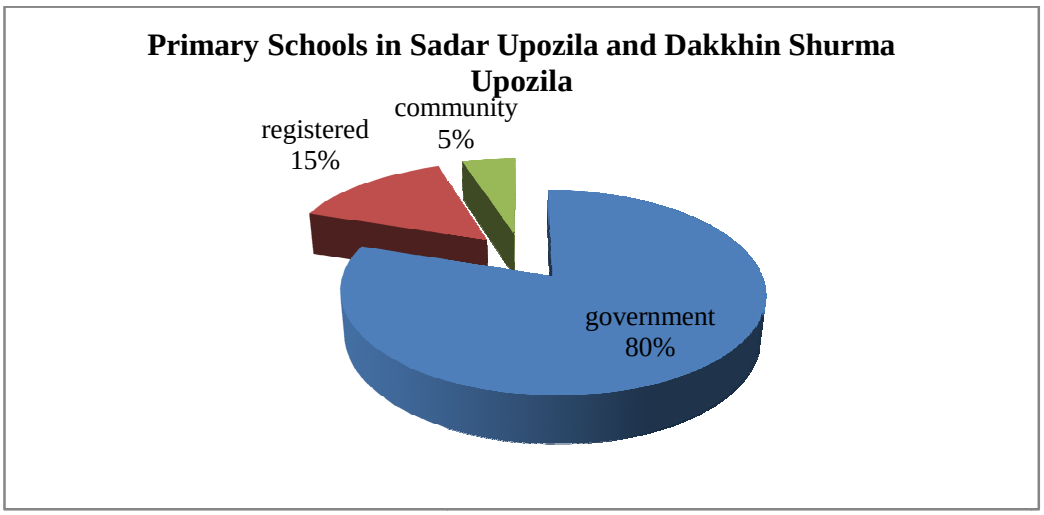


Figure 3.2 Showing the proportion of government, registered and community schools in SadarUpozila and DakkhinShurmaUpozila (Source:Upozila Primary Education Office, Khadimnagar, Sylhet).

The preliminary survey focused on Government primary schools, as the registered and community primary schools are mostly operating their programs in converted buildings including some floors of residential or commercial buildings, rather in a building designed for school purposes only. The list of 97 Government Primary Schools is given in Appendix B, where the particular schools which are located within the Sylhet City Corporation area are highlighted.

Among these 97 Government Primary Schools within Sadar Upozila and Dakkhin Shurma Upozila, the distribution of the schools area as follows:

a) Within the Union Parishod: 60 Schools
b) Within City Corporation area: 37 schools

Figure 3.3 is showing the proportion of government primary schools under Union Parishad and Sylhety City Corporation area within ShadarUpozila and DakkhinShurmaUpozila.

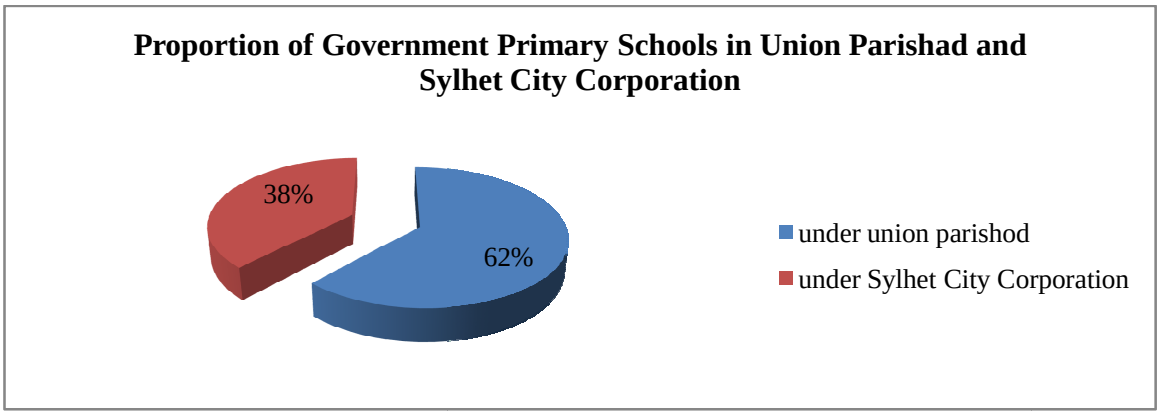


Figure 3.3 Showing the proportion of government primary schools under union parishad and Sylhety City Corporation area within ShadarUpozila and Dakkhin Shurma Upozila (Source:Upozila Primary Education Office, Khadimnagar, Sylhet).

The 37 schools, located within the Sylhet City Corporation area, were included in the pilot survey. The survey covered a broad area through a questionnaire about the physical characteristics of the primary school buildings in urban areas of Sylhet. Discussion on this segment (Table 3.1) will be limited with some criteria selected, to justify the rationale to select the case schools, for further detailed investigation.

Table 3.1 The specific items covered in the pilot survey, criteria's of case schools for detailed investigations and rationales for those criteria's.

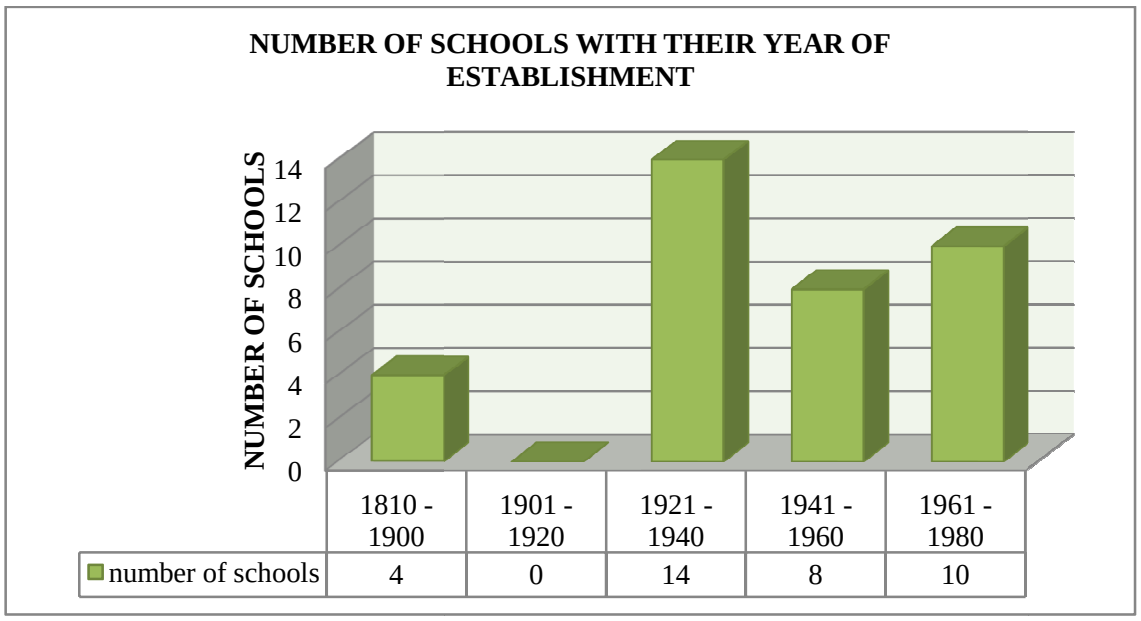
	Items covered in the pilot survey	**Criteria for example schools for detailed investigation**	**Rationale of the criteria**
01	**Nature of the structure:** Permanent or temporary (semi pucca) structure	Permanent Structure	Research data will be valid for a longer time considering the structure is permanent.
02	**Building height:** How many storied	Minimum double storied	Obstructions in the immediate surroundings (boundary wall, nearby buildings and plants) impact on the amount of daylight penetration, which differs in the lower levels and upper levels.
03	**Purpose built or converted building**	Principally Built as primary school building	As the research evaluates visual performance of the primary level students so the building should be designed as a primary school.
04	**Student number**	600 and above	Good number of students increases potential for the random sample selection.

05	**Co- education or gender specified education**	Combined education	The research data will be gender neutral.
06	**Yearly overall performance evaluated by the government**	Category 'A'	Experiment result for classified schools recognized by the Government will justify the implementation procedures and further relevant research. It ensures good quality of students which impacts the reliability in the testing.

3.5 FINDINGS OF THE PILOT SURVEY

3.5.1 DATE OF ESTABLISHMENT:

There are 37 primary schools within the Sylhet City Corporation area, established in different times, ranging from 1810 to 1974.Figure 3.4 gives a clear picture regarding their date of establishment.



None found after 1980

Figure 3.4 Total number of Schools within the Sylhet City Corporation area with their date of establishment (Source:Upozila Primary Education Office, Khadimnagar, Sylhet)

It is observed that, since 1981 there is no new establishment of government primary schools in the Sylhet city corporation area. So, this will have a great opportunity to introduce a better luminous environment by considering the utmost use of daylight in future constructions.

3.5.2 WORKING HOURS

The working hours in the surveyed schools are found mostly similar. There are 3 types of opening and closing times, found during the survey. Every school operates their program in two shifts.

a) Morning shift -4 hours (starts from 7:30 am, 8: 00 am, 8: 30 am)
b) Afternoon shift – 4 hours (starts from 11:30 am, 12:00 pm, 12:30 pm)

Table 3.2 shows the number schools with their working hours for the 37 primary schools, mentioned in section 3.5.1

Table 3.2 Government primary schools within Sylhet City Corporation area and their working hours (Source: physical survey)

No	Morning shift	Afternoon shift	Number of schools
01	7:30 am- 11:30 am	11:30 am- 3:30 pm	12 (33%)
02	8:00 am- 12:00 pm	12:00 pm- 4:00 pm	23(62 %)
03	8:30 am- 12:30 pm	12:30 pm- 4:30 pm	02 (5%)

It has been observed that all the surveyed primary schools operate their programs during the day time, though the specific opening and closing time is slightly dissimilar from each other. A few numbers of schools were found open in the evening with some administrative work, but no students and no classroom was found open after evening, and even after late afternoon. So, the findings reflect that the working hours coincide with daylight hours, for all the primary schools in the urban areas of Sylhet.

3.5.3 NATURE OF THE STRUCTURE

All the primary schools under Sylhet City Corporation area were found to have permanent structures, primarily made of brick and R.C.C roof. The structural system was found to be of a prototype and designed in post-lintel method.

3.5.4 BUILDING HEIGHT

The 37 urban primary schools were found to be of different heights, each structure having different stories of the building, starting from single storied to five storied.

Different numbers of stories in the primary schools under Sylhet City Corporation area are shown in figure 3.5.

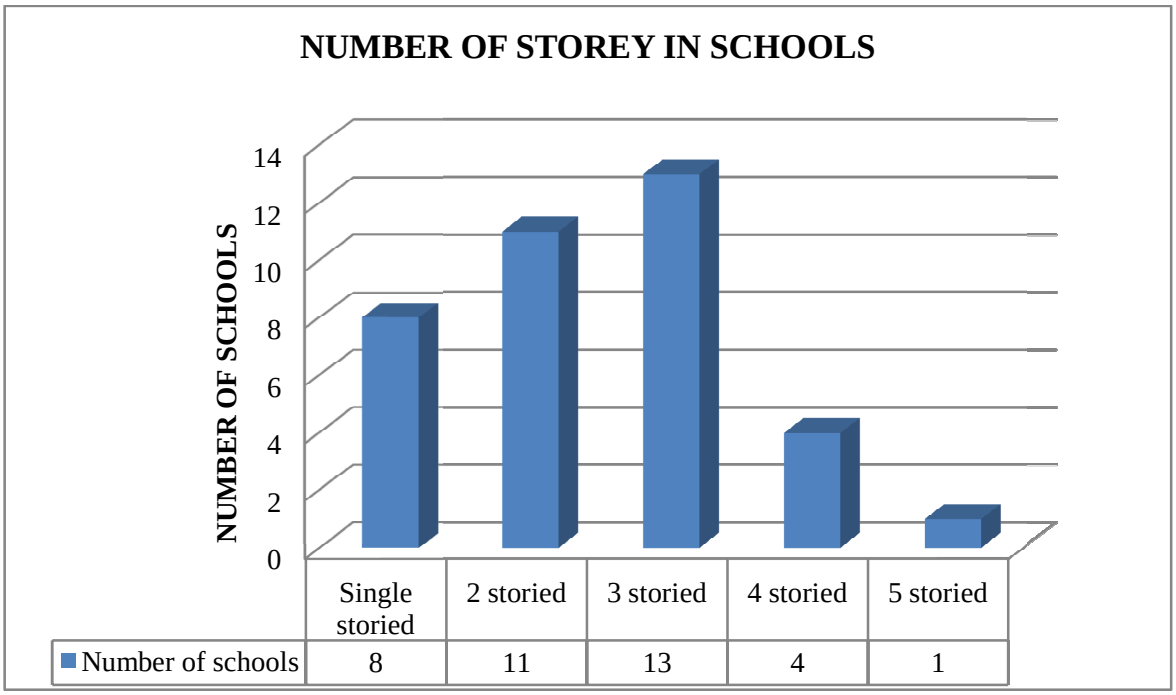


Figure 3.5 Different number of stories in the primary schools under Sylhet City Corporation area. (Source: Field survey)

3.5.5 ORIENTATION CLASSROOM BLOCKS

The classroom blocks were mostly found to be north-south oriented, other than a very few exceptions, to encourage natural ventilation, and to avoid excessive heat from the west side. The schools, which have a 'L' shaped floor plan, the classrooms of one axis got the north south orientation and the another axis got east-west.

3.5.6 DESIGNED AS A SCHOOL

All the Government primary schools under Sylhet City Corporation area were found to be purposefully designed as primary schools.

3.5.7 NUMBER OF STUDENTS

The total number of students range from 107 to 1350 found in the 37 surveyed primary schools. (Figure: 3.6)

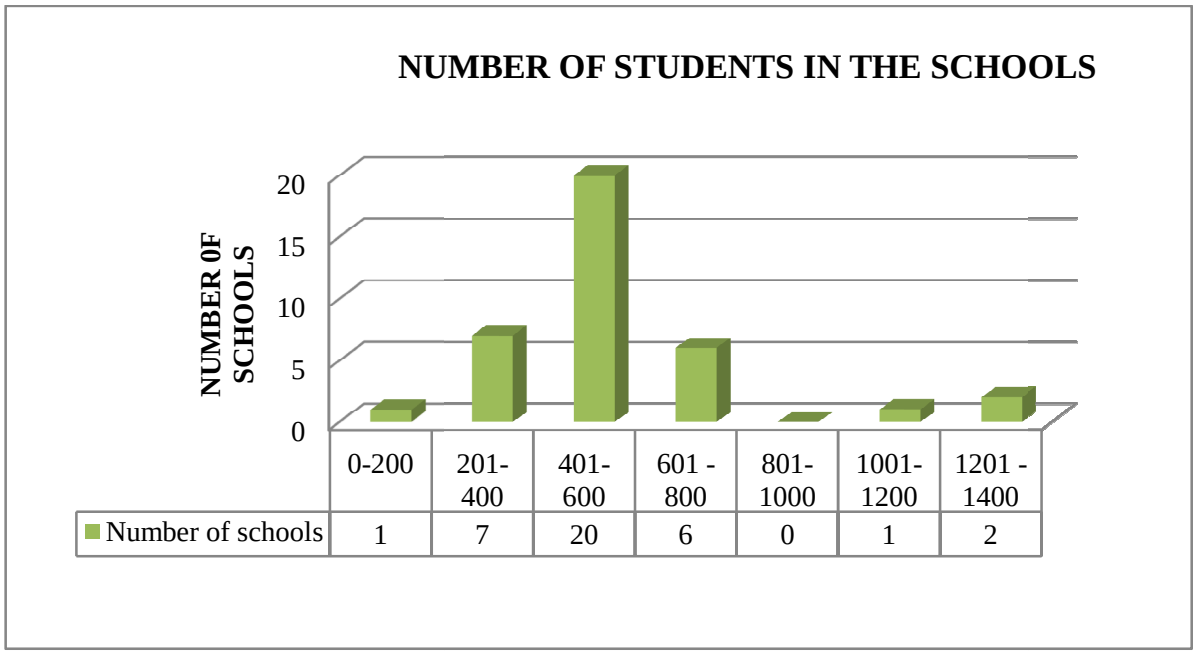


Figure 3.6 Showing the range of students' number in the surveyed primary schools. (Source: physical survey)

3.5.8 CO- EDUCATION / GENDER SPECIFIC

Among the 37 surveyed primary schools, 34 schools (91 %) were found to have combined education and the remaining 3 schools were found only for girls. Figure 3.7 showing the proportion of combined education schools and gender specific schools.

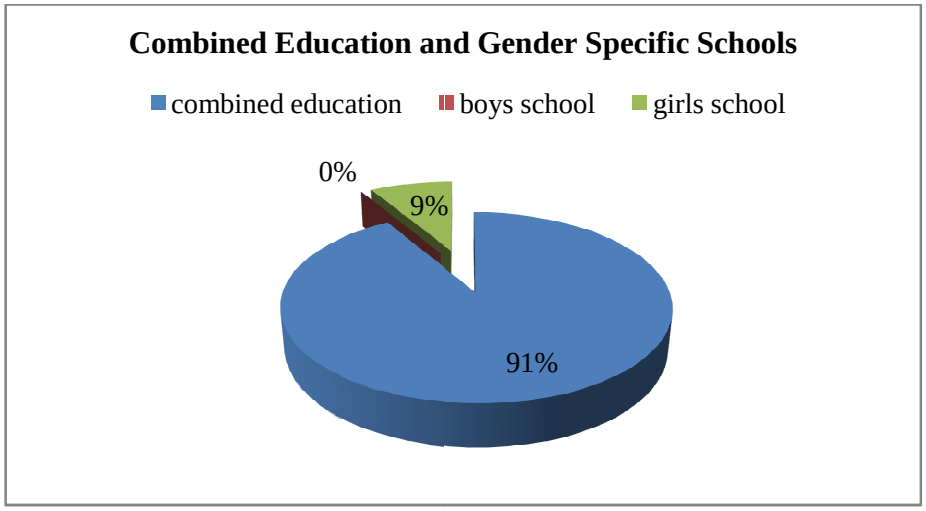


Figure 3.7 Showing the proportion of combined education schools and gender specific schools. (Source: Physical survey and Upozila Primary Education Office, Khadimnagar, Sylhet)

3.5.9 YEARLY PERFORMANCE EVALUATED BY THE GOVERNMENT

Under the Ministry of Primary Education, the Government evaluates the overall performances based on different criteria (number of student admission, number of fallouts, standard of the education, result in the public examinations, discipline etc.). Thus at the end of year each school gets individual evaluation grade (A, B, C, D) from the Government, based on their overall academic and extracurricular performance throughout the year. Figure 3.8 is showing the government evaluated grade of the surveyed primary schools.

For the purpose of this study, only 'A' graded schools were selected, which also fulfilled the other selection criteria mentioned in Table 3.1..

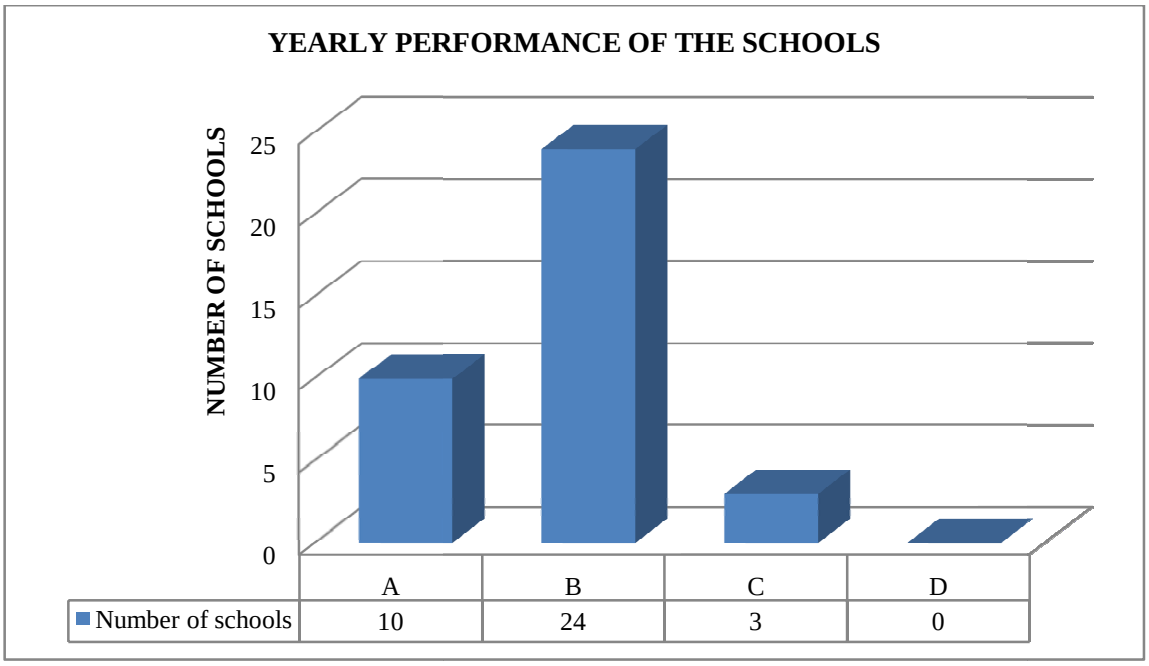


Figure 3.8 Showing the yearly evaluation grade in 2013 by the ministry of primary education. (Source: Upozila Primary Education Office, Khadimnagar, Sylhet)

3.6 CRITICAL OBSERVATIONS

1) Since 1981 there is no new establishment of government primary schools in the Sylhet City Corporation area. So, the findings of this study can be incorporated into new schools, for improved luminous environments, by considering the utmost use of daylight.
2) All the primary schools operate their academic program during the daylit hours. So, daylight can be an important tool in lighting design in the classroom spaces.

3) All the primary schools in Sylhet City Corporation area, are found in permanent structures, primarily made of brick and R.C.C. roof. So, the floors are vertically extended, and provision for day light is from side windows, either beside corridors or directly on the exterior.
4) Among the 37 schools surveyed in the primary investigation, buildings heights were found having different dimensions, starting from single storied to five storied. So, the luminous condition, based on daylight will be different for the different levels, due to surrounding natural and man-made obstructions.
5) In most of the primary schools investigated in the pilot survey, north- south oriented classrooms were found, for ensuring natural ventilation and protecting classrooms from excessive solar gain from the west side. Some classrooms were found east – west orientation in the 'L' shaped school buildings which can be observed from the figure 3.11, 3.18 and 3.22.
6) All the schools were designed and built as primary schools, so the day light availability can be compared easily with the standard index for primary school buildings.
7) Number of students in the classrooms plays a significant role, for finding the 'case schools' during detail investigation. The total number of students according to the size of the classroom, impacts on the luminous environment of a classroom space.
8) Most of the schools were found to be for boys and girls other than a few exceptions. So, the gender specific schools may be avoided in the final investigation, to keep the evaluation process gender-neutral.
9) The detailed investigation were conducted on schools that fulfilled the following aspects:
    a) Government Primary school
    b) Permanent structure
    c) Minimum double storied building
    d) Purposefully designed as a primary school.
    e) Student number should be minimum 600.
    f) School for girls, as well as boys.
    g) 'A' graded school.

3.7 SELECTION OF 'CASE' SCHOOLS FOR DETAILED INVESTIGATION

Findings from the pilot survey helped to choose the 'case schools' for detailed investigation. A total number of 37 schools (highlighted in the Appendix) have been surveyed, as they are Government primary schools and are located within the Sylhet City Corporation area. This initial investigation covered the criteria's mentioned in the Table 3.1 with necessary justification.

Table 3.3 gives a clear picture of which schools met all the selection criteria and were finalized for the detailed investigations.

Table 3.3 Government Primary Schools within Sylhet City Corporation area fulfilling the criteria's for generating example schools for detailed investigation using colored legend. (Source:physical survey and Upozila Primary Education Office, Khadimnagar, Sylhet)

No	Name of the School (colored names met all the given criteria's)	01. Permanent / temporary structure	02. Building height	03. Purpose built / converted building	04. Student number (boys/ girls)	05. Combined education or gender specified education	06. Grade (evaluated by government)
01	**KHASDOBIR GOVT. PRIMARY SCHOOL**	Permanent	2 storied	Purpose built	1350 (596/754)	Combined	A
02	**SYED HATIM ALI PRIMARY SCHOOL**	Permanent	4 storied	Purpose built	534 (160/ 374)	Combined	A
03	**AMBERKHANA DHORSHONDEWRI PRIMARY SCHOOL**	Permanent	4 storied	Purpose built	617 (287/ 330)	Combined	A
04	**BURHANUDDIN PRIMARY SCHOOL**	Permanent	3 storied	Purpose built	449 (226/ 223)	Combined	B
05	**SHONARPARA PRIMARY SCHOOL**	Permanent	3 storied	Purpose built	405 (198/ 207)	Combined	B
06	**MENDIBAG PRIMARY SCHOOL**	Permanent	1 storied	Purpose built	433 (215/ 218)	Combined	B
07	**BALUCHOR PRIMARY SCHOOL**	Permanent	1 storied	Purpose built	528 (248/ 280)	Combined	B
08	**NOBINCHANDRA PRIMARY SCHOOL**	Permanent	3 storied	Purpose built	700 (358/ 342)	Combined	B
09	**AMBERKHANA COLONY GOVT. PRIMARY SCHOOL**	Permanent	2 storied	Purpose built	432 (197/ 235)	Combined	B
10	**UMOR SHAH TERO RATAN PRIMARY SCHOOL**	Permanent	2 storied	Purpose built	483 (271/ 212)	Combined	B
11	**ABDUL HAMID PRIMARY SCHOOL**	Permanent		Purpose built	406 (175/ 231)	Combined	B
12	**PATHANTULA PRIMARY SCHOOL**	Permanent	1 storied	Purpose built	1096 (509/ 587)	Combined	B
13	**AKHALIA PRIMARY SCHOOL**	Permanent	2 storied	Purpose built	1284 (592/ 692)	Combined	B
14	**DURGAKUMAR PRIMARY SCHOOL**	Permanent	3 storied	Purpose built	415 (237/ 178)	Combined	B
15	**KISHORIMOHON PRIMARY SCHOOL**	Permanent	3 storied	Purpose	586	Combined	A

				built	(229/ 357)		
16	**GHASHITULA PRIMARY SCHOOL**	Permanent		Purpose built	560 (252/ 308)	Combined	B
17	**KANISHAILNAGAR PRIMARY SCHOOL**	Permanent	3 storied	Purpose built	270 (144/ 126)	Combined	C
18	**KAZI JALALUDDIN BALIKA PRIMARY SCHOOL**	Permanent	2 storied	Purpose built	457 (0/ 457)	Girls	B
19	**SHEIKHGHAT PRIMARY SCHOOL**	Permanent	2 storied	Purpose built	466 (264/ 202)	Combined	B
20	**GOVT. KINDER GARDEN PRIMARY SCHOOL**	Permanent	2 storied	Purpose built	459 (60/ 399)	Combined	A
21	**KISHORIMOHON BALIKA PRIMARY SCHOOL**	Permanent		Purpose built	356 (0/346)	Girls	B
22	**AMBERKHANA DARGAH GATE PRIMARY SCHOOL**	Permanent		Purpose built	583 (249/334)	Combined	A
23	**LAMABAZAR PRIMARY SCHOOL**	Permanent	4 storied	Purpose built	800 (461/ 339)	Combined	A
24	**ZINDABAZAR PRIMARY SCHOOL**	Permanent	3 storied	Purpose built	511 (312/ 199)	Combined	B
25	**JATIYO SHIKKA KENDRO PRIMARY SCHOOL**	Permanent		Purpose built	294 (121/ 173)	Combined	B
26	**KUDRATULLAH ISLAM PRIMARY SCHOOL**	Permanent		Purpose built	246 (139/ 107)	Combined	B
27	**RAMKRISHNO PRIMARY SCHOOL**	Permanent		Purpose built	579 (274/ 305)	Combined	B
28	**MODHUSHOHID PRIMARY SCHOOL**	Permanent	3 storied	Purpose built	647 (410/ 237)	Combined	A
29	**MOINUNNESA PRIMARY SCHOOL**	Permanent	2 storied	Purpose built	376 (0/ 376)	Girls	B
30	**RAINAGAR PRIMARY SCHOOL**	Permanent	5 storied	Purpose built	513 (241/ 272)	Combined	B
31	**DARGAH JALALIA PRIMARY SCHOOL**	Permanent		Purpose built	370 (173/ 197)	Combined	B
32	**HAZI SHAHMIR PRIMARY SCHOOL**	Permanent		Purpose built	754 (346/ 408)	Combined	B
33	**BHATALIA PRIMARY SCHOOL**	Permanent	2 storied	Purpose built	107 (43/ 64)	Combined	B
34	**RADHARANI**	Permanent	4 storied	Purpose	645	Girls	A

	PRIMARY SCHOOL			built	(342/ 303)		
35	**BAKHTIYAR BIBI PRIMARY SCHOOL**	Permanent	2 storied	Purpose built	436 (207/ 229)	Combined	A
36	**JHALOPARA PRIMARY SCHOOL**	Permanent	3 storied	Purpose built	357 (168/ 189)	Combined	C
37	**MUNKHULA MURA BIBI PRIMARY SCHOOL**	Permanent	3 storied	Purpose built	478 (224/ 254)	Combined	C

From the Table 3.3 it is observed that, 4 primary schools met all the criteria among the 37 initially surveyed school buildings. These four schools were selected for detailed study of physical parameters. Among these four schools, a particular one was selected, where the visual performance tests of the students were conducted. The selection of primary schools was done in order that, as a whole, all the features identified in the pilot survey could be represented. The visual performance test of the students was conducted in one of those classrooms.

Details of the physical parameters found in the survey, are given below.

a) CASE SCHOOL: 01

KHASDOBIR GOVERNMENT PRIMARY SCHOOL

This is a two (2) storied school building, established in 1973. It is located in between Amberkhana point and Subitbazar .

Figure 3.9 KHASDOBIR GOVERNMENT PRIMARY SCHOOL . (Source: Field Survey)

Figure 3.10 shows the site plan , Figure 3.11 shows the ground and typical floor plan and Figure 3.12 showing the sections of Khasdobir Government Primary School.

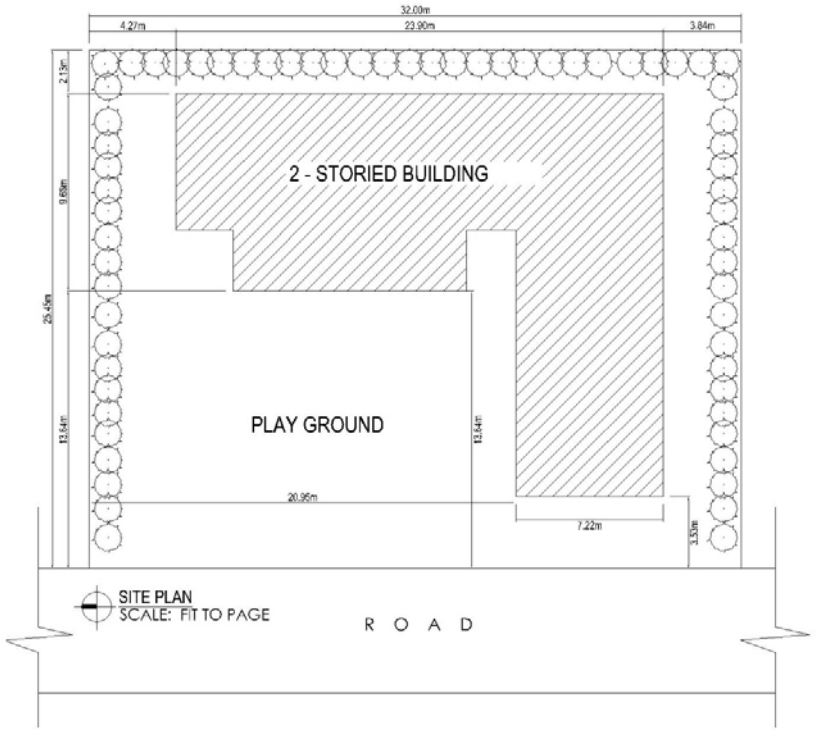


Figure 3.10 Site plan of KHASDOBIR GOVERNMENT PRIMARY SCHOOL . (Source: author)

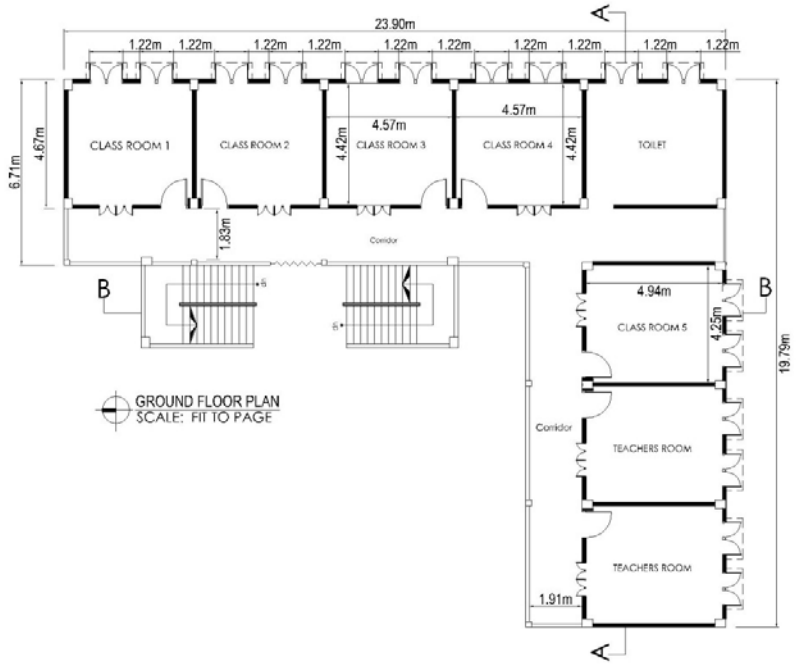


Figure 3.11 Ground and typical 1st floor plan of KHASDOBIR GOVERNMENT PRIMARY SCHOOL . (Source: author)

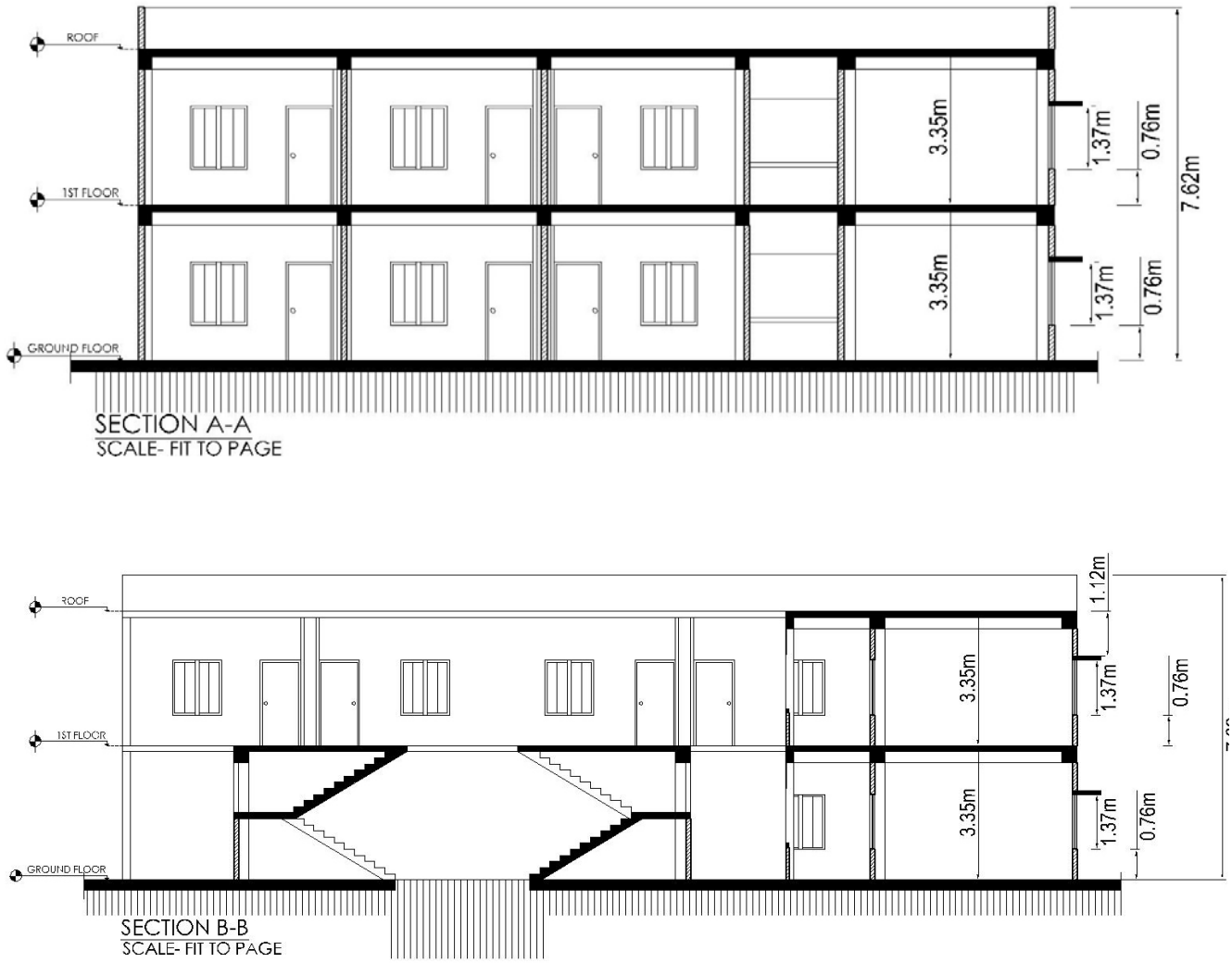


Figure 3.12 Sections of KHASDOBIR GOVERNMENT PRIMARY SCHOOL. (Source: author)

b) CASE SCHOOL: 02
MADHUSHAHID GOVERNMENT PRIMARY SCHOOL

This is a three (3) storied schoolbuilding established in 1974. It is located in Madhushahid, opposite to the main gate of Sylhet medical College & hospital.

Figure 3.13 MADUSHAHID GOVERNMENT PRIMARY SCHOOL. (Source: Field Survey)

Figure 3.14 shows the site plan, ground and typical floor plan and Figure 3.15 showing the sections of Madhushahid Government Primary School.

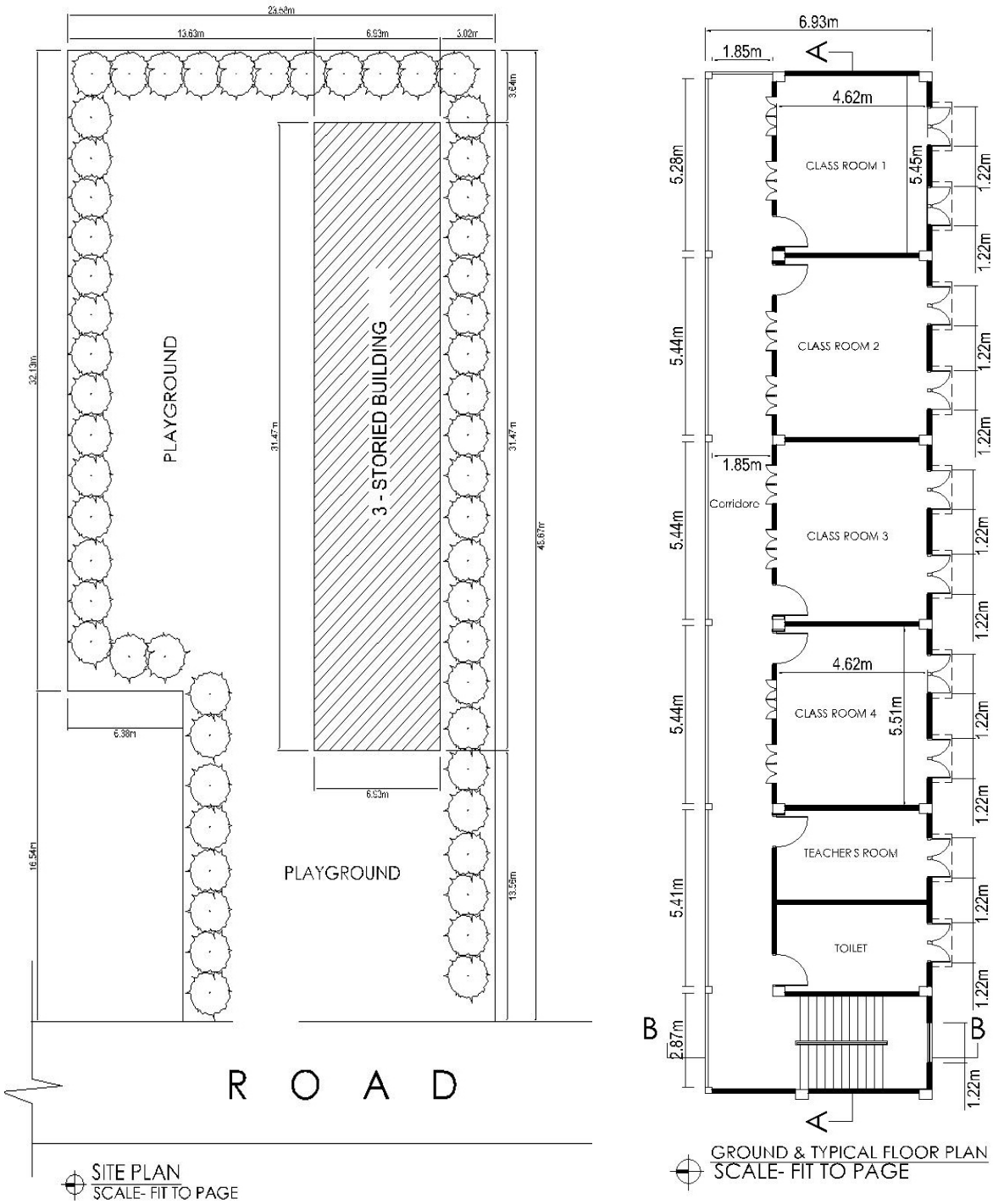
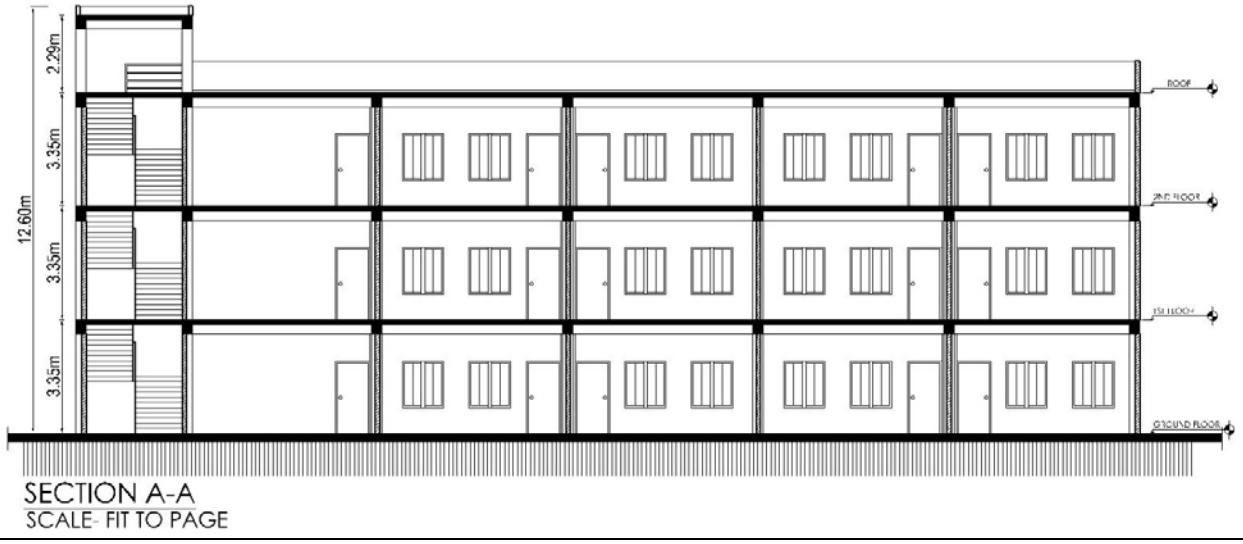


Figure 3.14 Site plan, Ground floor plan and typical floor plan of MADHUSHAHID GOVERNMENT PRIMARY SCHOOL . (Source: author)



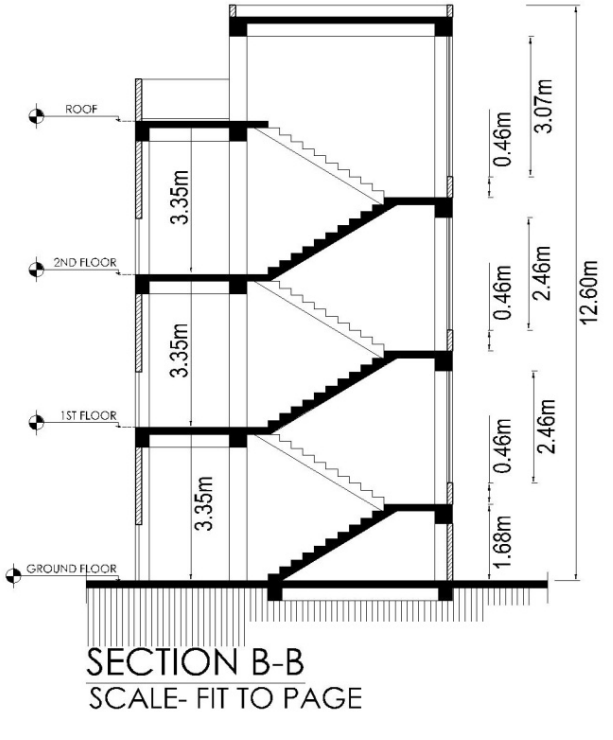


Figure 3.15 Sections of MADHUSHAHIDGOVERNMENT PRIMARY SCHOOL . (Source: author)

c) CASE SCHOOL: 03

AMBERKHANA DARSHANDEURI GOVERNMENT PRIMARY SCHOOL

This is a four (4) storied schoolbuilding established in 1955. This primary school is located near Amberkhana point.

Figure 3.16 AMBERKHANA DARSHANDEURI GOVERNMENT PRIMARY SCHOOL . (Source: Field Survey)

Figure 3.17 shows the site plan; Figure 3.18 shows the ground and typical floor plan and Figure 3.19 shows the sections of Amberkhana Darshandeuri Government Primary School.

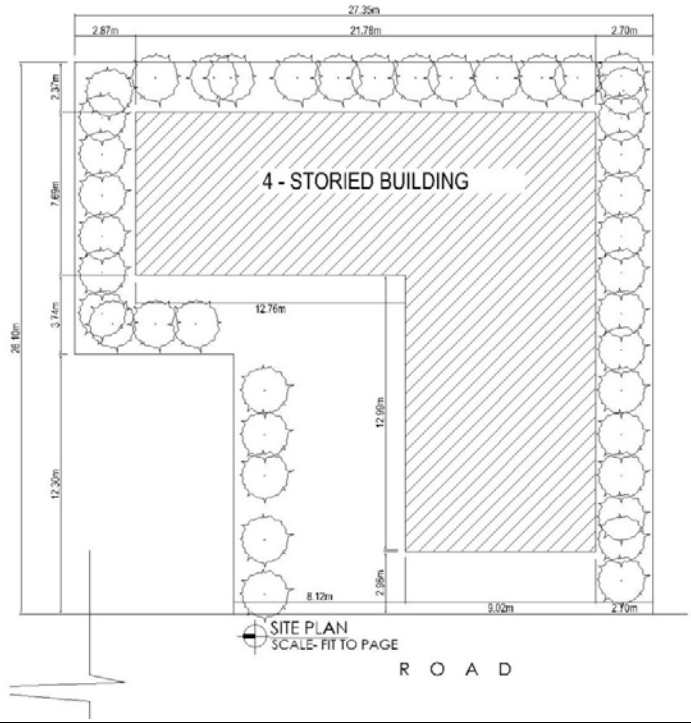
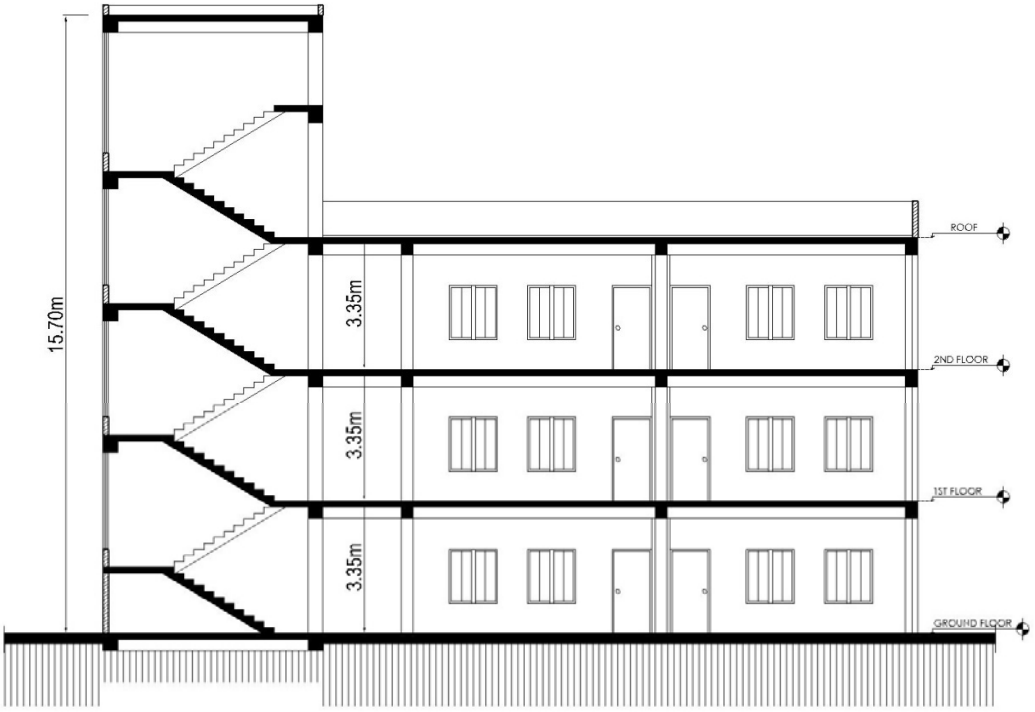


Figure 3.17 Site plan of AMBERKHANA DARSHANDEURI GOVERNMENT PRIMARY SCHOOL . (Source: author)

Figure 3.18 Ground and Typical floor plan OF AMBERKHANA DARSHANDEURI GOVERNMENT PRIMARY SCHOOL . (Source: author)



SECTION A-A
SCALE- FIT TO PAGE

SECTION B-B
SCALE- FIT TO PAGE

Figure 3.19 Sections of AMBERKHANA DARSHANDEURI GOVERNMENT PRIMARY SCHOOL . (Source: author)

d) CASE SCHOOL: 04

LAMABAZAR GOVERNMENT PRIMARY SCHOOL

This is a four (4) storied school building established in 1885. This primary school is located in Lamabazar near to Sylhet stadium and Modonmohon College.

Figure 3.20 LAMABAZAR GOVERNMENT PRIMARY SCHOOL. (Source: Field Survey)

Figure 3.21 shows the site plan; Figure 3.22 shows the ground & typical floor plan and Figure 3.23 shows the sections of Lamabazar Government Primary School.

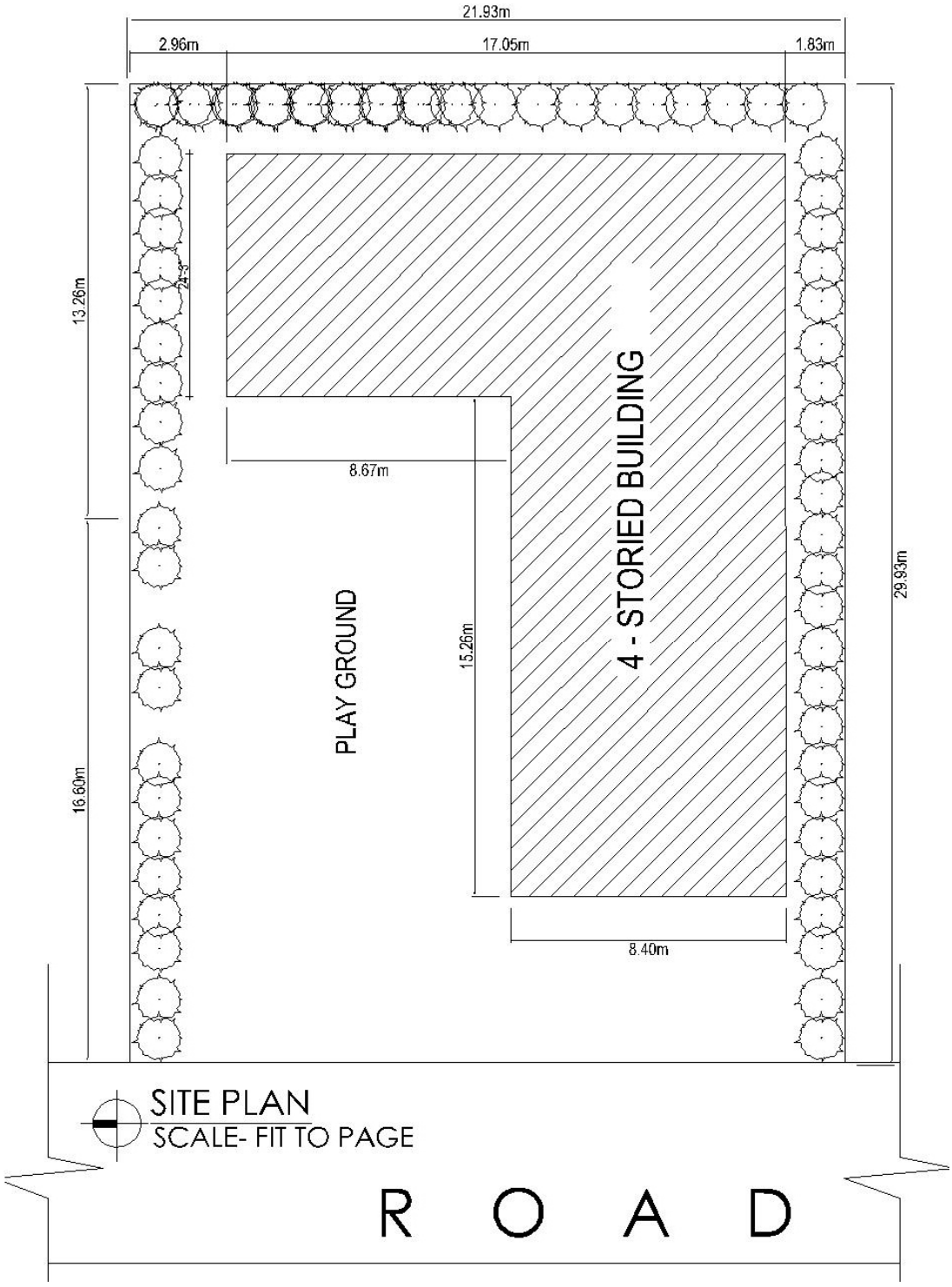


Figure 3.21 Site plan of LAMABAZAR GOVERNMENT PRIMARY SCHOOL . (Source: author)

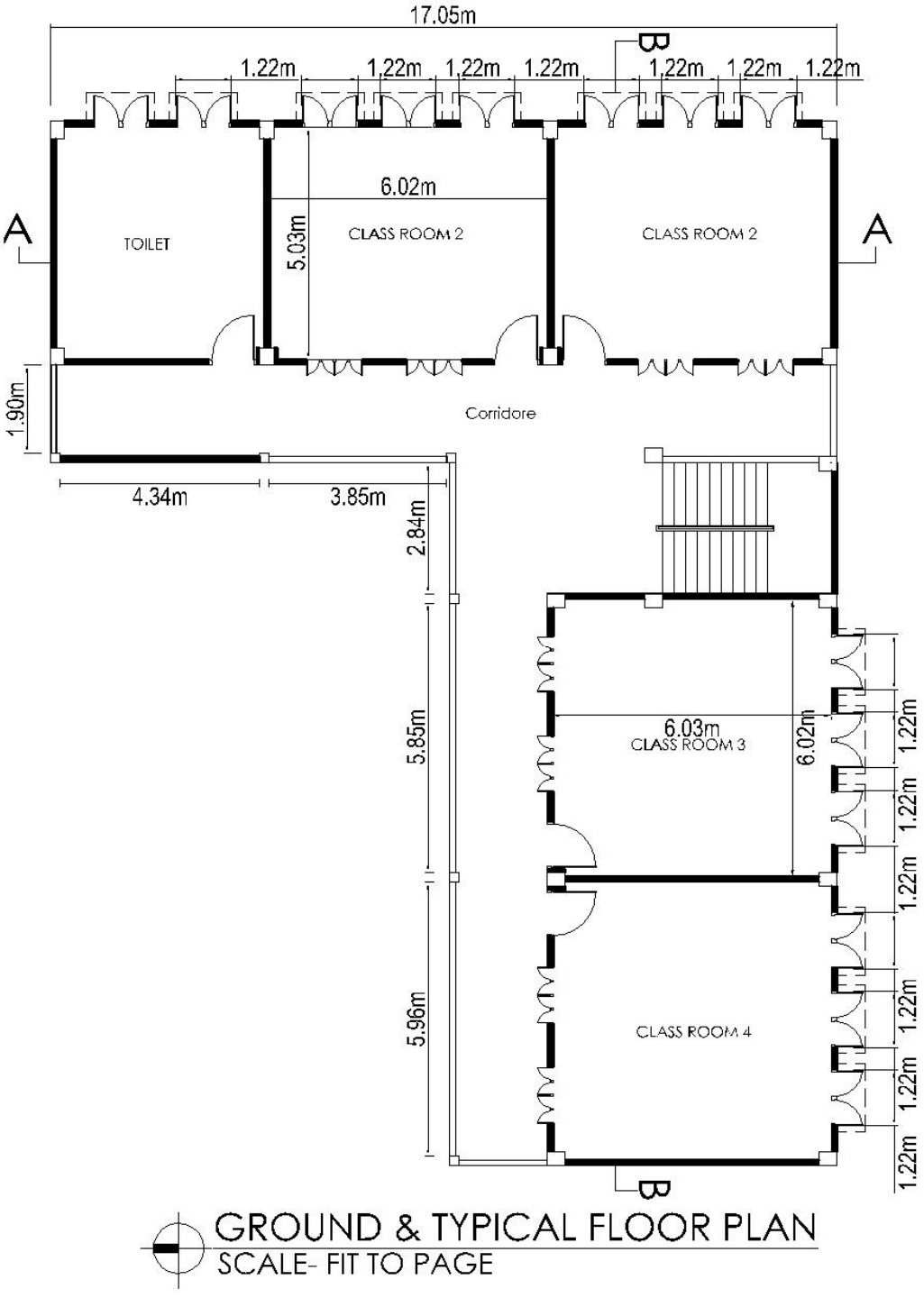
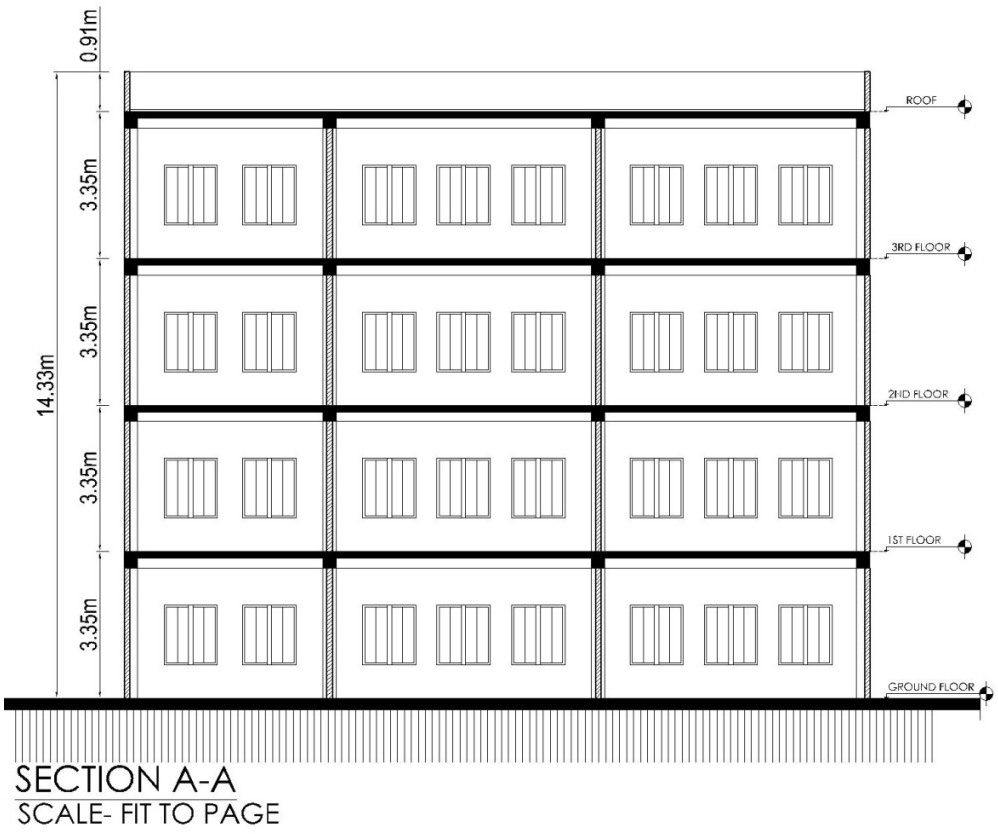


Figure 3.22 Ground& Typical Floor plan of LAMABAZAR GOVERNMENT PRIMARY SCHOOL . (Source: author)



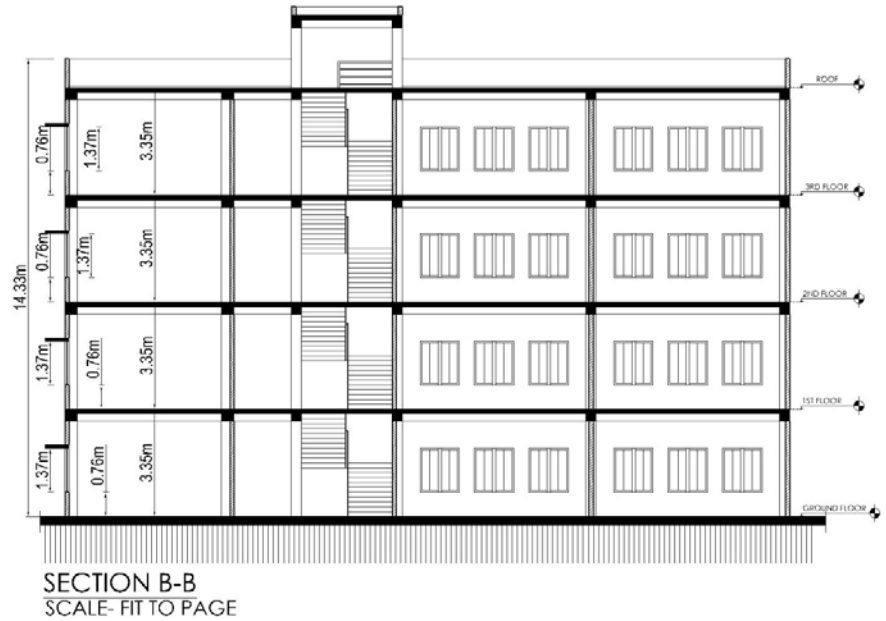


Figure 3.23 Sections of LAMABAZAR GOVERNMENT PRIMARY SCHOOL . (Source: author)

3.8 INSTRUMENTS FOR MEASUREMENT

Digital lux meter (Product Name: Digital Lux Meter Luminous Flux Meter, Model: FOB QINGDAO) was used for measuring available day light within the different locations of the classroom spaces at desktop level. Measurements were taken beside window, beside corridor and at the middle portion of the classroom, where the daylight availability is found lowest. Luminous measurement was taken in two situations; for the classroom spaces where the visual performance test is going to be held, one under clear sky situation and one under overcast situation.

Stop watch was used for determining the required time taken by the students, during the visual performance tests.

The details of the digital light meter and stop watch are given in the appendix A.

3.9 DAYLIGHT CONDITIONS OF THE CASE SCHOOLS

Daylight measurements were taken in the example schools. This section reports the findings.

The shaded portions of the tables represent the daylight availability within standard range of 300 to 500 lux (section 2.6).

3.9.1 KHASDOBIR GOVERNMENT PRIMARY SCHOOL

Number of story: Two storied building
Date of survey: 16.01.2013 (under clear sky) and 16.07.2013 (under overcast condition)

A. CONTEXT: GROUND FLOOR

Table 3.4 Ground floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	407	117	44	12	186	45
AT **12.00 P.M**	512	125	50	17	225	33
AT **4.00 P.M**	376	97	38	19	161	39

B. CONTEXT: FIRST FLOOR

Table 3.5 First floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	872	135	102	29	220	52
AT **12.00 P.M**	961	152	108	26	196	39
AT **4.00 P.M**	607	102	91	25	186	46

Figure 3.24 showing the comparison of daylight availability in different levels of this school.

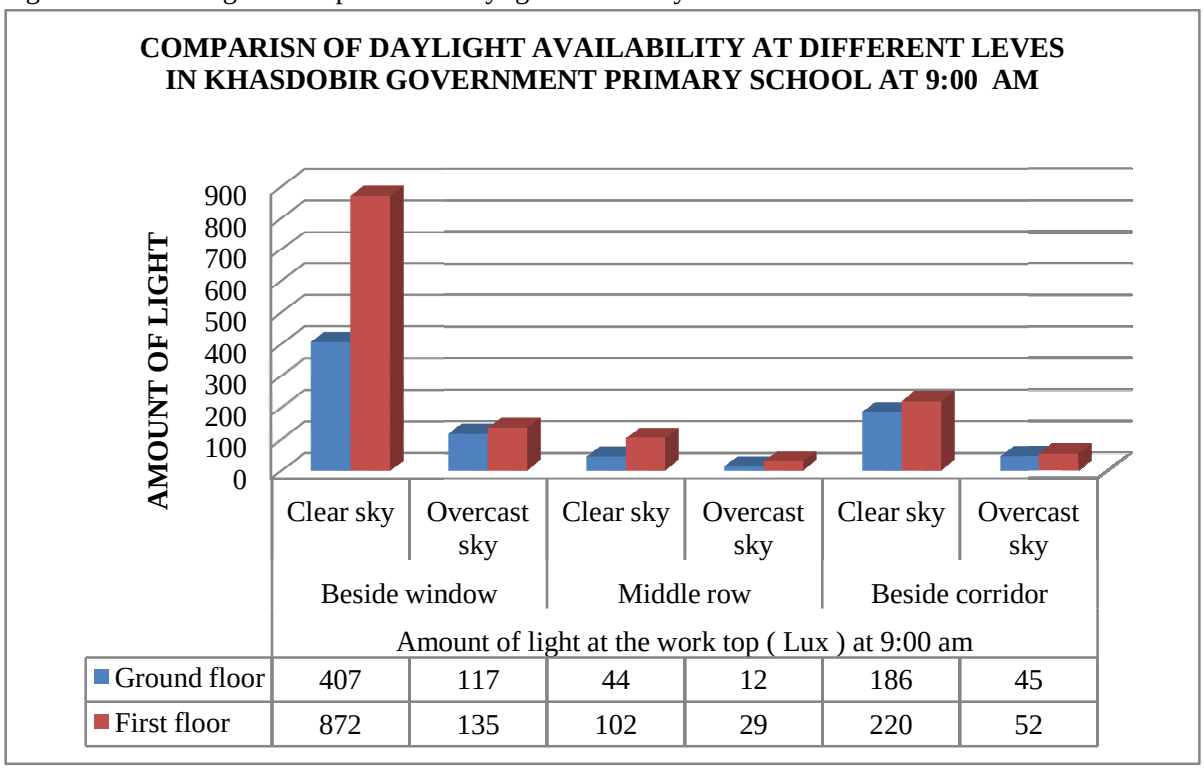


Figure 3.24 Comparison of daylight availability in different levels of this school. *(Source: Field Survey)*

It is observed from the above chart that, only the window side desktops, under clear sky situation (shaded in the table), have the standard illumination range of **300-500 lux** (Chapter Two, 2.6). So, it is clear from the above table that, other than the situation beside window, all other positions are much short of the adequate amount of light, which leads to dependence on artificial lighting. Though the lighting level is found higher in the first floor, but it still remained less than the desired level of standard illumination.

3.9.2 MADHUSHAHID GOVERNMENT PRIMARY SCHOOL

Number of story: Three storied building
Date of survey: 16.01.2013 (under clear sky) and 16.07.2013 (under overcast condition)

A. CONTEXT: GROUND FLOOR

Table 3.6 Ground floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	303	103	52	12	196	55
AT **12.00 P.M**	345	105	43	10	205	33
AT **4.00 P.M**	256	84	55	16	178	43

B. CONTEXT: FIRST FLOOR

Table 3.7 First floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

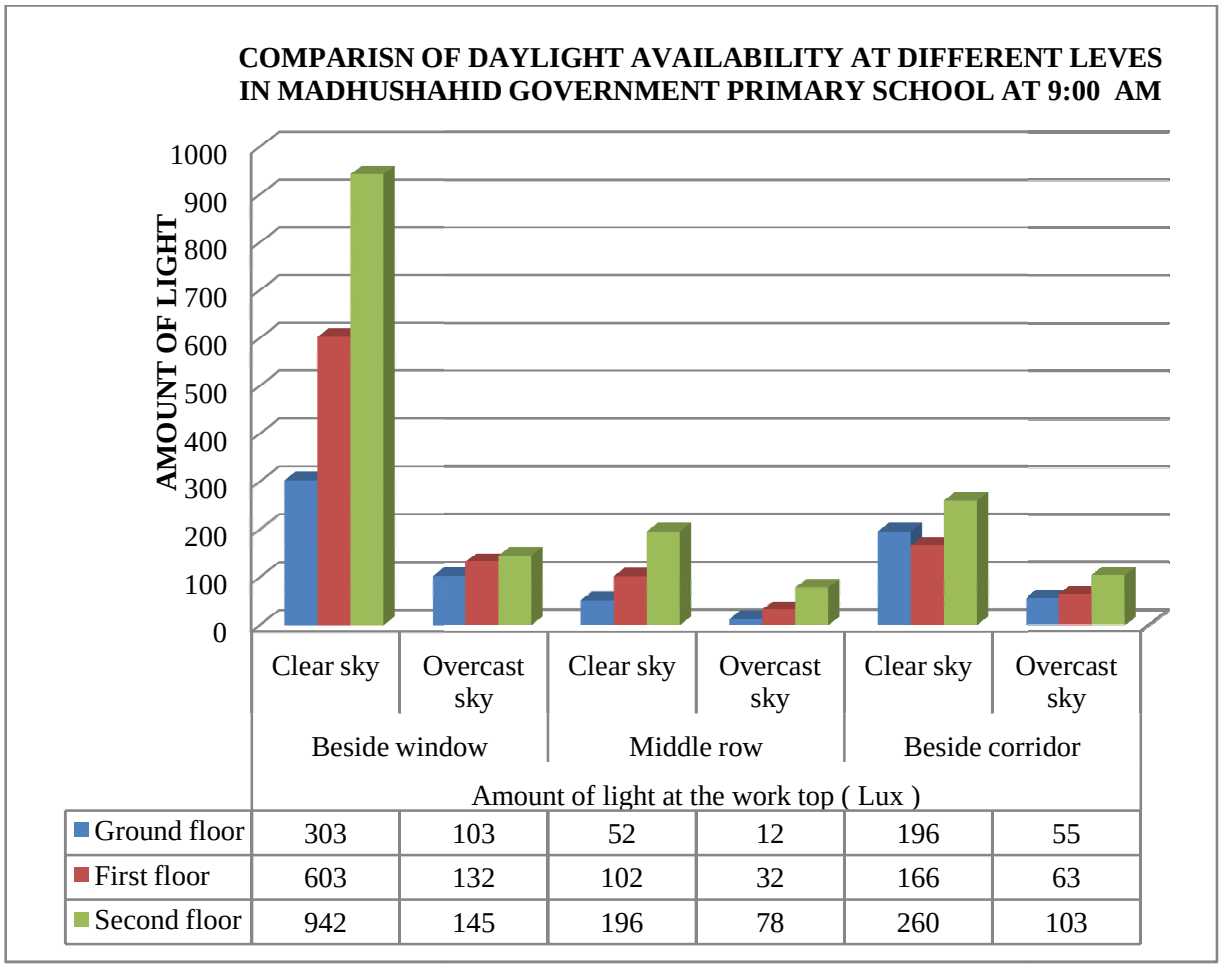
TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	603	132	102	32	166	63
AT **12.00 P.M**	586	148	88	27	245	65
AT **4.00 P.M**	512	110	109	45	219	34

C. CONTEXT: SECOND FLOOR

Table 3.8 Second floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	942	145	196	78	260	103
AT **12.00 P.M**	1015	169	156	45	214	58
AT **4.00 P.M**	920	112	178	56	274	73

Figure 3.25 showing the comparison of daylight availability in different levels of this school.



	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
Ground floor	303	103	52	12	196	55
First floor	603	132	102	32	166	63
Second floor	942	145	196	78	260	103

Figure 3.25 Comparison of daylight availability in different levels of this school. *(Source: Field Survey)*

It is observed from the above chart that, only the window side desktops under clear sky situation (the shaded cells in the table), have the standard illumination range of **300-500 lux** (mentioned in chapter two, 2.6),even though at ground floor, even the window side desktops revealed less than the standard illumination level at 4 p.m. So, it is clear from the above table that, other than the condition beside window, all other positions are much short of sufficient amount of light, which leads to reliance on artificial lighting. Here, the lighting level is also found higher in the first and sequential upper floors, but still remaining lower than the desired level of standard illumination at middle row and corridor side desktops of the classroom.

3.9.3 AMBERKHANA DARSHANDEURI GOVERNMENT PRIMARY SCHOOL

Number of story: Four storied building
Date of survey: 16.01.2013 (under clear sky) and 16.07.2013 (under overcast condition)

A. CONTEXT: GROUND FLOOR

Table 3.9 Ground floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	346	85	34	14	175	36
AT **12.00 P.M**	375	101	38	14	113	39
AT **4.00 P.M**	291	83	29	10	132	27

B. CONTEXT: FIRST FLOOR

Table 3.10 First floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	432	103	92	21	189	48
AT **12.00 P.M**	456	117	90	20	202	46
AT **4.00 P.M**	392	99	71	21	176	31

C. CONTEXT: SECOND FLOOR

Table 3.11 Second floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	456	118	80	29	196	60
AT **12.00 P.M**	413	130	102	37	213	58
AT **4.00 P.M**	404	106	89	31	214	68

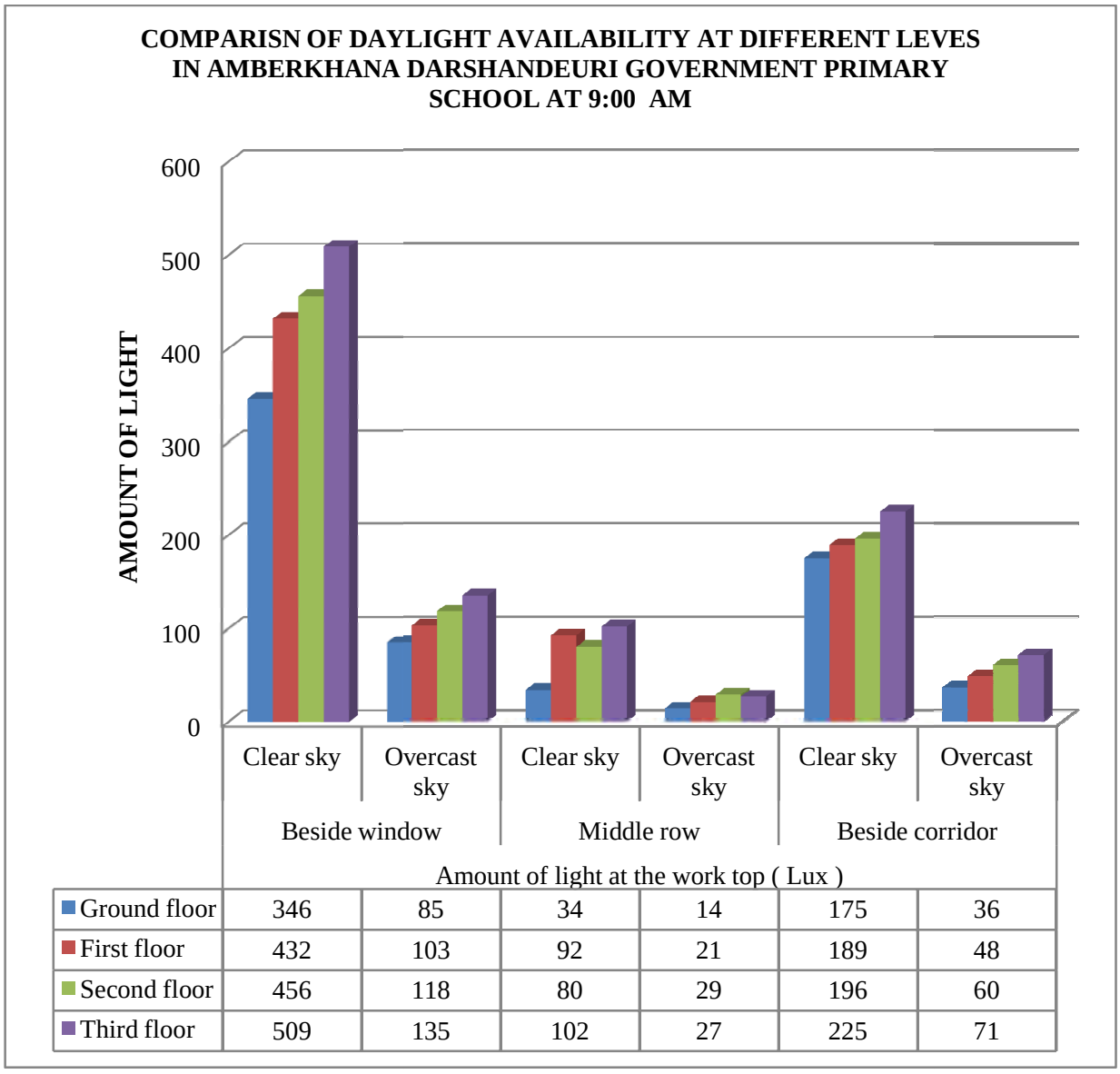
D. CONTEXT: THIRD FLOOR

Table 3.12 Third floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	509	135	102	27	225	71
AT **12.00 P.M**	493	102	86	30	269	50
AT **4.00 P.M**	466	98	105	21	198	53

Figure 3.26 shows the comparison of daylight availability in different levels of this school.

It is seen from the above tables that, only the window side desktops under clear sky situation (shaded cells in the table), attained the standard illumination range of **300-500 lux** (mentioned in chapter two, 2.6) which is supposed to be there, even though at ground floor, the window side desktop was measured less than the standard illumination level at 4 p.m. So, it is obvious that, other than the condition beside window, all other positions are much short of satisfactory amount of light, which leads to dependence on artificial lighting. Here, the lighting level is also found higher in the first and sequential upper floors, but still remaining lower than the desired level of standard illumination at middle row and corridor side desktops of the classroom.



Ground floor	346	85	34	14	175	36
First floor	432	103	92	21	189	48
Second floor	456	118	80	29	196	60
Third floor	509	135	102	27	225	71

Figure 3.26 Comparison of daylight availability in different levels of this school. *(Source: Field Survey)*

3.9.4 LAMABAZAR GOVERNMENT PRIMARY SCHOOL

Height: Four storied building
Date of survey: 16.01.2013 (under clear sky) and 16.07.2013 (under overcast condition)

A. CONTEXT: GROUND FLOOR

Table 3.13 Ground floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	276	73	35	19	150	28
AT **12.00 P.M**	281	93	41	21	171	21
AT **4.00 P.M**	301	79	40	17	148	30

B. CONTEXT: FIRST FLOOR

Table 3.14 First floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	404	112	82	35	175	57
AT **12.00 P.M**	432	135	76	39	209	62
AT **4.00 P.M**	356	103	83	24	202	44

C. CONTEXT: SECOND FLOOR

Table 3.15 Second floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	483	115	101	32	201	71
AT **12.00 P.M**	455	127	113	24	195	45
AT **4.00 P.M**	410	128	107	39	177	52

D. CONTEXT: THIRD FLOOR

Table 3.16 Third floor daylight condition in different time of the day under clear sky and overcast situation (Source: Field Survey)

TIME OF THE DAY	Amount of light at the work top (Lux)					
	Beside window		Middle row		Beside corridor	
	Clear sky	Overcast sky	Clear sky	Overcast sky	Clear sky	Overcast sky
AT **9.00 A.M**	723	163	125	45	229	102
AT **12.00 P.M**	690	145	117	59	202	96
AT **4.00 P.M**	655	112	142	69	296	107

Figure 3.27 shows the comparison of daylight availability in different levels of this school.

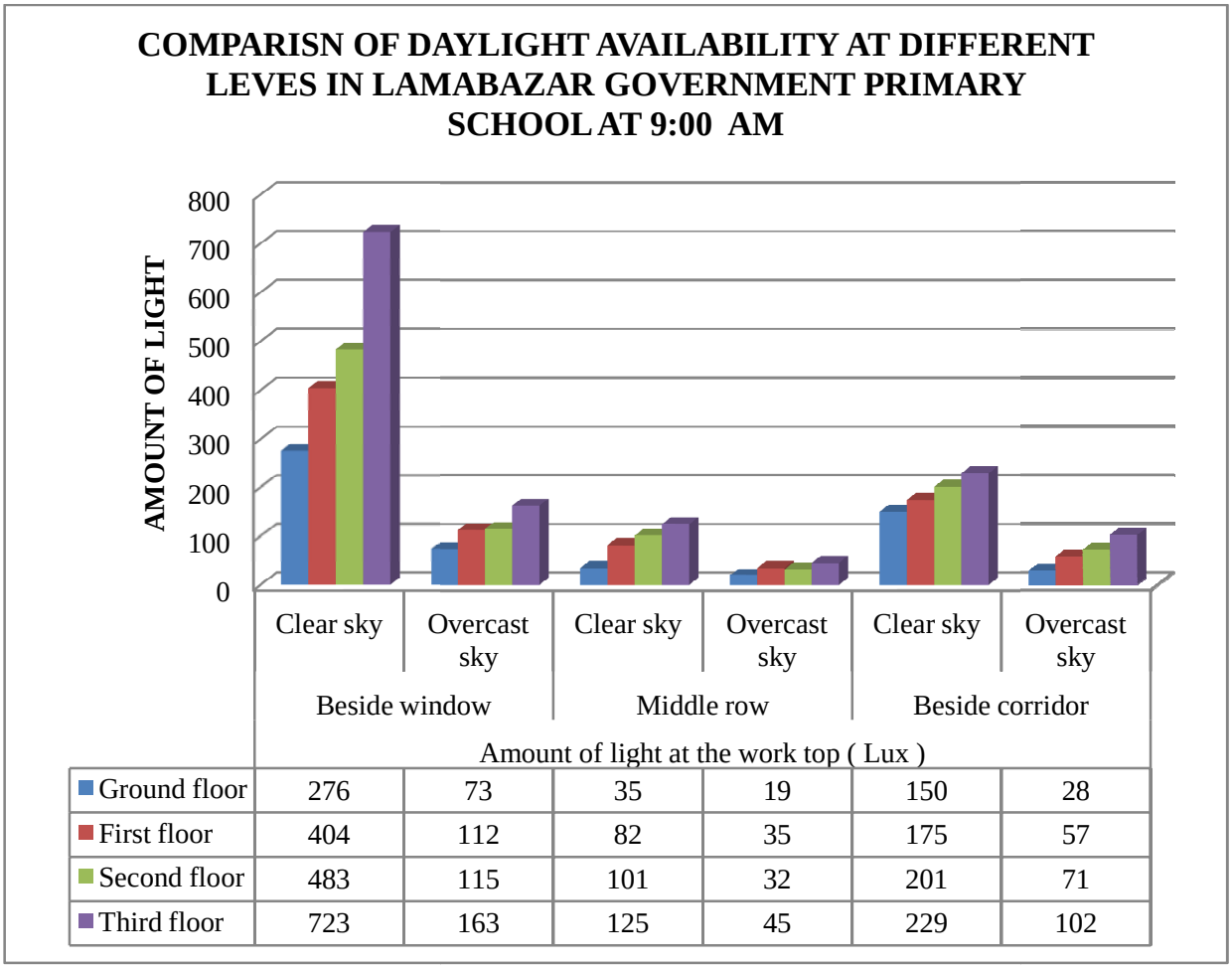


Figure 3.27 Comparison of daylight availability in different levels of this school. *(Source: Field Survey)*

It is seen from the above tables that, only the window side desktops under clear sky situation (shaded cells in the table), have the standard illumination range of **300-500 lux** (mentioned in chapter two, 2.6), which is required for the classroom. At ground floor, even the window side desktop was measured as having less than the standard illumination level at 4 p.m. So, it is obvious that, other than the condition beside

window, all other positions are much short of satisfactory amount of light, which leads to dependence on artificial lighting. Here, the lighting level is also found higher in the first and sequential upper floors, but still lower than the desired level of standard illumination at middle row and corridor side desktops of the classroom.

3.9.5 CRITICAL FINDINGS ON DAYLIGHT CONDITIONS:

a) It is clearly observed that daylight was found lowest in the middle row of all the classrooms.
b) Lower level classrooms had lower amount of daylight, especially, ground floor classrooms are found with lowest level of daylight penetration, due to site surroundings and obstructions. .
c) Amount of Daylight under overcast conditions is significantly less, than the daylight measurement taken under clear sky situations.
d) Only other than window side positions under clear sky situations, among all the surveyed classroom spaces, all other spaces are found with quite inadequate amount of illumination levels, which is not good for both physical and psychological development for the students, and which is also responsible for the high dependence on electrical lighting system.

3.10 : PHYSICAL PARAMETERS OF THE CLASSROOMS FOR VISUAL PERFORMANCE TEST AND COMPARISON WITH STANDARDS

Studies mentioned several different physical parameters (section 2.7), that affect the penetration of daylight inside classroom spaces, which also influence the overall luminous condition of the classroom. These physical parameters of the classrooms surveyed were observed, where the visual performance tests were taken, and compared with the standards mentioned in Chapter Two. The observations are recorded in this section.

A) THE SIZE AND ORIENTATION OF THE CLASSROOMS (LENGTH AND BREADTH).

Size and orientation of the classrooms are very important aspects for the distribution of daylight. Other than a few exceptions (some classrooms of ‘L” shaped School buildingss were found to be east-west oriented), most of the classrooms studied during this research were found north- south oriented. Size of the classrooms, used in visual performance test is shown in figure 3.28.

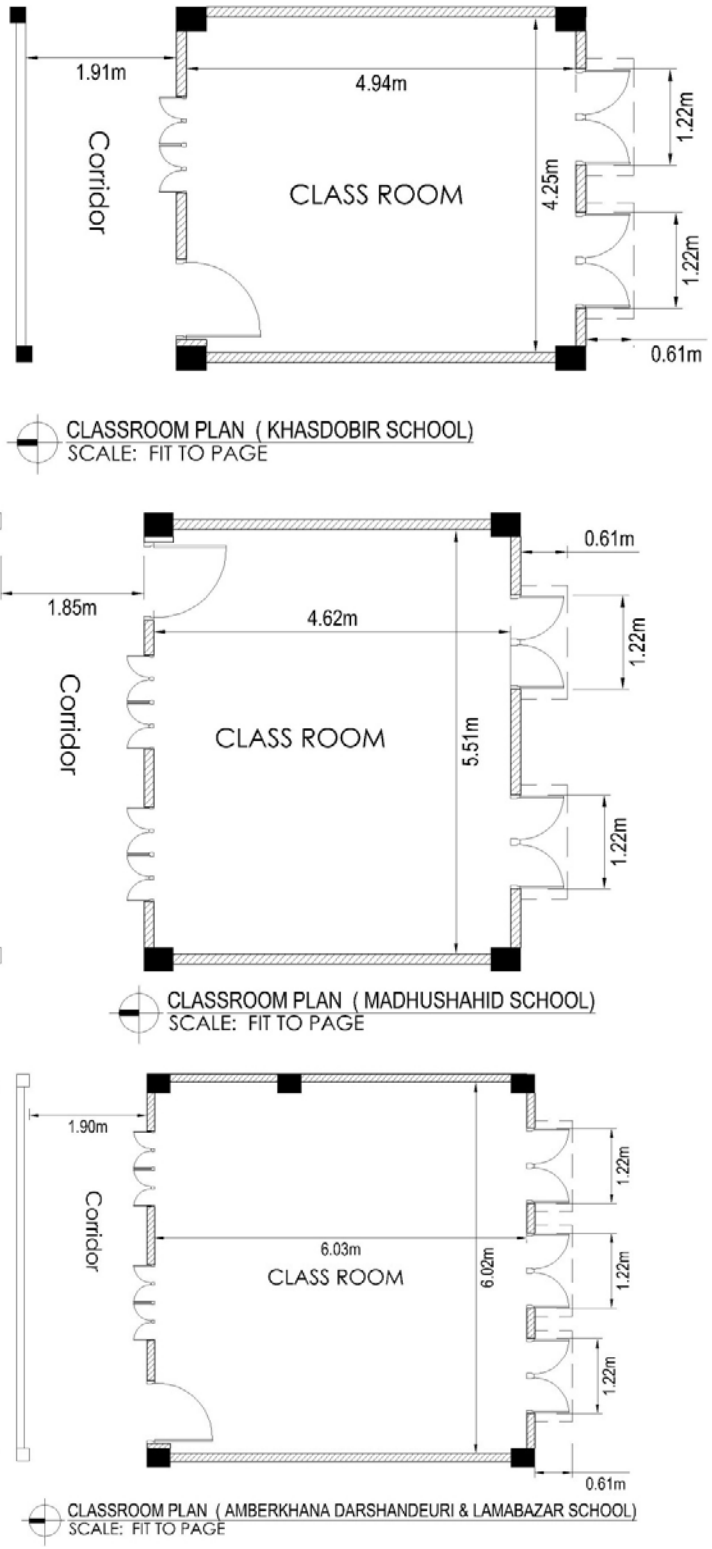


Figure 3.28 Classrooms with measurements. *(Source: Field Survey)*

It is observed from the field investigation, that, the size of the classrooms found is on average of 20.21 sqm. Though it is designed for 30 pupils, which does not satisfy the standard size (70 – 76 sqm) of the 30 student classroom. Again, the reality is, in these small classrooms, the average number of students found is 50 – 75, (Chapter One, Figure 1.9),which create extensive shadows and related visual discomfort situation. The amount of space per pupil was found to range between 0.27 sqm to 0.4 sqm, where the standard suggests 2.33 sqm to 2.53 sqm for each student.

B) HEIGHT OF THE CLASSROOMS.

All the surveyed classrooms were found with a clear height of 3.20 m. Figure 3.29 shows the height of the classrooms in typical classroom sections. The heights of the classrooms, surveyed in this research are found to match the standard height of 3.15 m suggested for the classrooms with 30 student's capacity.

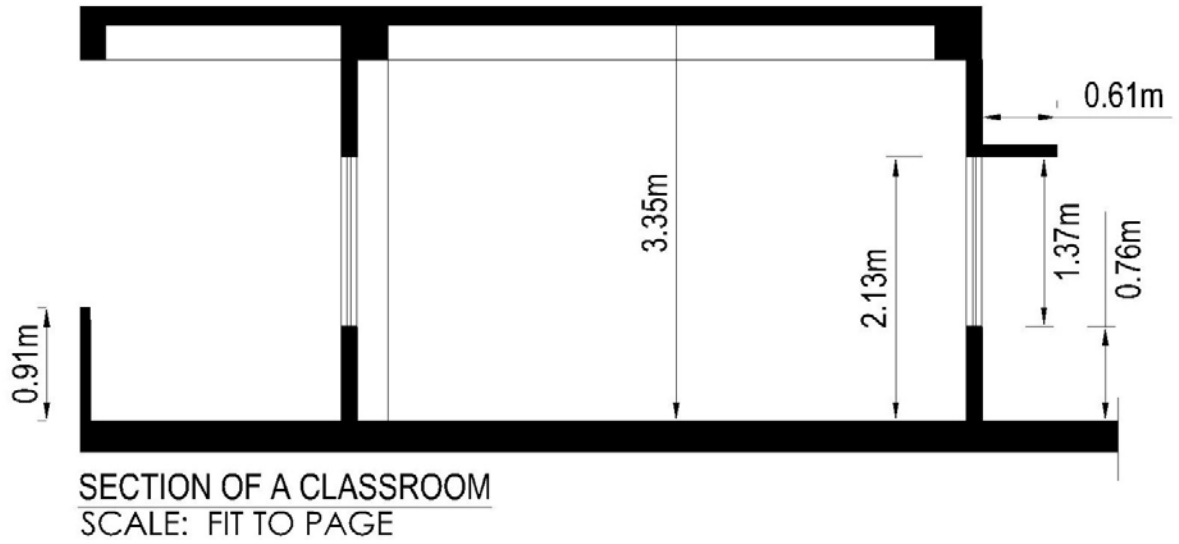


Figure 3.29 Section of a classroom showing the heights. *(Source: Field Survey)*

C) FLOOR-WISE LOCATION OF THE CLASSROOM

Location of the classroom, in terms of floor level affects daylight penetration. In the survey, it was found that, classrooms at upper levels receive better daylight penetration, due to minimum outdoor obstructions.

D) SIZE AND ORIENTATION OF THE OPENINGS.

The size of the windows measured at 1.22 m x 1.22 m. All the classrooms were found with swing windows and swing doors. The orientations of the windows were mostly in the north south direction.

E) MATERIAL AND TEXTURE OF THE OPENINGS.

Windows were found to have a single strip of clear glass, 6 mm in thickness. Only in one of the schools, the windows were found to be made of wood and steel sheet. Windows on the corridor side were found painted, to restrict vision towards the corridor from the classrooms. This is an enormous obstruction for daylight penetration, and violates the standard and most common way for daylighting classrooms. The authorities believe that, otherwise students' attention can be diverted by activities in the corridor and/or outdoors. Figure 3.30 shows this in details.

Figure 3.30 Different types of window materials, found in the field survey. (Source: Field Survey)

F) MATERIAL, COLOR AND TEXTURE OF WALLS, FLOOR AND CEILING.

Partition walls were found to be made of bricks, columns, beams and slabs of R.C.C. The entire inner surfaces were found painted with white color, with floor finish of gray neat cement finish. Figure 3.31 shows the wall, floor and ceiling colors, most commonly found in the survey.

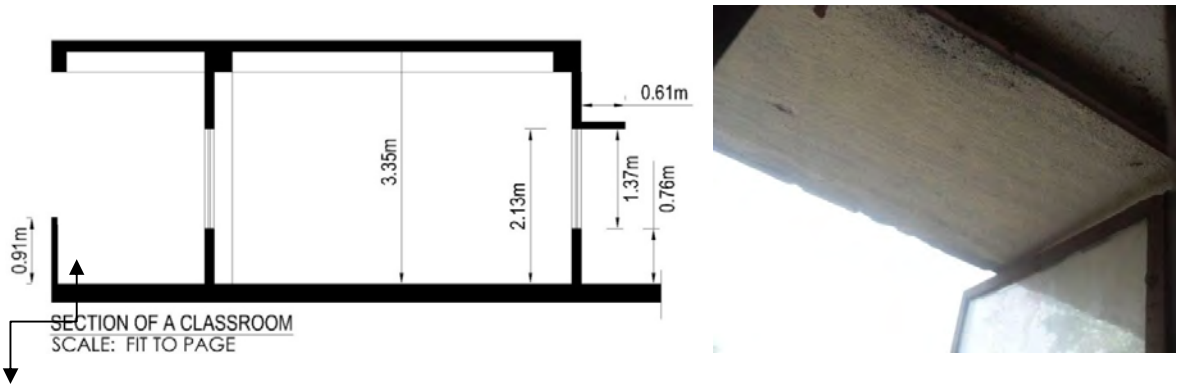
Figure 3.31 Color of classroom walls, floor & ceiling. (Source: Field Survey)

G) THE RATIO OF WINDOW AREA AND FLOOR AREA.

The ratio of window area and floor area was found dissimilar in different schools. In Khasdobir Government Primary School, this ratio was found as 1: 7 (14.28 %), in Madhushahid Government primary school, the ratio is, 1:4.25 (23.52%), and in the other two schools, this value is 1: 4.50 (22.22%). It is observed that, 3 schools are found to have a similar ratio of window area and floor area, but one has a much higher ratio. Though the calculations satisfy the standard for the ratio of window area and floor area (20%, mentioned in Chapter Two, section 2.7,F) , but still the amount of daylight found within the classrooms is quiet inadequate, because the other relevant factors are found dissimilar with the standard measures.

H) NATURE OF THE SHADING DEVICES

The schools use R.C.C. Shading devices with a depth of 0.5 m at lintel level, which is 2.14 m high from the floor. This is the prototype shading, and the dimensions are not derived through any analysis regarding the orientation of the building, and principles of shading and light shelf design, which is addressed in Chapter Two, Section 2.7, H. This is another reason for the poor daylighting condition found within the classroom spaces. Figure 3.32 shows a typical section of shading devices found in the classrooms of the surveyed schools. Moreover shades on exterior walls, were not found to be orientation dependent, and on the corridor side, the veranda provides deeper shading for the windows, thus cutting off more of the available daylight.



Veranda is working as a deeper shading.

Figure 3.32 shading devices. (Source: Field Survey)

I) SURROUNDINGS OF THE CLASSROOM.

Surrounding objects are one of the most important physical attributes that affect daylight penetration. Among the four sides of the surveyed classrooms, two are solid partition walls, corridor at one side and the only the remaining side is open to exterior which has the highest potential for welcoming daylight. But due to the dense urban situation, all the surveyed schools are immediately surrounded by neighboring structures, boundary walls and some trees also. All these obstructions reduce the amount of available daylight in the interiors of the classrooms.

Figure 3.33 Surrounding structures near school building. (Source: Field Survey)

In this research, the physical parameters were studied, as they have strong influence on the overall daylight condition of the classrooms. However, during the visual performance tests, the attempt was made, to consider these parameters as constant, and find situations of similarity, so that, the performance test could be made unbiased towards these specific parameters. This allowed the focus of the study to remain on relating the student's visual performance on available daylight level only.

The study of the physical parameters identifies the existing condition of the classroom spaces in urban primary schools in Sylhet, and how they rank accordingly to standards for such spaces. The daylight situation can be improved by an attempt to reach the standards, which will serve the basis for improving the daylight design of the spaces, which, however, remains beyond the scope of this particular investigation.

3.11 VISUAL PERFORMANCE TEST UNDER EXISTING DAYLIGHT CONDITION

Among the four case schools, where the detailed luminous condition, was studied, Khasdobir Government Primary School was selected for the visual performance test of the students on a random basis. 24 students (12 boys and 12 girls) from class four, were taken as the sample of this testing. As, the school is two storied and the location of class four is at the 1st floor, so, the classroom at 1st floor was considered in this research for the testing of visual performances.

3.11.1 DETAIL METHODOLOGY OF TESTING THE VISUAL PERFORMANCE

The control group was randomly selected of 12 boys and 12 girls from class four, based on their interest for appearing in the test, without any fear as that they may feel in other academic examinations. During the selection, subjective dissimilarities were considered constant, such as avoiding students who seem ill,

or arrived just before the visual performance test appears, without allowing the time to reconcile the eye with the current brightness of the classroom, etc. These 24 selected students were finally appeared in the visual performance test.

These 24 students (numbered sample 01 to sample 24) were equally divided in to 2 groups named 'Group 01' and 'Group 2'. These two groups appeared in the visual performance test separately considering the convenient management of this test. Each group was also divided into three sub groups, named X, Y and Z, where each subgroup contained of 2 boys and 2 girls. These 12 students individually appeared in the visual performance test thrice, altering their positions between window side, middle row and corridor side, where the amount of light is different discussed detail in section 3.9.In each test, they got a new question set, of similar complexity. The questionnaire designed for conducting this test, is based on the numerous related researches, which were described in the chapter 2.

Thus the research ensured that, every student of the control group, appeared on a separate visual performance test, with different day lighting situation, with different question sets for each situation. There was1 person assigned for each of the groups, consisting of 4 students each with stopwatches to monitor the required time, and collect the answer scripts when the test is over. The number of errors of each test computed later, from these answer scripts, along with the time for completion. This methodology of taking visual performance test was applied on the both groups.

The alternating position of the students during the visual performance tests is shown in the figure 3.34 a, b and c.

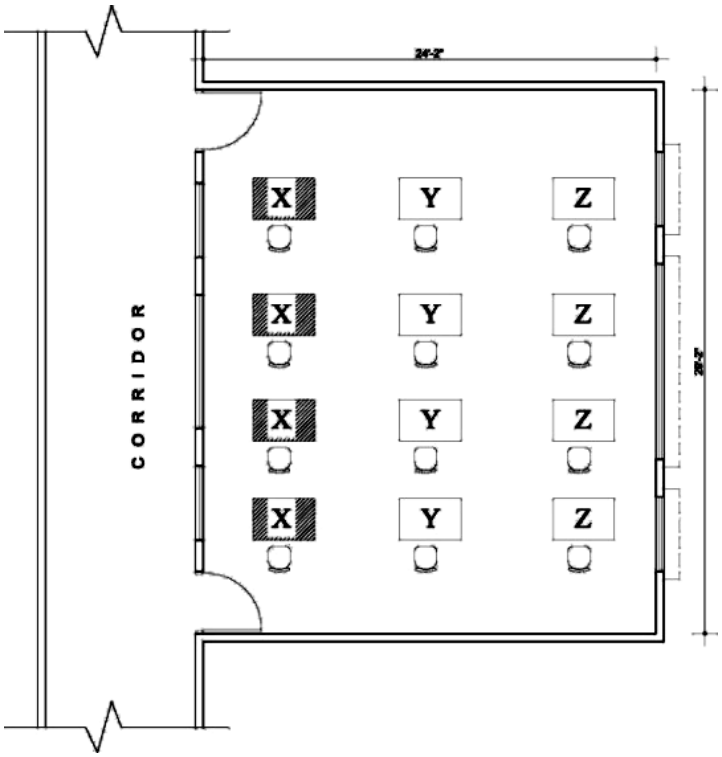


Figure 3.34 a *Position of the students during visual performance test -1.*

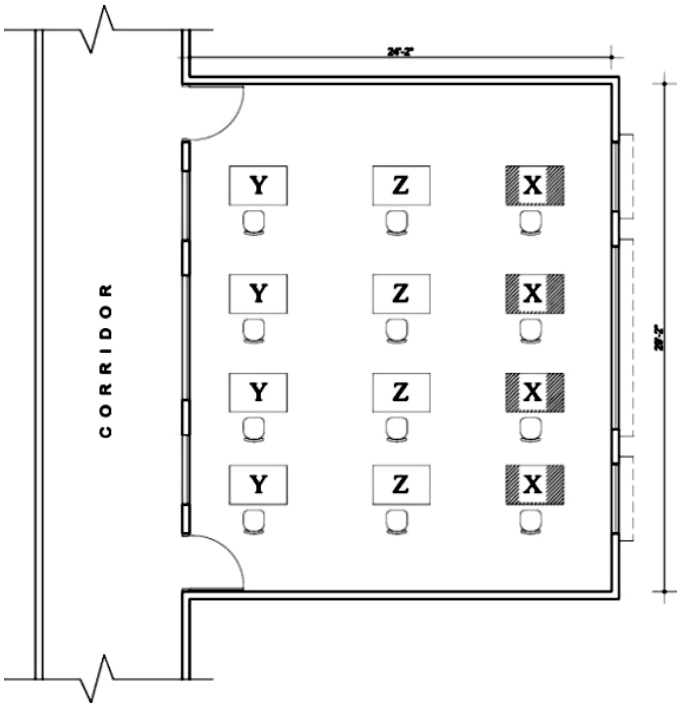


Figure 3.34 b *Position of the students during visual performance test -2.*

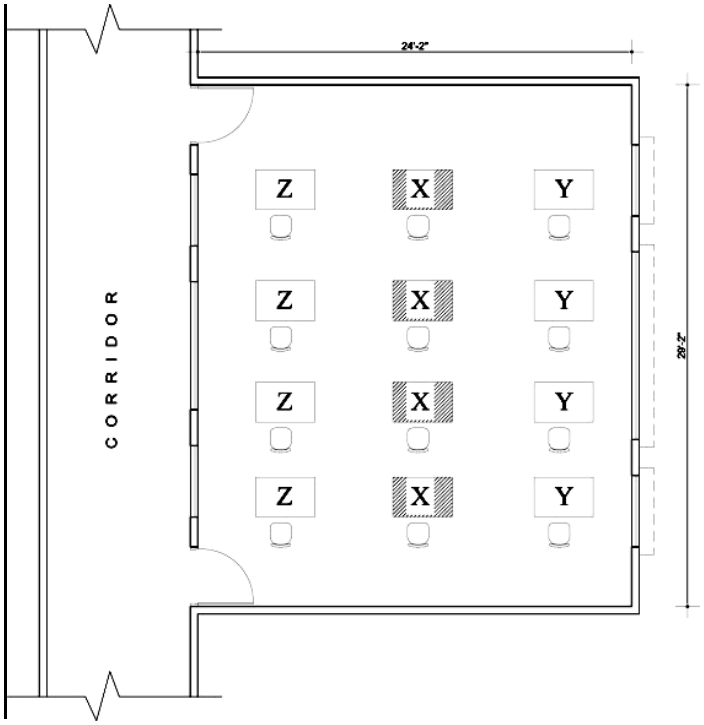


Figure 3.34 c *Position of the students during visual performance test- 3.*

The results of the visual performance tests revealed 3 scores, for each sample student, in 3 types of lighting situations, first at the window side where the illumination level was highest among all the positions within the classroom, secondly at the corridor side, where the illumination level was found lower than the window side and finally at the middle row, where the illumination level was found lowest among all other positions within the classroom.

The evaluation procedure consisted of calculating the percentage of error and required time, to complete all the answers for each student. These were analyzed to determine the percentage of mistakes a student does, and how much time the student takes to finish the answers under three different conditions of daylight and relate these to the illumination level. Thus the research focused on, how the daylight condition impacted on both individual and overall student's visual performance**.**

3.11.2 CONDUCTING THE VISUAL PERFORMANCE TEST AND RESULTS

Based on the literature survey, three sets of questionnaire were prepared for these visual performance tests for the students. The test consisted of identifying certain symbols from an A4 page of printed symbols (Appendix D). Three question sets were prepared, as the tests were conducted under three different daylight situations. There are total 500 randomly placed different symbols in the each set of questionnaire, where there are a total of 100 specific symbols, which the student needs to identify. The students were instructed to touch the desired symbol with pen and raise their hands when they felt the task was completed for the whole page. They were not informed that, there were 100 target symbols in each page out of these randomly distributed different symbols. Their task was limited only within seeing the target symbols, and to mark them with the pen provided.

The individual's total completion time was measured with stop watches. The numbers of untouched targets along with wrong targets were counted as the quantity of errors in this visual performance test, reflecting in their performance.

Every set of questionnaire was made unique, only in terms of the arrangements of the symbols. The details of this questionnaire sets shown in the appendix D.

The students were selected to reduce related visual variables, by using the following criteria, and identifying samples based on them.

a) Good eyesight
b) enthusiastic
c) class teacher's feedback
d) Good response found in pre-survey period, having received instruction of the test properly, to the satisfaction of the surveyor.
e) Gender equality.
f) Familiarity with the physical environment of the classroom.

The results of the tests are given in the following section and the questionnaire is provided in the appendix D.

3.11.2.1 GROUP 01

a) Name of the School :**KHASDOBIR GOVERNMENT PRIMARY SCHOOL**
b) Class : IV
c) Classroom position: 1st floor
d) Control group: 12 students (06 Boys and 06 Girls)
e) Number of groups: 03 (X,Y,Z)
f) Students in each Group: 04 (02 Boys and 02 Girls)
g) Total number of question sets: A, B, C.
h) Total number of tests taken: 03 (students altering their positions between Beside window, Middle row, beside corridor)

Table 3.17 Showing the error percentage and required time under different daylight conditions during the visual performance test

	POSITION	**Amount of light at the work top (Lux)**					
		Beside window (above 500 lux)		Beside corridor (200 lux – 350 lux)		Middle row (above 10lux – 80 lux)	
	NO	**Error percentage**	**Time required (Second)**	**Error percentage**	**Time required (Second)**	**Error percentage**	**Time required (Second)**
GROUP X	**sample 01**	7%	284	13%	316	19%	376
	sample 02	2%	229	5%	223	14%	301
	sample 03	13%	306	17%	330	23%	392
	sample 04	3%	245	5%	292	11%	315
GROUP Y	**sample 05**	15%	291	18%	316	29%	396
	sample 06	9%	222	13%	255	16%	304
	sample 07	5%	306	5%	333	10%	345
	sample 08	9%	225	15%	305	12%	339
GROUP Z	**sample 09**	9%	316	12%	386	18%	405
	sample 10	14%	255	19%	299	20%	328
	sample 11	8%	290	10%	318	10%	331
	sample 12	12%	247	19%	251	21%	307

3.11.2.2 GROUP :02

a) Name of the School :**KHASDOBIR GOVERNMENT PRIMARY SCHOOL**
b) Class : IV
c) Classroom position: 1st floor
d) Control group: 12 students (06 Boys and 06 Girls)
e) Number of groups: 03 (X,Y,Z)
f) Students in each Group: 04 (02 Boys and 02 Girls)
g) Total number of question sets: A, B, C.

h) Total number of tests taken: 03 (students altering their positions between Beside window, Middle row, beside corridor)

Table 3.18 Showing the error percentage and required time under different daylight conditions during the visual performance test

	POSITION	Amount of light at the work top (Lux)					
		Beside window (above 500 lux)		Beside corridor (200 lux – 350 lux)		Middle row (above 10lux – 80 lux)	
	NO	**Error percentage**	**Time required (Second)**	**Error percentage**	**Time required (Second)**	**Error percentage**	**Time required (Second)**
GROUP X	**sample 13**	6 %	290	13 %	293	24 %	375
	sample 14	7 %	276	11 %	315	28 %	346
	sample 15	13 %	315	14 %	366	17 %	407
	sample 16	10 %	241	18%	300	21 %	413
GROUP Y	**sample 17**	7 %	288	10 %	299	18 %	319
	sample 18	2 %	307	8 %	309	9 %	326
	sample 19	3 %	270	4%	275	6 %	285
	sample 20	6 %	282	7 %	321	13 %	377
GROUP Z	**sample 21**	8 %	318	10 %	331	17 %	339
	sample 22	6 %	304	21 %	350	26 %	412
	sample 23	3 %	276	14 %	290	19 %	309
	sample 24	7 %	228	9 %	240	10 %	299

A preliminary observation of the test results reveals the following

1) Error percentage for each individual sample is clearly related to amount of available daylight.
2) Times required for completion of the tests are also related to available daylight.

Further analyses of these results are provided in Chapter Four.

3.12 CONCLUSION:

This chapter has discussed the objective of the field study, and described the study area. This chapter also illustrates pre survey works, pilot survey with its findings, presenting the procedure of selecting the 'case' schools for detailed investigation. The condition of daylight in the classroom spaces are given in this chapter under different aspects, and are found to have an overall picture in the luminous situation in the urban primary school buildings of Sylhet. Here, the luminous conditions found in the field survey were compared with the internationally standard illumination levels. This chapter also reported on the visual performance tests, conducted on students, under different daylight conditions, along with the background and the visual environment during the visual performance tests with other related information. The test results have been measured with primary data found in this chapter. Both luminous condition and the result of the visual performance test will be analyzed in the following chapter (chapter four).

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CHAPTER: FOUR

RESULT ANALYSIS: EVALUATION OF VISUAL PERFORMANCES

4.1 Introduction

4.2 Result analysis

4.3 Conclusion

CHAPTER: FOUR

RESULT ANALYSIS: EVALUATION OF VISUAL PERFORMANCES

4.1 INTRODUCTION:

The previous chapter (Chapter Three) reports on the field investigations which included the rational for selecting study area, pilot survey along with its findings, and critical observations and the selection process of 'case schools' for detailed investigation of physical parameters and relationship with daylight availability. The detailed luminous reading was recorded and finally the information of results regarding the visual performance tests was reported.

This chapter will highlight the analysis of those results derived in Chapter four. The analysis process will primarily focus on the error percentage of each individual sample, and at the same time it will observe the required time under different daylight situations, during the visual performance test.

4.2 RESULT ANALYSIS

The previous chapter reports on the visual performance test (Chapter Three), which was taken under three circumstances, first one beside the window, where the amount of daylight found was more than 500 lux, secondly, beside corridor, where the amount of daylight found was in a range of 200 to 350 lux and thirdly at the middle row of the classroom, where, the amount of daylight found, was below 80 lux.

The visual performance test scripts were checked carefully, where the amount of error percentage came out for each student under the three types of luminous conditions. During the test, the amount of time required for each student, for each of the 3 tests, was also carefully taken with stopwatch.

In this Chapter, the result of the visual performance test will be analyzed, based on the error percentage and required time, and related to the amount of light. During the analysis of the findings, related in the previous chapters, three types of interrelations arise which diagrammatically present the relationship between the amount of light and students visual performance. These are:

a) Amount of light vs. error percentage
b) Amount of light vs. required time
c) Amount of light vs. number of errors per unit time.

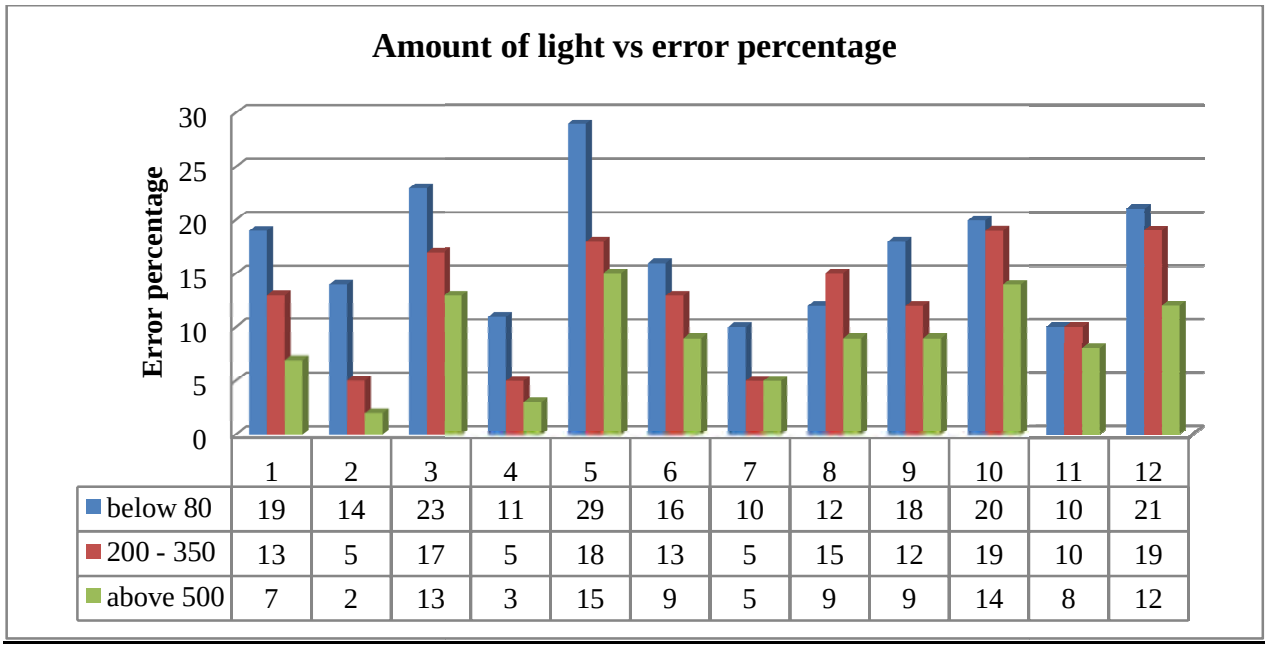
Findings from the visual performance tests are presented in the following sections:

4.2.1 GROUP 01: SAMPLES 01 –12

Six boys and six girls from Class IV appeared in this visual performance test for three separate tests, exchanging their positions, as they were instructed. Each was thus exposed to three luminous conditions for their visual performance testing. These 12 students are described as sample 1 to sample 12, in the following chart. The test was held in the 1st floor of the two storied Khastobir Government Primary School. (Chapter Three).

A) Amount of light vs. error percentages:

Figure 4.1 shows the comparison of error percentages for each student under different daylight situation.



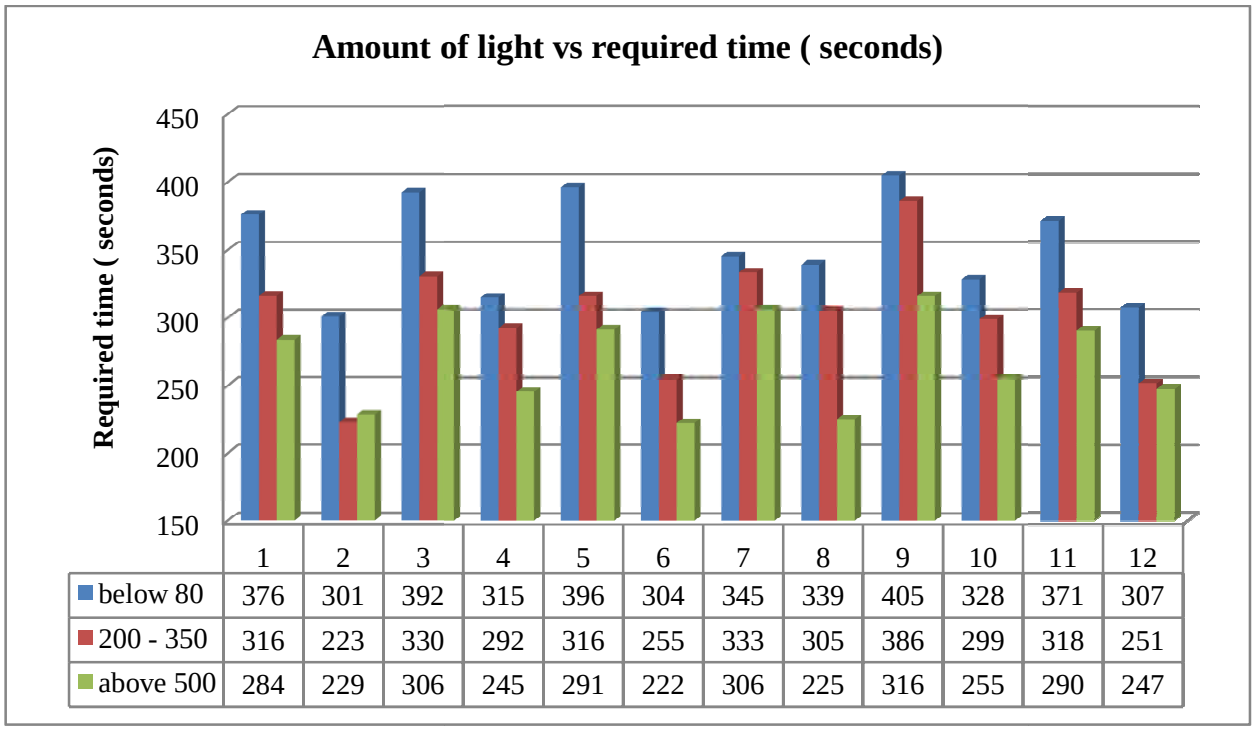
	1	2	3	4	5	6	7	8	9	10	11	12
below 80	19	14	23	11	29	16	10	12	18	20	10	21
200 - 350	13	5	17	5	18	13	5	15	12	19	10	19
above 500	7	2	13	3	15	9	5	9	9	14	8	12

Figure 4.1 Showing the comparison of error percentages for each student (Sample 01-12) under different daylight situation.

It is clearly observed from the above figure that, in most of the cases (except sample 7 & 8), when the amount of light increased, the error percentage of the each individual sample decreased. This indicates one major hypothesis of this research, that each individual's number of error is related to the amount daylight, which he/she was exposed.

B) <u>Amount of light vs. required time:</u>

Figure 4.2 shows the comparison of required time in seconds for each student under different daylight situation.



	1	2	3	4	5	6	7	8	9	10	11	12
below 80	376	301	392	315	396	304	345	339	405	328	371	307
200 - 350	316	223	330	292	316	255	333	305	386	299	318	251
above 500	284	229	306	245	291	222	306	225	316	255	290	247

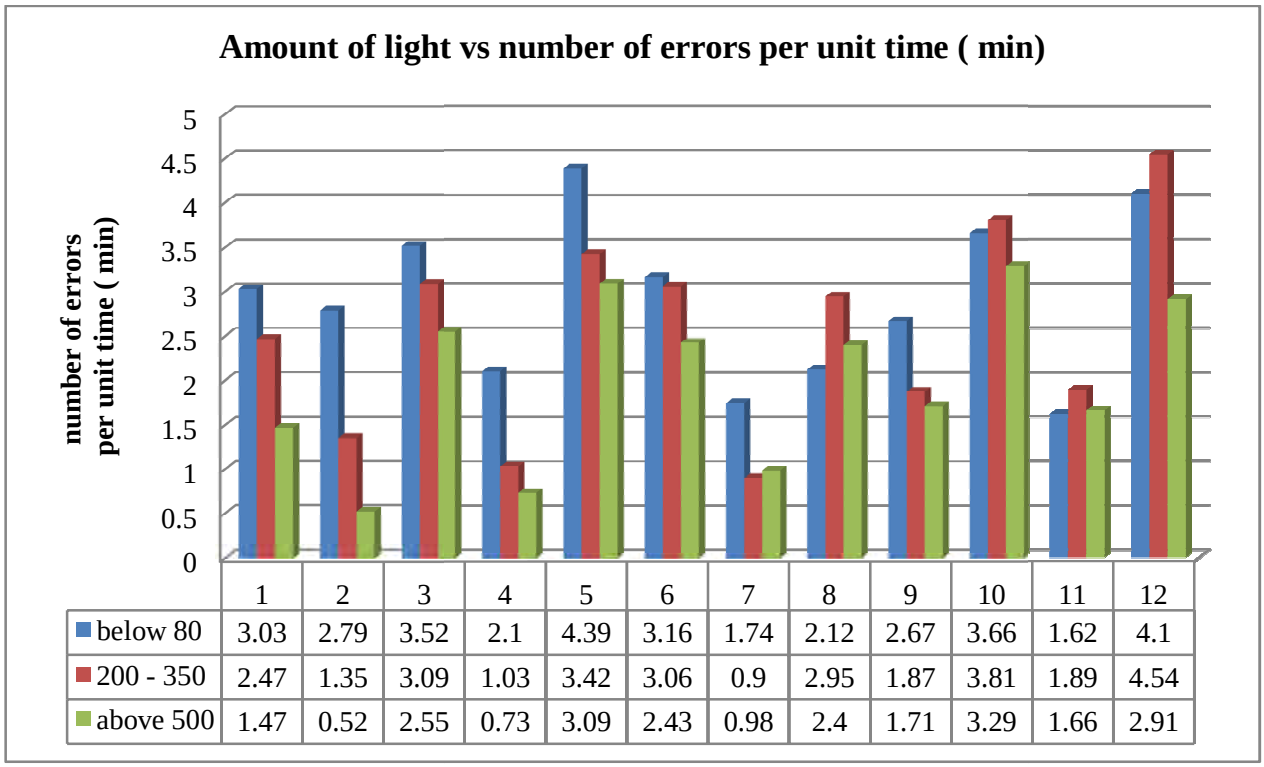
Figure 4.2 Showing the comparison of required time in seconds for each individual student (Sample 01-12) under different daylight situation.

Again the amount of time to complete the performance test is seen to vary from sample to sample and is obviously dependent on many subjective factors like intelligence, attentiveness, visual acuity etc, which were considered to be neutralized during the sample selection process in this research. But, it is clearly observed from the above figure that, when the amount of daylight was increased, the potential time for completing the task was reduced in every case.

However, if we compare the time to compare the performance test with the amount of error percentage, it is clear that the quickest performer may not be the one with the least errors.

C) Amount of light vs. number of errors per unit time (Minute)

Figure 4.3 shows the comparison of number of errors per unit time for each student under different daylight situation.



	1	2	3	4	5	6	7	8	9	10	11	12
below 80	3.03	2.79	3.52	2.1	4.39	3.16	1.74	2.12	2.67	3.66	1.62	4.1
200 - 350	2.47	1.35	3.09	1.03	3.42	3.06	0.9	2.95	1.87	3.81	1.89	4.54
above 500	1.47	0.52	2.55	0.73	3.09	2.43	0.98	2.4	1.71	3.29	1.66	2.91

Figure 4.3 Showing the comparison of number of errors per unit time for each individual student (Sample 01-12) under different daylight situation.

To calculate the number of errors per unit time under three lighting conditions, the unit time was considered to be a minute, i.e. 60 seconds. The total number of errors for each sample was divided by the total time in minutes. Figure 4.3 is a cumulative record of the 12 samples.

It is observed from the above figure that in some of the cases (sample 1, 2, 3,4,5,6,7,9 & 12), when the amount of light increases, then the number of errors per unit time is reduced. Again, in some other cases (sample 8,10 &12), it is found that, the number of errors per unit time increased at 200-350 lux, but again started decreasing enormously, when the amount of daylight is highest among the considered values of day light levels. And, for case 11, the number of error per unit time is found lowest in the lowest amount of daylight situation.

As a whole, it is seen that, when the amount of daylight increases, the trend of these values goes downward, which reflects overall improved visual performance, with daylight level..

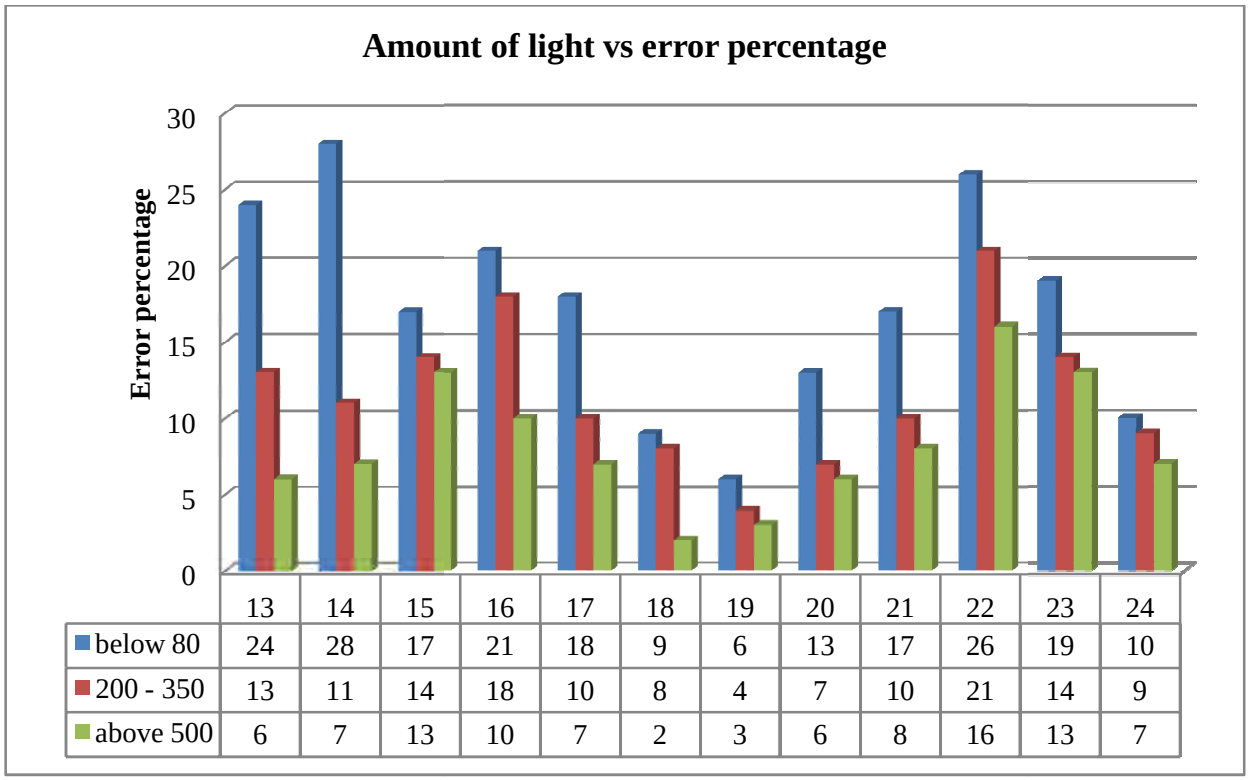
4.2.2 GROUP 02: SAMPLE 13 - 24

Again, six boys and six girls from the same class appeared in this visual performance test for three times, exchanging their positions, as they were instructed previously. This test was also taken under daylight

conditions only, and the electrical lights were turned off. These 12 students are described as Sample 13 to Sample 24 in the following chart. It was held in the same classroom where the previous test took place.

A) Amount of light vs. error percentage

Figure 4.4 shows the comparison of error percentages for each student under different daylight situation.



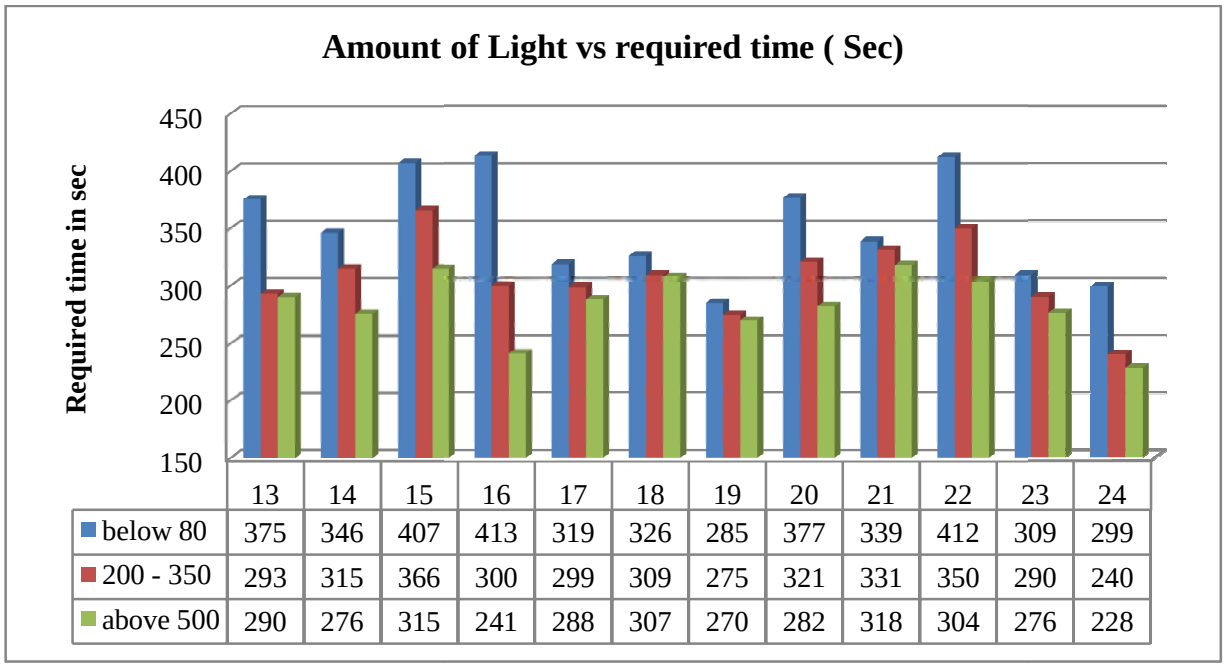
	13	14	15	16	17	18	19	20	21	22	23	24
below 80	24	28	17	21	18	9	6	13	17	26	19	10
200 - 350	13	11	14	18	10	8	4	7	10	21	14	9
above 500	6	7	13	10	7	2	3	6	8	16	13	7

Figure 4.4 Showing the comparison of error percentages for each student (Sample 13-24) under different daylight situation.

It is observed from the above figure that, in all of the cases when the amount of light increases then the performance is potentially higher as the error percentage is found low. So, from the above figure, it is clear that, there is an inverse relationship between the amount of daylight, and the amount of error percentage, for each sample.

B) Amount of light vs. required time

Figure 4.5 shows the comparison of required time in seconds for each student under different daylight situation.



	13	14	15	16	17	18	19	20	21	22	23	24
below 80	375	346	407	413	319	326	285	377	339	412	309	299
200 - 350	293	315	366	300	299	309	275	321	331	350	290	240
above 500	290	276	315	241	288	307	270	282	318	304	276	228

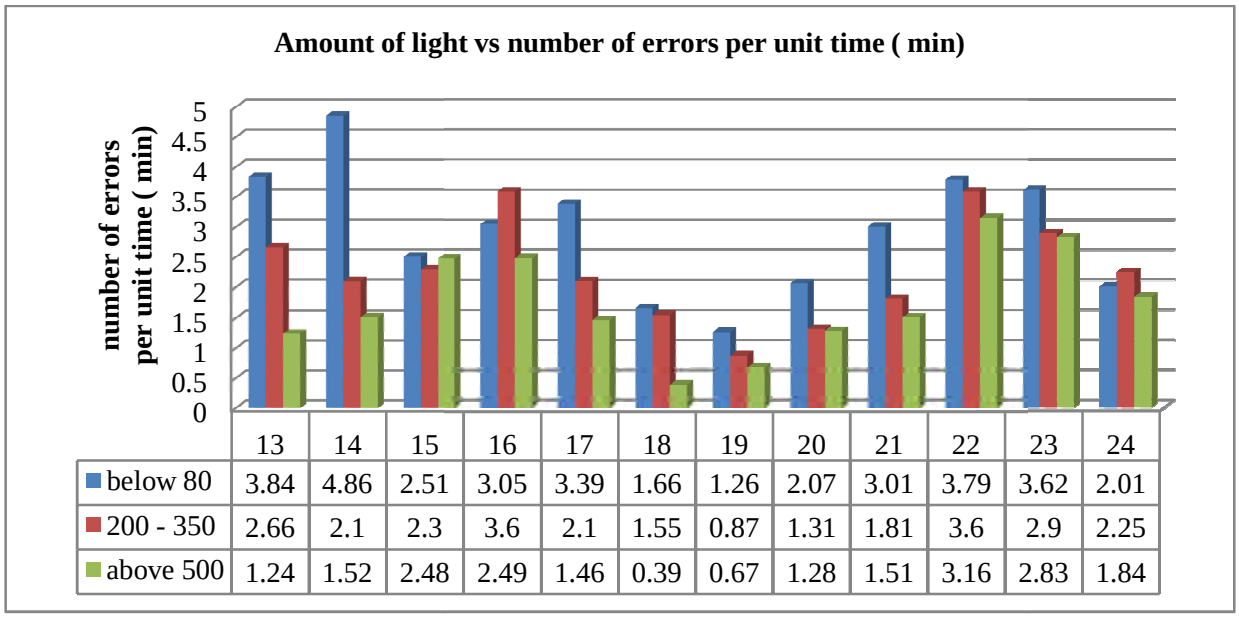
Figure 4.5 Showing the comparison of required time in seconds for each individual student (Sample 13-24) under different daylight situation.

In this case, the amount of time to complete the performance test is also seen to differ from sample to sample. The time taken to complete a task is a sign of performance, this gives an inverse performance relationship between time and daylight level.

Commonly, it is observed from the above figure that in all of the cases, when the amount of light decreases then the required time is found higher to complete the visual performance test. In other words, student's performance increases directly with daylight availability.

c) Amount of light vs. number of errors per unit time (minute)

Figure 4.6 shows the comparison of number of errors per unit time for each student under different daylight situation.



	13	14	15	16	17	18	19	20	21	22	23	24
below 80	3.84	4.86	2.51	3.05	3.39	1.66	1.26	2.07	3.01	3.79	3.62	2.01
200 - 350	2.66	2.1	2.3	3.6	2.1	1.55	0.87	1.31	1.81	3.6	2.9	2.25
above 500	1.24	1.52	2.48	2.49	1.46	0.39	0.67	1.28	1.51	3.16	2.83	1.84

Figure 4.6 Showing the comparison of number of errors per unit time for each individual student (Sample 13-24) under different daylight situation.

To calculate the number of errors per unit time, under the three lighting conditions, the unit time was considered, as before, to be a minute, i.e. 60 seconds. The total number of errors for each sample was divided by the total time in minutes. Figure 4.6 is a cumulative record of samples 13 to 24.

In this case, it is also seen from the above figure that in a single case (sample 15), when the amount of light increases then the number of errors per unit time is found higher. But, in rest of the cases, it is observed that, when the amount of daylight is increased, the value of errors per unit time decreased.

But, in the broad-spectrum, it is well observed that, when the amount of daylight increases, the trend of this value goes downward, which reflects the general improved level of visual performance. It is clear that, there is consistency in the results of the 24 samples, which are studied in this research. The following section compares all the test cases.

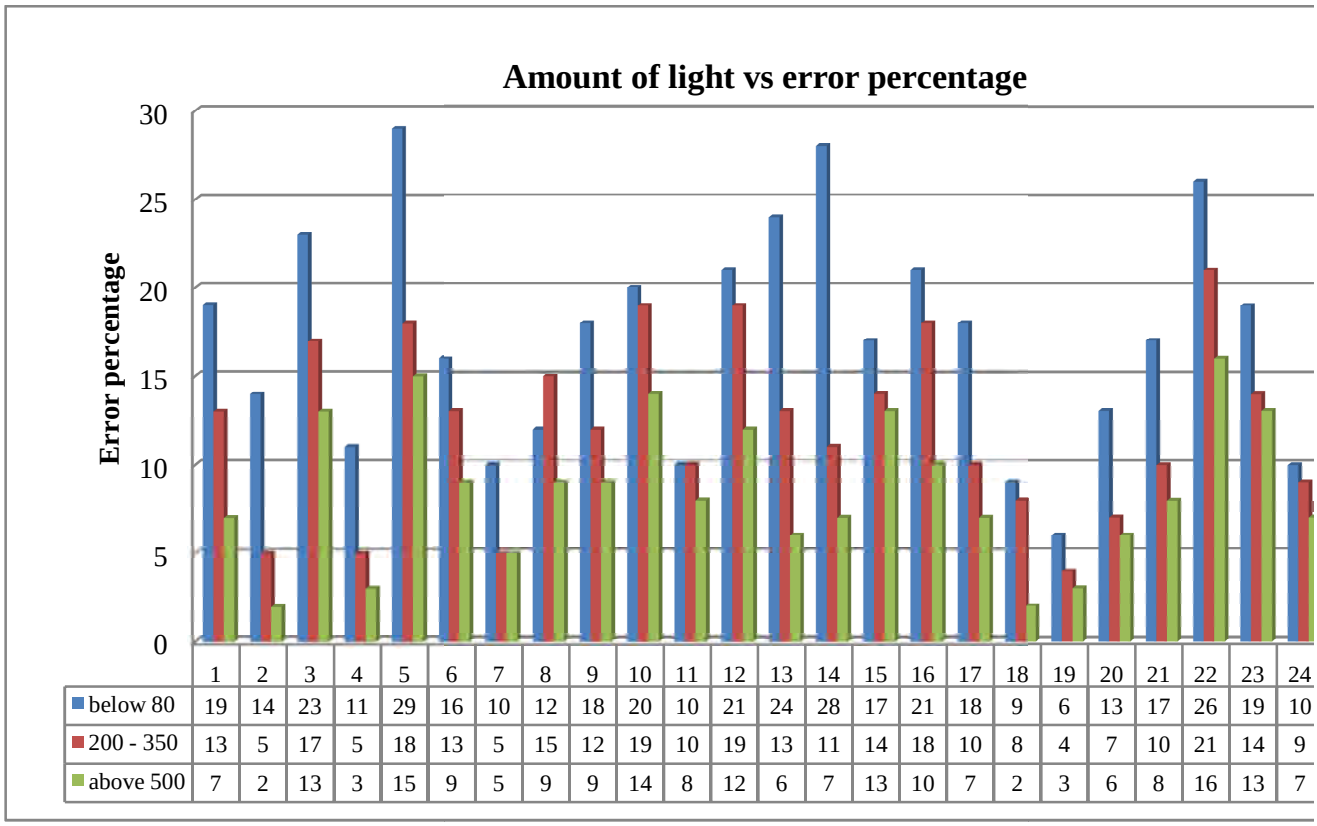
4.2.3 INTEGRATION OF THE CASE STUDIES:

Twelve boys and twelve girls from Class IV, from Khasdobor Government Primary school had appeared in the entire process of visual performance test for three individual tests, exchanging their positions, as they were instructed. These 24 students are described as sample 1 to sample 24 in the following chart. This chart will be a cumulative result of all cases discussed above.

In all the cases, students were exposed to daylight, where the artificial lights were turned off during the visual performance tests.

A) Amount of light vs. error percentage:

Figure 4.7 shows the Error percentages of overall situation under different daylight conditions in the visual performance test. The higher the error, the lower is the visual performance.



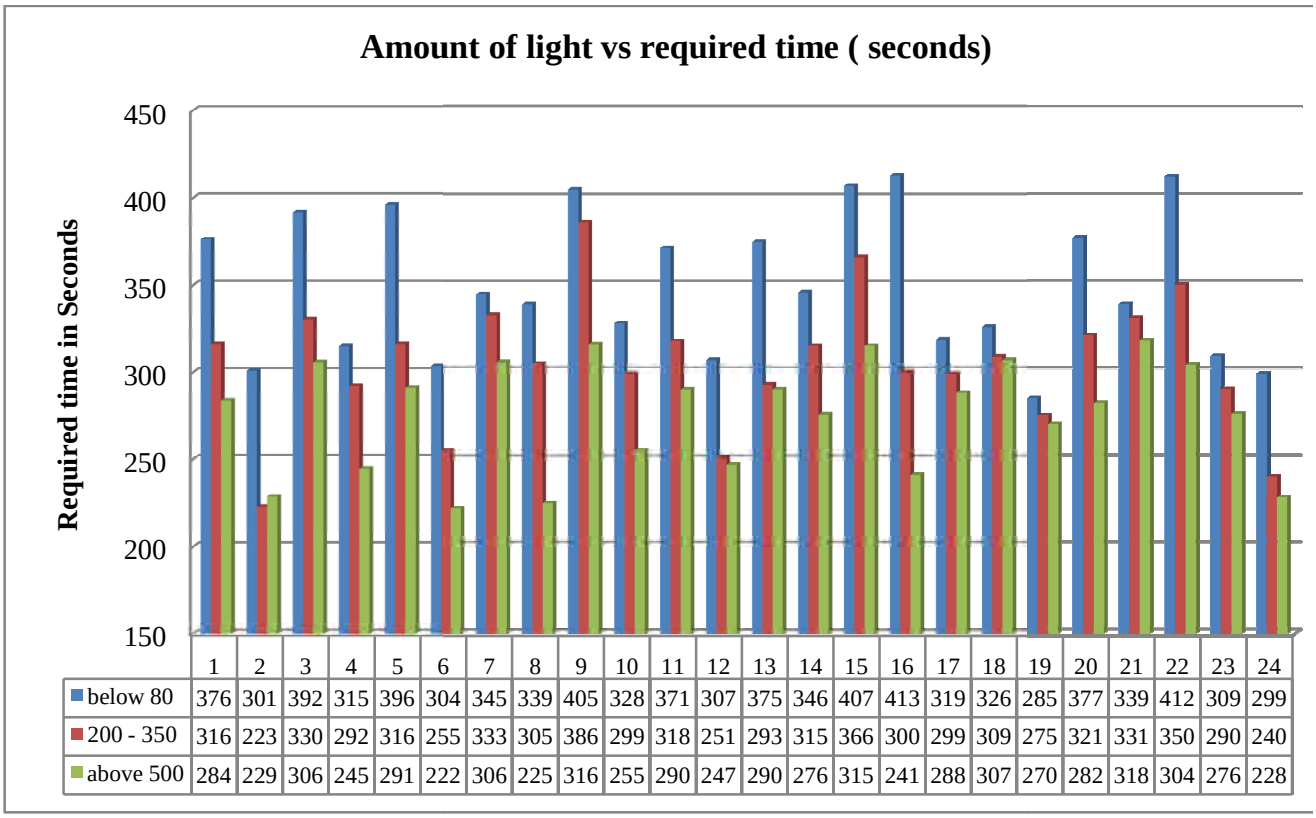
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
below 80	19	14	23	11	29	16	10	12	18	20	10	21	24	28	17	21	18	9	6	13	17	26	19	10
200 - 350	13	5	17	5	18	13	5	15	12	19	10	19	13	11	14	18	10	8	4	7	10	21	14	9
above 500	7	2	13	3	15	9	5	9	9	14	8	12	6	7	13	10	7	2	3	6	8	16	13	7

Figure 4.7 Showing Error percentages of overall situation under different daylight conditions in the visual performance test.

It is clearly observed from Figure 4.7, that, the error percentage remained lowest for each individual sample for lighting levels of 500 lux and above. This error percentage grows a little higher under the medium range of lighting in the graph, when the amount of light was found to be between 200 lux to 350 lux. And the error percentage is found highest when the measured light level is below 80 lux. This is one outcome of this study, for the primary level students, amount of daylight is proportional to their visual performance as error percentage is one of the indicators of students' visual performance.

B) Amount of light vs. time required

Figure 4.8 shows the overall picture of required time, under different daylight conditions, in the visual performance test.



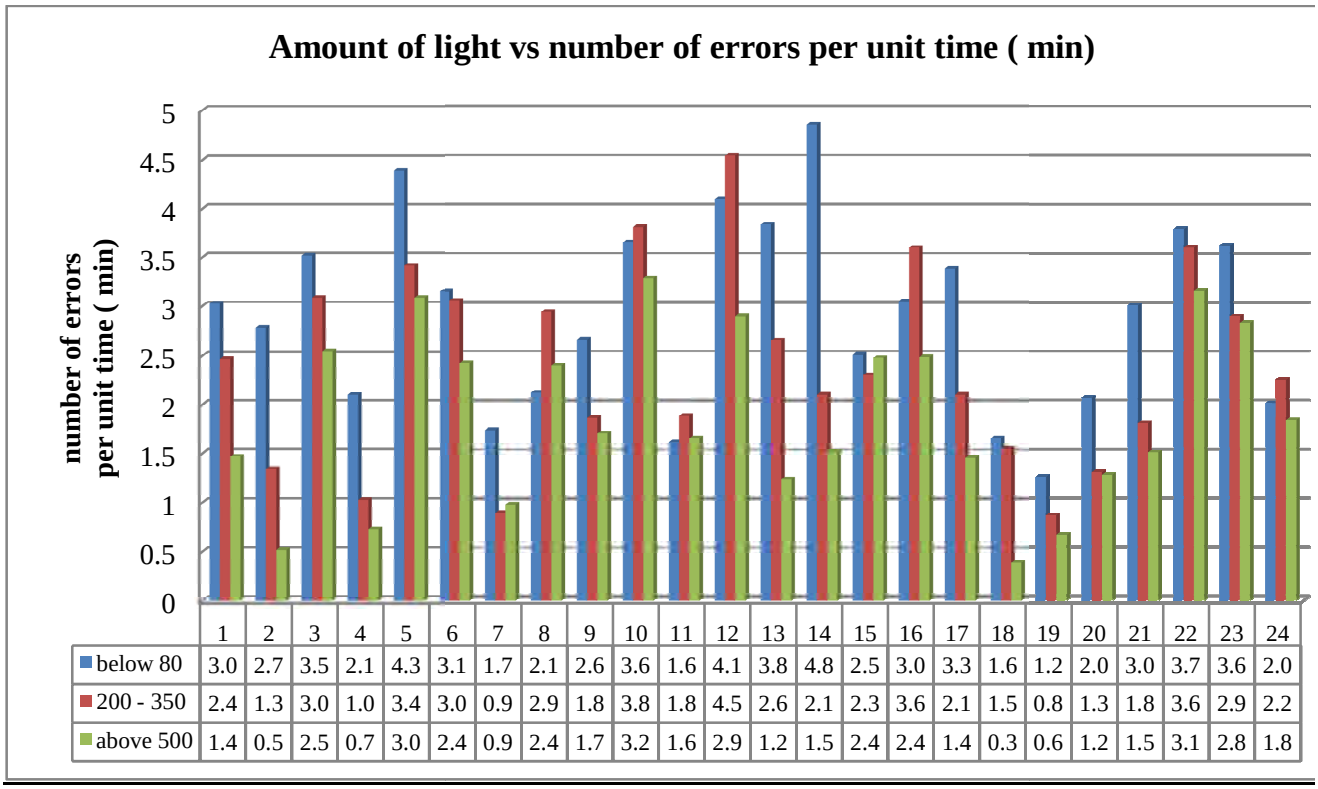
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
below 80	376	301	392	315	396	304	345	339	405	328	371	307	375	346	407	413	319	326	285	377	339	412	309	299
200 - 350	316	223	330	292	316	255	333	305	386	299	318	251	293	315	366	300	299	309	275	321	331	350	290	240
above 500	284	229	306	245	291	222	306	225	316	255	290	247	290	276	315	241	288	307	270	282	318	304	276	228

Figure 4.8Overall picture of required time under different daylight conditions in the visual performance test.

Again it is clearly observed from the Figure 4.8, that, the required time for the visual performance test took lowest when the lighting level measured 500 lux or more. This required time grows a little higher for the lighting levels between 200 lux to 350 lux. And the required time zone is highest when the measured light level is below 80 lux. So, this result again indicates that, for the primary level students, amount of daylight is proportional to their visual performance, as required time for completing the task is one of the indicators of the students' visual performance.

C) Amount of light vs. number of errors per unit time (minute)

Figure 4.9 overall value of number of errors per unit time under different daylight situation (Source: author).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
below 80	3.0	2.7	3.5	2.1	4.3	3.1	1.7	2.1	2.6	3.6	1.6	4.1	3.8	4.8	2.5	3.0	3.3	1.6	1.2	2.0	3.0	3.7	3.6	2.0
200 - 350	2.4	1.3	3.0	1.0	3.4	3.0	0.9	2.9	1.8	3.8	1.8	4.5	2.6	2.1	2.3	3.6	2.1	1.5	0.8	1.3	1.8	3.6	2.9	2.2
above 500	1.4	0.5	2.5	0.7	3.0	2.4	0.9	2.4	1.7	3.2	1.6	2.9	1.2	1.5	2.4	2.4	1.4	0.3	0.6	1.2	1.5	3.1	2.8	1.8

Figure 4.9 Overall numbers of errors per unit time under different daylight situation.

To calculate the number of errors per unit time under three lighting conditions, the unit time was considered to be a minute, i.e. 60 seconds. The total number of errors for each sample was divided by the total time in minutes. Figure 4.9 is a cumulative record of the 24 samples.

It is observed from the above figure, that, the trend of error percentage per unit time, for the visual performance test is lower under highest considered daylight level. It has grown a little higher in the graph when the amount of light was measured to be in between 200 lux to 350 lux. And this became highest in the above graph when the measured light level is below 80 lux. As error percentage per unit time can be considered as one of the indicators of students visual performance, it can be clearly be concluded that, increased daylight directly contribute to increased visual performance of primary level students.

In other words, for primary level students, amount of daylight is proportional to their visual performance.

4.3 CONCLUSION:

In this chapter, the results of visual performance tests have been analyzed, based on their error percentage and required time during the visual performance test. This chapter reveals a concrete relationship between daylight and visual performances of primary level students. the relationship can be summarized as follows:

1) Error percentage is inversely proportional to amount of daylight.
2) The required time is also inversely proportional to amount of daylight.
3) Number of errors per unit time is also inversely proportional to amount of daylight.

The following chapter (chapter five) will provide the recommendations based on the outcome of this entire study and suggest the scope for future research, as related to the limitations here identified.

CHAPTER: FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

5.2 Review of research objectives

5.3 Discussion on the results

5.4 Recommendations

5.5 Conclusion and suggestion for further research

CHAPTER: FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

In this research, the classroom environment of urban primary school building in Sylhet, Bangladesh was studied, which is the first field study based investigation of its kind in the country. The main aim of this research was to evaluate visual performance of primary level students, under daylight conditions, and relate the physical parameters of classroom spaces, with the daylight condition. The primary focus of this research was to establish a clear relationship, reflecting the daylight impacts on student's visual performance, within the classroom spaces, both in qualitative and quantitative aspects.

Daylighting design is both an art and a science. Qualitative information and visual feedback on a given daylighting concept are usually as important for the building designer, as the quantitative figures, that reflect the engineering aspects of lighting design. Environmentally conscious assessments of building design, are recognizing that daylight (along with the natural fresh air) is an important commodity, and should be exploited to the full. Generally, people when asked, always prefer to work in a daylit environments. There is a growing acknowledgement that daylight produces positive effects, both physiological and psychological**.** These concepts have been discussed in Chapter two of this thesis.

'Chapter 1' of the thesis described briefly about the overall objective of the work, background, methodology of the research, quality considerations, and scope of the study. The literature review related to visual environment, illumination conditions and students visual performance testing, which were briefly illustrated in 'Chapter Two'. According to the methodology, the detailed investigation on the classroom spaces, which involved the field survey and students visual performance test, was explained in 'Chapter Three'. The immediate past chapter (Chapter Four) analyzed the overall outcomes, where the clear relationship between amount of daylight and students visual performance test, was established.

This concluding chapter will discuss briefly, about the overall problems identified during the research conducted, along with some directions towards future scope of work in this field.

5.2 REVIEW OF RESEARCH OBJECTIVES

This research aimed to study the daylight conditions of urban primary schools in Sylhet, and to evaluate the visual performance under daylight conditions.

The objectives (stated in the section 1.7) of this research, have been fulfilled by the findings of this investigation. The objectives of this research and the way they were addressed are discussed below:

1) To evaluate visual performance of primary level students under daylight condition.

During this study, student's visual performance test was conducted under different amounts of daylight levels. The result analysis of these tests, evaluates the performance scenario of the primary level students, where clear relationships could be established between visual performance and available daylight. (Chapter 3 and 4)

2) To relate physical parameters of classroom spaces with daylight condition.

In this research, after a pilot survey of schools in Sylhet, four schools were selected for detailed luminous investigation, according to criteria set for the exercise, after literature review and pilot survey. The visual performance tests were conducted in a single classroom of Khasdobir Government Primary School. There are several physical parameters found to be significantly affecting the daylight condition inside the classrooms spaces. These factors are discussed in Chapter Three, Section 3.10. The physical parameters were compared to international standards in an effort to establish their adequacy. Classrooms of these schools were investigated in the observational strategy of this research and measurements were taken in the classrooms to determine the condition of daylight within these spaces. It was found that, the parameters do not generally meet the internationally recommended standards for classroom spaces. Therefore, daylight condition in the classroom spaces was found to be poor.

5.3 DISCUSSION ON THE RESULTS

5.3.1 BROAD FINDINGS

The research was based on the field investigation and measurements for detailed understanding of luminous environment inside the typical classrooms of Sylhet urban area, under mainly overcast situations, considering the different times of a day (morning, noon and afternoon). The indoor luminous environment was measured by digital light meter (Appendix A), and the timing of the performance test was taken by stopwatch. A standard questionnaire format (Appendix D) was followed for recording the visual performance under the measured luminous conditions.

The field survey was conducted only under daylight conditions, keeping the artificial lights turned off. It may be mentioned here that, most of the primary schools in Sylhet urban area were found, during the pilot survey, to have high dependency on artificial lights. This section summarizes the major findings of this study. This research followed both subjective as well as objective studies, to determine the relationship of students' visual performance with available daylight within the classroom spaces. The major findings of this research are summarized in the following sub-sections.

5.3.1.1 FINDINGS ON THE DAYLIGHT CONDITIONS IN CLASSROOM

The findings of the research in daylight condition in the classrooms are summarized below:

1) In all the cases, middle row of the classroom receives the lowest amount of daylight under both clear sky and over cast situations (less than 80 lux), which is much lower than international standards for classroom spaces.
2) Classrooms at ground floor receive the lowest amount of daylight, compared to other floors, with height level increasing progressively at upper levels. This was identified as being due to the obstructions, which restricts daylight penetration.
3) Using paint on glass, which seems to be a common feature among the schools in Sylhet, also reduces the amount of daylight penetration within the classroom spaces. The material used for windows is mostly glass, but painting over glass restricts the daylight penetration.
4) The classrooms are found to be very small in size when comparing with international standards. 20-25 sqm area is found with 50-75 pupils where the standard suggests 70-76 sqm for 30 pupils.
5) Ceiling heights of the classrooms were found to be similar with the standard, which is 3.15m.
6) Walls and ceiling were found with white paint but the floor finish is gray in color, which has a lower refection value, thus reducing daylight distribution.
7) The ratio of window area and floor area was found to be similar with the standards (20%) in general.
8) The nature of the shading devices were found to be prototypes, following the codes but not satisfying daylight purposes, due to restriction of sky view.
9) The corridor side windows are shaded by veranda, which is deeper than sunshades, and though higher than the sunshades, these are more restrictive to daylight penetration.
10) Obstructions were found very close to the school buildings, which is responsible for restricting the flow of daylight in to the classroom spaces, particularly in the lower levels of the building.

5.3.1.2 FINDINGS ON VISUAL PERFORMANCE TEST

During the visual performance test, the following clear indications could be derived from the test:

1) Error percentage is inversely proportional to the amount of daylight available at the desktop.
2) Required time for the visual performance test is inversely proportional to the amount of daylight available at the desktop.
3) Number of errors per unit time is also inversely proportional to the amount of daylight available at the desktop.

There is therefore a clear indication that, visual performance of primary level students is directly related to daylight penetration.

5.3.2 PROBLEMS FACED DURING INVESIGATION

It has been one of the aims of this study, to present overview of the luminous environment, within different types of primary school buildings, that exist in Sylhet city, where aspects that affect this environment, have been examined in a number of case studies.

Surveys show that, lighting design in general is a neglected aspect of the overall design of spaces in Sylhet. This is clear from the measured illumination levels at the typical Government Primary school

buildings, where the lighting levels are well below acceptable standards, in all the instances examined. This indicates that, lighting, particularly daylight, is not considered during design in an organized way, to fit the function, or to satisfy any standards.

However, it was the first and foremost field survey based comprehensive study on luminous environment of the classrooms of Sylhet urban area. A few difficulties arose during the collection of climatic data of Sylhet, as that is not as freely available, as of the capital district, Dhaka.

Another problem during the test was identified as the fear of students for appearing in examinations. In order to dispel this fear, initiatives were taken to motivate them for appearing in the visual performance test, without any fear. This was done by counseling them, and explaining that the test wouldn't be counted in any academic evaluation.

5.4 RECOMMENDATIONS

The recommendations in this section are based on the results of visual performance test under daylight condition. From the study, the following recommendations were drawn for primary school design, in the context of urban areas of Sylhet, to improve the level of visual performance.

A) Among all the positions in a classroom, the middle row was found with lowest amount of daylight, and while a student is appearing in the performance test in this particular zone, he/she is taking higher time, with a higher percentage of error, than in other positions. So, it is necessary to consider these aspects in the design process of a school building, so that this problem can be resolved.
B) It is also important to emphasize in the design process, on how to increase daylight penetration in the lower levels of school buildings, where the surrounding buildings, trees and other obstructions exists, as in urban areas.
C) It is necessary for the users or the school management to realize the importance of availability of daylight within the classroom spaces, so that, they can avoid measures such as painting in the glass, which drastically affects the daylight penetration inside the classrooms.

5.5 CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

In this thesis, basic daylight strategies were linked to students' visual performance. Through the connections, design steps can easily be implemented in Sylhet, if the designers are aware of the issues discussed. The recommendations suggested in this chapter can be applied, during design of primary school buildings, as well as after construction during interior design, or during general renovation works.

Only ways of increasing daylight inclusion are discussed in this thesis. However, in the tropics, unwanted heat may enter, with the light. Too much or unguided daylight, may cause glare and light pollution,which can adversely affect visual performance. All these negative effects have energy implications, i.e. active energy (electricity) consumption may be required to rectify these adverse effects. Therefore, an informed balance must be struck between energy saved by limiting use of artificial lighting due to daylight inclusion, and that spent to get rid of excess heat by air conditioning. Likewise, there will be other balances to be taken in to account, related to ventilation, acoustics and other subjective concerns of

privacy and view. Such aspects require to be studied with care, in order to create sustainable building solutions, but these were beyond the scope of this research.

Some of the most important areas that need to be explored in future, with special reference to primary school buildings of Sylhet, and in Bangladesh, are summarized below:

1) More research is needed to assess the impacts of daylight inclusion on the classrooms of primary school buildings in rural settings.
2) Further study is required to assess the specific impact of changing physical parameters of the classrooms on daylight inclusion and distribution.
3) The consequences of daylight inclusion on overall energy savings for primary school building need to be studied, which will include both thermal as well as ventilation concerns.
4) More analysis can be done to fix contextual comfort levels of daylight, artificial light and the total visual environment for the students.
5) Luminous investigation needs to be conducted in the other climatic zones of Bangladesh with longer observations, to establish appropriate luminous standards.

This work aimed to explore the nature of the luminous environment of primary school buildings in Sylhet and to identify parameters that can help to improve the luminous environment through daylight inclusion in primary school buildings of Sylhet city. It further aimed to determine relationships between daylight availability and primary school students visual performance, this research can be used as a basis for additional investigations to examine the consequences of daylight inclusion in schools and learning spaces, as the direct relationship of daylight in the visual performance of children has been proven without doubt.

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APPENDIX

A) Specifications of light meter
B) List of schools in sadar upozila and dakkhin surma upozila
C) Climatic data of Sylhet which affects the daylight penetration
D) The questionnaire used during the survey
E) Answer scripts of visual performance test

APPENDIX A

TES1332 DIGITAL LUX METER

SPECIFICATIONS:

- Display 3-1/2 digit LCD
- Measuring range : 20/200/2000/20000/200000 LUX
- Over range display : highest digit of (1) is displayed
- Resolution : 0.1 LUX
- Accuracy: ± 3% rdg ± 0.5 % (Calibrated to standard incandescent tamp. 2856° K.)
- Spectral response : CIE photopic (CIE human eye response curve)
- Spectral Accuracy : CIE V Ǒ Function f°1 < = 6%
- Repeatability : ± 2%
- Temperature characteristics: ± 0.1 %/ ° C
- Measuring rate: Approximately 2.0 time/ sec
- Photo sensor : silicon photodiodes
- Operating temperature and humidity : 0° C - 40° C (32 °F - 104° F) and 0-80% RH

Ranges (LUX)	Allowance
0-200/0.1	± 3% rdg ± 5%
0-2000/1	f.s. (<10000 LUX)
0-20000/10	± 4% rdg ± 10dgt
0-200000/100	f.s. (<10000 LUX)

FEATURES:

- Accurate and instant response
- Data hold function
- Special sensitivity close to CIE photopic curve
- Cosine angular corrected
- Analog output jack for recording
- CNS 5119 class II

Figure: TES 1332 Digital LUx Meter

APPENDIX B

LIST OF SCHOOLS IN SADAR UPOZILA AND DAKKHIN SURMA UPOZILA

The list of total government primary Schools in Sadar Upozila and Dakkhin Surma Upoozila is given here, the highlighted schools are located in urban area and the rest of the schools are located in rural areas.

NO	NAME OF THE SCHOOL (WITH SADAR UPOZILA AND DAKKHIN SHURMA UPOZILA)	Year of establishment	School Code
01	KALIRGAON PRIMARY SCHOOL Address: Jalalabad, Pirer Bazar	1952	602010101
02	SHOTOR PRIMARY SCHOOL Address: Hatkhula, Shiber Bazar	1937	602010102
03	HATKHULA PRIMARY SCHOOL Address: No.2 Hatkhula, Shiber Bazar	1940	602010103
04	RAZARGAON PRIMARY SCHOOL Address: No.2 Hatkhula, Shiber Bazar	1936	602010104
05	BOROKAPON PRIMARY SCHOOL Address: No.2 Hatkhula, Shiber Bazar	Not found	602010105
06	NANDIRGAON PRIMARY SCHOOL Address: No.2 Hatkhula, Shiber Bazar	1949	602010106
07	NOAGAON PRIMARY SCHOOL Address: No.2 Hatkhula, Shiber Bazar	1956	602010107
08	BHADESHSHOR PRIMARY SCHOOL Address: No.2 Hatkhula, Shiber Bazar	1900	602010108
09	——————————— Address: No.2 Hatkhula, Shiber Bazar	1970	602010109
10	UMAIRGAON PRIMARY SCHOOL Address: No.2 Hatkhula, Shiber Bazar	1945	602010110
11	LAKHAURA PRIMARY SCHOOL Address: No.3 Khadim Nagar, Lakhaura	1956	602010201
12	DHUPAGUL PRIMARY SCHOOL Address: No.3 Khadim Nagar, Shaheber Bazar	1959	602010202
13	SALIA PRIMARY SCHOOL Address: No.3 Shalutikar	1938	602010203
14	BIMANBONDOR PRIMARY SCHOOL Address: Khadimnagar, Cadet College	1958	602010204
15	FORINGDHORA PRIMARY SCHOOL Address: Khadimnagar, Shaheber Bazar	1926	602010205
16	BAISHTILA PRIMARY SCHOOL Address: No.3 Khadimnagar, Cadet College	1975	602010206
17	NAKHARGUL PRIMARY SCHOOL Address: Khadimnagar, Shaheber Bazar	1954	602010207
18	CHANPUR PRIMARY SCHOOL Address: Khadimnagar, Shaheber Bazar	1952	602010208
19	CHATAL PRIMARY SCHOOL	1951	602010209

	Address: Khadimnagar, Shonatala		
20	LAUGUL PRIMARY SCHOOL Address: Khadimnagar, Shaheber Bazar	1973	602010210
21	KRISHNAGOBINDA MODEL PRIMARY SCHOOL Address: Khadimpara, Khadimnagar	1914	602010301
22	KOLLOGRAM PRIMARY SCHOOL Address: No.4 Khadimpara, Khadimnagar	1955	602010302
23	KHADIMNAGAR PRIMARY SCHOOL Address: No.4 Khadimpara, Khadimnagar	1934	602010303
24	JAHIRIA PRIMARY SCHOOL Address: No.4 Khadimpara, Khadimnagar	1962	602010304
25	TURIANOD PRIMARY SCHOOL Address: Khadimnagar, Jalalabad	1928	602010305
26	DEBPUR GOVT. PRIMARY SCHOOL Address: Khadimpara, Islampur	1952	602010306
27	SYED JAHAN PRIMARY SCHOOL Address: Khadimpara, Islampur	1957	602010307
28	MURADPUR GOVT. PRIMARY SCHOOL Address: No.4 Khadimpara, Muktir Chok	1948	602010308
29	MUKTIRCHOK PRIMARY SCHOOL Address: Khadimpara, Muktirchok	Not found	602010309
30	CHUABOHOR PRIMARY SCHOOL Address: Khadimpara, Khadimnagar	Not found	602010310
31	HAZRAT SHAH SHUNDOR PRIMARY SCHOOL Address: No.4 Khadimpara, Khadimnagar	1973	602010311
32	KHASDOBIR GOVT. PRIMARY SCHOOL Address: Sylhet City Corporation, Sylhet	1973	602012001
33	SYED HATIM ALI PRIMARY SCHOOL Address: Sylhet City Corporation, Sylhet	Not found	602012002
34	AMBERKHANA DHORSHONDEWRI PRIMARY SCHOOL Address: No.4 Sylhet City Corporation, Sylhet	1955	602012003
35	BURHANUDDIN PRIMARY SCHOOL Address: No.24 Ward, Sylhet City Corporation, Sylhet	1941	602012004
36	SHONARPARA PRIMARY SCHOOL Address: Sylhet City Corporation-2, Ward No.21, Sylhet Sadar	1960	602012005
37	MENDIBAG PRIMARY SCHOOL Address: No.23 Ward, Sylhet City Corporation, Sylhet	1977	602012006
38	BALUCHOR PRIMARY SCHOOL Address: Tulatikar, Sylhet	1960	602012007
39	NOBINCHANDRA PRIMARY SCHOOL Address: No.20 Ward, Sylhet City Corporation, Sylhet	1938	602010407
40	AMBERKHANA COLONY GOVT. PRIMARY SCHOOL Address: No.4 Ward, Sylhet City Corporation, Sylhet	1973	602010408
41	UMOR SHAH TERO RATAN PRIMARY SCHOOL Address: Sylhet City Corporation, Sylhet	1973	602010409
42	ABDUL HAMID PRIMARY SCHOOL Address: Sylhet City Corporation, Sylhet	1973	602010410

43	TUKER BAZAR PRIMARY SCHOOL Address: Tukerbazar, Sylhet	1810	602010501
44	PATHANTULA PRIMARY SCHOOL Address: No.9 Ward, Sylhet City Corporation, Sylhet	1936	602011901
45	MOIYARCHOR PRIMARY SCHOOL Address: No.6 Tukerbazar, Shonataal	1944	602010503
46	SHAHPUR PRIMARY SCHOOL Address: Tukerbazar, Sylhet	1952	602010504
47	AKHALIA PRIMARY SCHOOL Address: No.6 Tukerbazar, Akhalia	1979	602010505
48	SHEIKHPARA PRIMARY SCHOOL Address: No.6 Tukerbazar	1973	602010506
49	AMANATPUR PRIMARY SCHOOL Address: No.7 Sonargaon, Karimganj Bazar	1850	602010601
50	MUGHLAGAON PRIMARY SCHOOL Address: Mughlagaon, Sonatala	1927	602010602
51	LAMAGAON, TALUKPARA PRIMARY SCHOOL Address: No.7 Sonargaon, Jalalabad	1978	602010603
52	KAZIRGAON PRIMARY SCHOOL Address: Mughlagaon, Sonatala	1959	602010604
53	FOTEHPUR PRIMARY SCHOOL Address: No.7 Mughlgaon, Jalalabad	1950	602010605
54	LALARGAON PRIMARY SCHOOL Address: No.7 Mughlgaon, Jalalabad	Not found	602010606
55	AWSHA PRIMARY SCHOOL Address: No.7 Sonargaon, Jalalabad	1981	602010607
56	LAMA AKILPUR PRIMARY SCHOOL Address: No.7 Sonargaon, Jalalabad	1953	602010608
57	NOAGAON PRIMARY SCHOOL Address: Mughlagaon, Karimganj	1972	602010609
58	JHANGAIL PRIMARY SCHOOL Address: Kandigaon, Tuker Bazar	1927	602010701
59	SONATALA PRIMARY SCHOOL Address: Kandigaon, Sonatala	1952	602010702
60	CHAMAURAKANDI PRIMARY SCHOOL Address: No.8 Kandi, Sonatala	1960	602010703
61	SHUJATPUR PRIMARY SCHOOL Address: Kandigaon, Tuker Bazar	1954	602010704
62	MEDINIMAHAL PRIMARY SCHOOL Address: Kandigaon, Kamalbazar	1890	602010705
63	ANANTAPUR PRIMARY SCHOOL Address: Kaligaon, Mullargaon	1944	602010706
64	MULLARGAON PRIMARY SCHOOL Address: Kandigaon, Tuker Bazar	1952	602010707
65	MIRPUR PRIMARY SCHOOL Address: No.8 Kandigaon, Bolaura	1973	602010708
66	BOLAURA PRIMARY SCHOOL Address: Kandigaon, Bolaura	1975	602010111
67	BAHAIRPAR PRIMARY SCHOOL Address: Jalalabad, Shiberbazar	1880	602010112

68	RAYERGAON PRIMARY SCHOOL Address: No.1, Jalalabad, Shiberbazar	1945	602010113
69	PURAN KALADAKA PRIMARY SCHOOL Address: No.1, Jalalabad, Islambazar	1935	602010114
70	DILBAK, NOAGAON PRIMARY SCHOOL Address: No.1, Jalalabad, Islambazar	1968	602010115
71	ALINAGAR PRIMARY SCHOOL Address: Jalalabad, Rampurbazar	1946	602010116
72	GHOPAL PRIMARY SCHOOL Address: No.8 Kandigaon, Tukerbazar	1975	602010710
73	DURGAKUMAR PRIMARY SCHOOL Address: Sylhet City Corporation, Sylhet	1885	602011715
74	KISHORIMOHON PRIMARY SCHOOL Address: Sylhet City Corporation-2, Sylhet	1930	602011716
75	KAZI JALALUDDIN BALOK PRIMARY SCHOOL Address: No.17 Kazitula	1935	602011717
76	GHASHITULA PRIMARY SCHOOL Address: No.10 Ward, Sylhet	1937	602010810
77	KANISHAILNAGAR PRIMARY SCHOOL Address: No.10, Sylhet City Corporation, Sylhet	1943	602010811
78	KAZI JALALUDDIN BALIKA PRIMARY SCHOOL Address: Sylhet City Corporation	1943	602011714
79	SHEIKHGHAT PRIMARY SCHOOL Address: Sylhet City Corporation	1930	602011705
80	GOVT. KINDER GARDEN PRIMARY SCHOOL Address: Sylhet City Corporation-2	1931	602011706
81	KISHORIMOHON BALIKA PRIMARY SCHOOL Address: No.16 Ward, Sylhet City Corporation, Sylhet	1937	602011707
82	AMBERKHANA DARGAH GATE PRIMARY SCHOOL Address: No.17, Sylhet City Corporation	1810	602011708
83	LAMABAZAR PRIMARY SCHOOL Address: Sylhet City Corporation	1885	602011709
84	ZINDABAZAR PRIMARY SCHOOL Address: Sylhet City Corporation	1970	602011710
85	JATIYO SHIKKA KENDRO PRIMARY SCHOOL Address: No.1, Sylhet City Corporation	1963	602011701
86	KUDRATULLAH ISLAM PRIMARY SCHOOL Address: Sylhet City Corporation	1930	602011702
87	RAMKRISHNO PRIMARY SCHOOL Address: Kumarpara, Sylhet City Corporation	1928	602011703
88	MODHUSHOHID PRIMARY SCHOOL Address: No.11 Ward, Sylhet City Corporation, Lamabazar	1974	602011704
89	MOINUNNESA PRIMARY SCHOOL Address: Sylhet City Corporation-1	1935	602011705
90	RAINAGAR PRIMARY SCHOOL Address: No.18, Kumarpara, Sylhet City Corporation	1933	602011706
91	DARGAH JALALIA PRIMARY SCHOOL Address: Sylhet City Corporation	1930	602011707

92	HAZI SHAHMIR PRIMARY SCHOOL Address: No.19, Sylhet City Corporation	1970	602019720
93	BHATALIA PRIMARY SCHOOL Address: Sylhet City Corporation	1941	602011707
94	RADHARANI PRIMARY SCHOOL Address: No.1, Sylhet City Corporation	1931	602011708
95	BAKHTIYAR BIBI PRIMARY SCHOOL Address: No.19, Sylhet City Corporation	1931	602011719
96	JHALOPARA PRIMARY SCHOOL Address: No.26 Ward	1882	602012013
97	MUNKHULA MURA BIBI PRIMARY SCHOOL Address: Sylhet City Corporation	1960	602012014

APPENDIX C

CLIMATIC DATA OF SYLHET

1) Sunshine hours

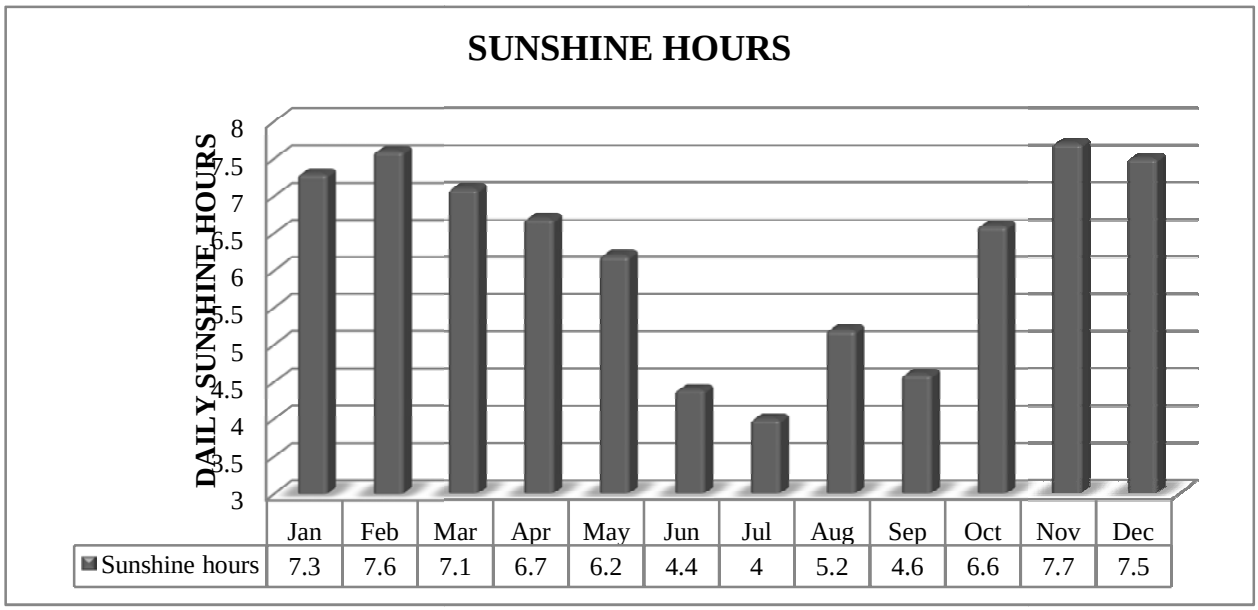
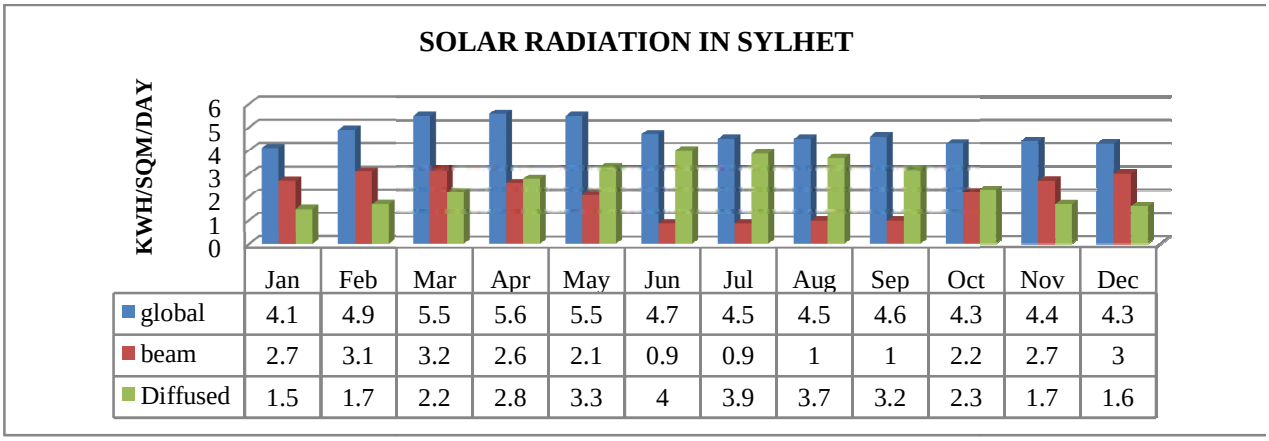


Figure : Monthly average sunshine hours in Sylhet.(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2014)

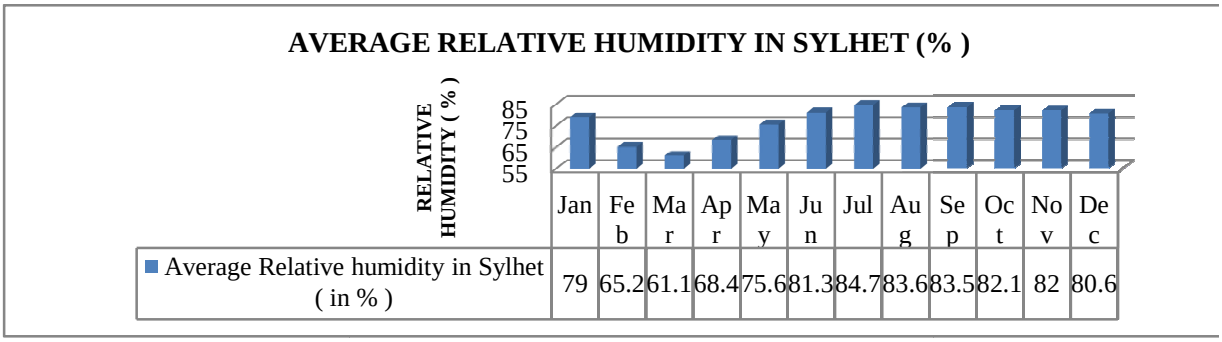
2) Solar radiation



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
global	4.1	4.9	5.5	5.6	5.5	4.7	4.5	4.5	4.6	4.3	4.4	4.3
beam	2.7	3.1	3.2	2.6	2.1	0.9	0.9	1	1	2.2	2.7	3
Diffused	1.5	1.7	2.2	2.8	3.3	4	3.9	3.7	3.2	2.3	1.7	1.6

Figure : Monthly average solar radiation in Sylhet.(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2014

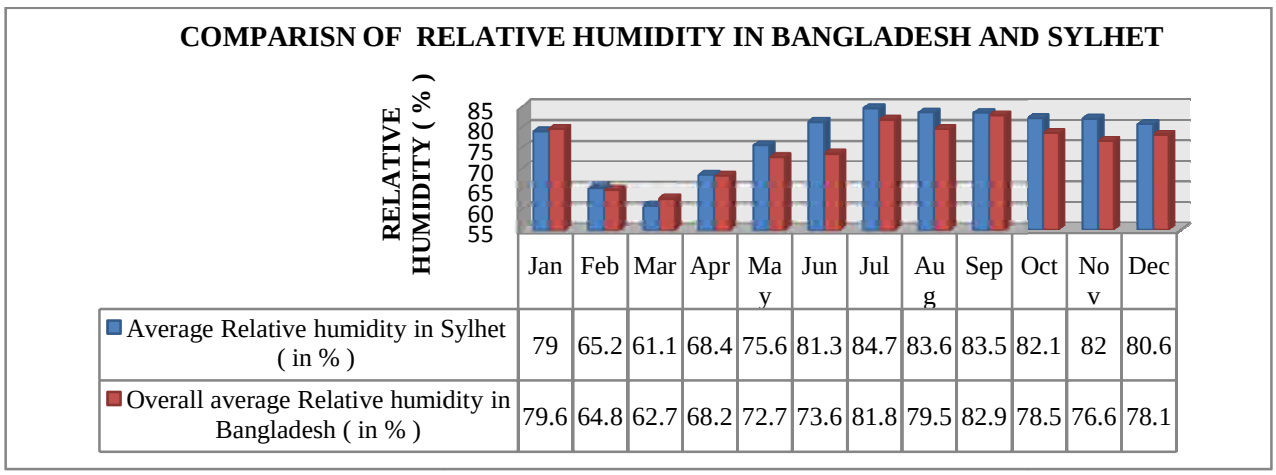
3) Relative humidity



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Relative humidity in Sylhet (in %)	79	65.2	61.1	68.4	75.6	81.3	84.7	83.6	83.5	82.1	82	80.6

Figure : Monthly average relative humidity in Sylhet.(Source: Bangladesh Bureau of Statics, 2009)

4) Comparison of RH in Bangladesh and Sylhet



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Relative humidity in Sylhet (in %)	79	65.2	61.1	68.4	75.6	81.3	84.7	83.6	83.5	82.1	82	80.6
Overall average Relative humidity in Bangladesh (in %)	79.6	64.8	62.7	68.2	72.7	73.6	81.8	79.5	82.9	78.5	76.6	78.1

Figure|: Comparison of Monthly average relative humidity in Bangladesh and Sylhet. (Source: Bangladesh Bureau of Statics, 2009)

5) Monthly average cloud coverage

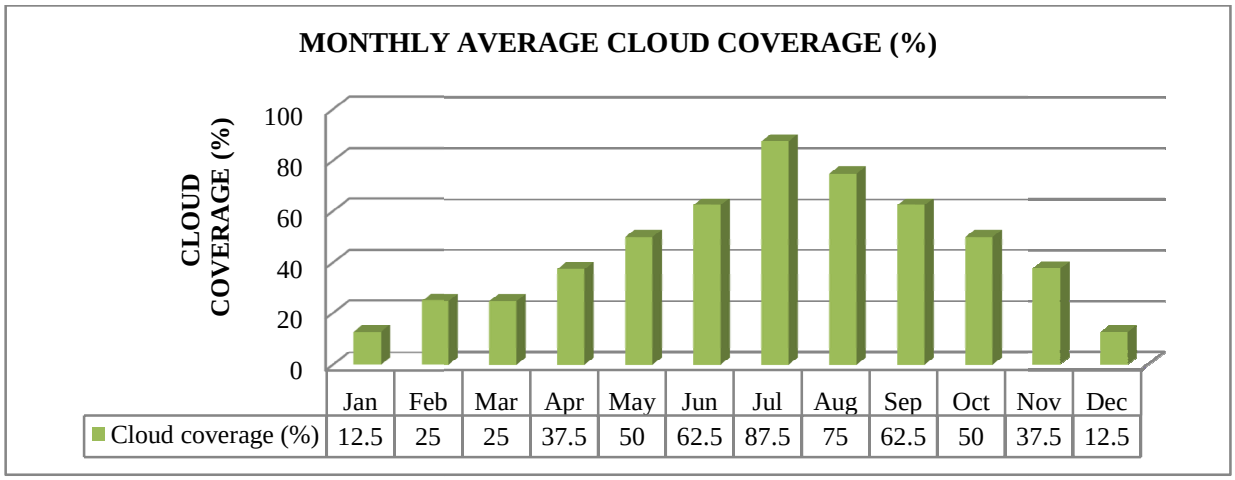


Figure: Monthly average cloud coverage in Sylhet.(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2014

6) Monthly average rainfall

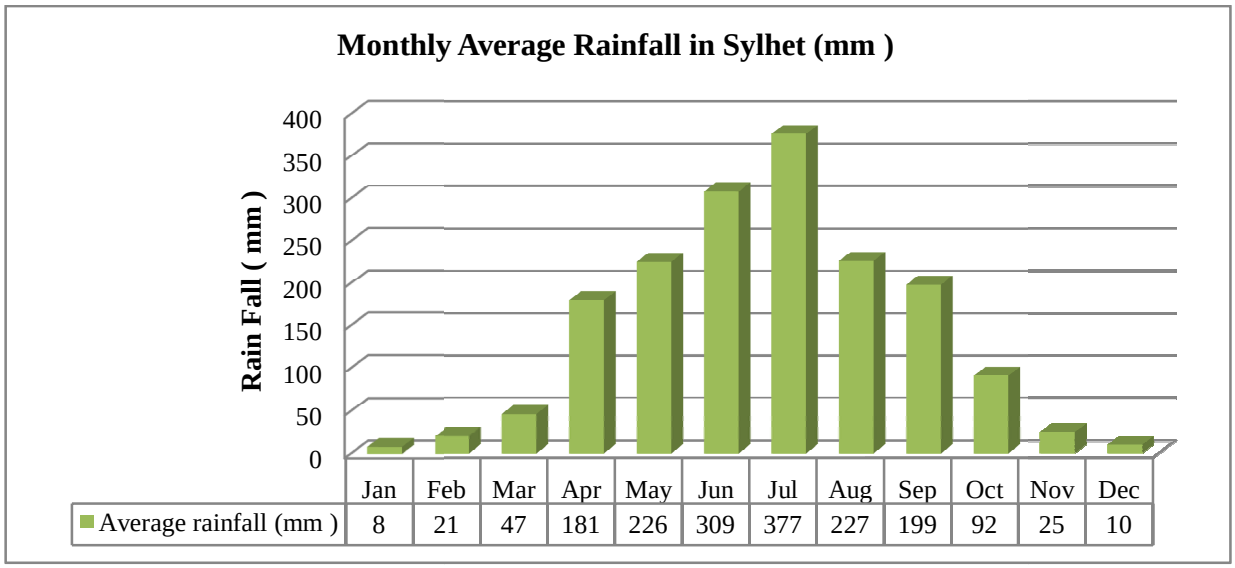


Figure: Monthly averages Rainfall in Sylhet.(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2014)

7) Annual average rainfall in Sylhet and other divisions in Bangladesh

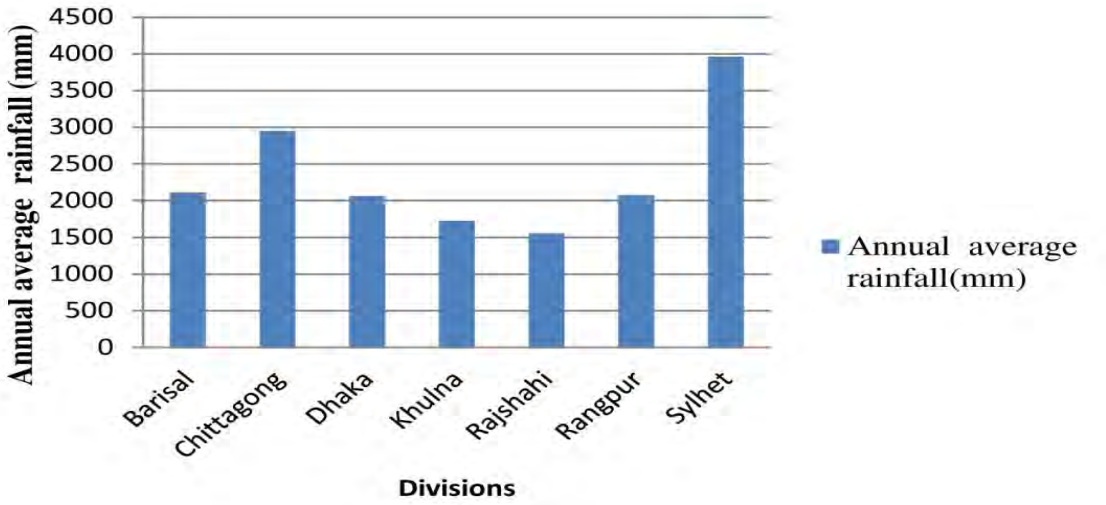


Figure: Annual average Rainfall in Sylhet and other divisional cities. (Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2014)

8) Comparison of monthly average rainfall between Bangladesh and Sylhet

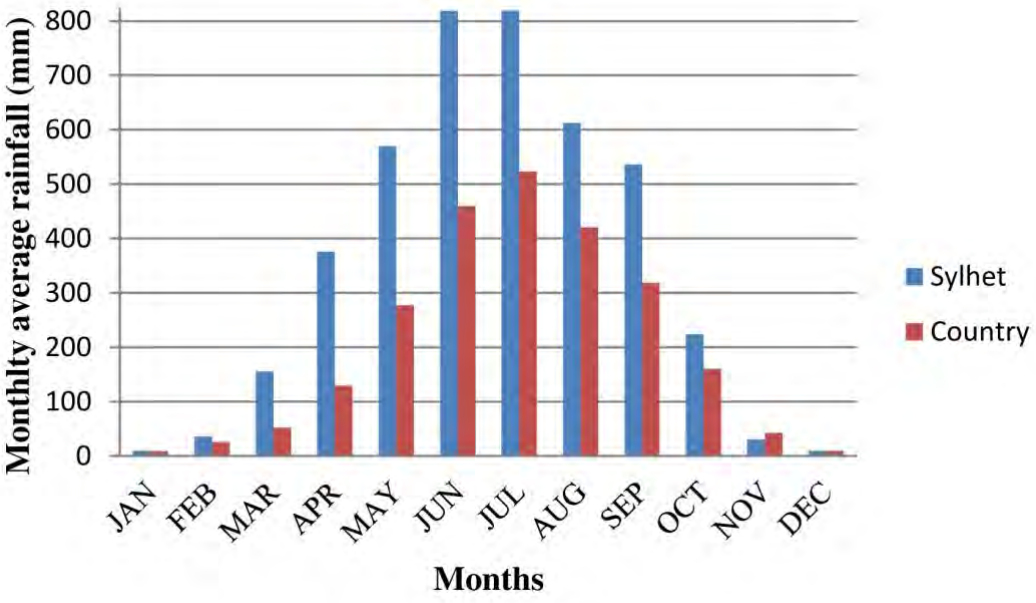


Figure: Monthly average Rainfall in Sylhet and total country.(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2014)

9) Monthly average rainy days in Sylhet

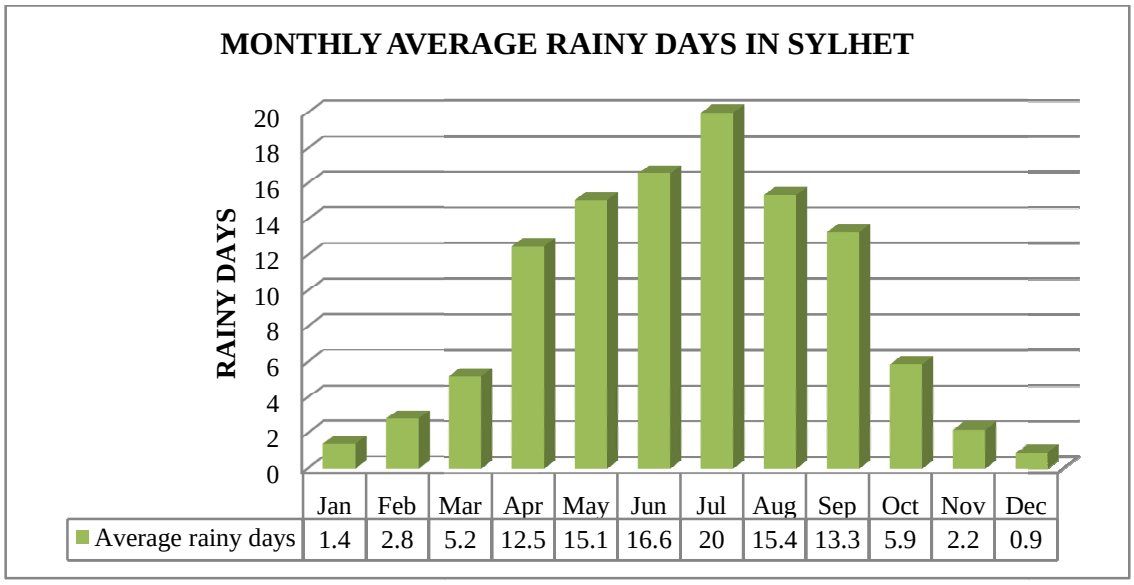


Figure: Monthly average Rainy Days in Sylhet.(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2014)

APPENDIX D

TEST SHEET USED DURING VISUAL PERFORMANCE TEST 01

QUESTION SET: A
SAMPLE NO:
SITTING POSITION OF THE STUDENT:
(BESIDE WINDOW/ MIDDLE ROW/ BESIDE CORRIDOR)

Error percentage:
Score:
Time required:
Score:

Name of the student:(/ নাম) :

Find out the symbol 'π '

€ π β μ β π ± μ ÷ € π ∑
± Ω ¥ π ÷ ¥ π € ≠ ∑ © μ
π £ ≥ € μ ≤ π α π α Ω

≤ π ≥ μ ≥ π Ω © Ω ± β ¥ α
π Ω ¥ π £ α £ ± ≤ Ω ± μ
β α μ β μ ¥ π ¥ μ ¥ π ¥
∑ ± ± ∑ Ω α Ω ∑ ± α μ €
β ± ± β £ ∑ ¥ μ α ¥ α μ β
μ α Ω π £ ¥ μ ¥ £ π ∑
± Ω ¥ Ω ± ∑ α π £® ± μ
Ω π ≤ © Ω β μ £ € ≤ π
€ © α ¥ ∑ Ω π € β ≤ μ ∑ ± π €
£ ≤ € α ≥ α € ∞ ± × α ® £ ®
π ≤ π Ω β ≠ ∑ € © ∞ ☺ π ∑ ± € π ∞ π ©
× Ω ® ≠ ∞ π ≠ ¥ ∑ ≥ ∑ ± ≤ Ω π ≥ ±
∑ ± β ≤ ¥ π ≥ ± β ∑ α π α Ω μ π ≤
€ © ≤ π Ω Ω π α ± © € μ π
β £ α € α Ω β ¥ £ π € Ω ≥ ± ± ¥
≥ π ≤ £ ± Ω ≥ π © ≤ α ± ∑
≤ £ ☺ α ® £ α ∞ μ ¥ π Ω π α π £ π ≤ ≥ © ∑ α © ≥
£ π ± β ® α π Ω β β μ π ± £ π μ ∑ π
¥ β π © © μ ≥ £ ± π β α Ω β
π ® ¥ ≠ € β β Ω © π £ ≠ ¥ π ¥ ≥
α ¥ π © π ® ± μ ≥ ± μ π β ® ® β © ± Ω €
± β π μ μ π β β £ Ω £ α β π μ ± €
¥ ≥ ≤ π ± μ ± ¥ ± μ π β Ω ¥
Ω β π © μ ± μ © π £ € β
€ £ π α © μ © α π ± € μ £ β © μ π ©
π μ π μ ± π € α Ω π ≤ ≤ π μ β
π ≤ © α ≤ π Ω ® μ © ® Ω μ π ® ¥
π £ β μ π ≤ π μ ® Ω ©
μ π ± € α α ± π μ ¥ π μ π ±
£ ± π β ¥ π ¥ ¥ β μ μ β
¥ π © ± π μ μ π ± β α π β π β
α ± μ ¥ £ € Ω ± ± Ω
€ £ ¥ α ± μ β π ± π μ β π
β β π μ π μ ¥ £ π β β €
€ β π ± β ± ± β π μ £ Ω μ π
≤ π £ ≤ β © Ω π μ ≥ £
β Ω © ≤ π £ ≥ ¥ € © ≤ Ω β π μ
∑ α © ≤ ¥ ± ∑ μ ® ¥ α € £
€ α ∑ μ Ω £ π ∑ Ω μ α ±

TEST SHEET USED DURING VISUAL PERFORMANCE TEST 02

QUESTION SET: B **SAMPLE NO:** **SITTING POSITION OF THE STUDENT:** **(BESIDE WINDOW/ MIDDLE ROW/ BESIDE CORRIDOR)**	**Error percentage:** **Score:** **Time required:** **Score:**

Name of the student:(/ নাম) :

Find out the symbol 'π '

π	β	μ	β	π	±		μ	÷	€	π	∑	±	Ω ¥
	π	÷ ¥	π	€	≠	∑		©	μ	π	£	≥	€
		μ	≤	π	α	π	α	Ω					
≤	Ω	≥	μ	≥	π	Ω	©	Ω	±	β	¥	α	
	π	Ω	¥			£	α	£	±	≤	Ω	± μ	
	β		α			μ	β	μ	¥	π	¥	μ	¥ π
¥	∑	±	±	∑		Ω	α	π	∑	±		α	
μ		€	β	±	±	β	£	∑	¥	μ	α	¥	α	μ	β
	μ	α	Ω	π	£	¥	μ		¥	£	π	∑	
±	π	¥		Ω	±	∑	α	π	£®		±	μ	
			Ω	π	≤	π	Ω	β	μ	£	€	≤	
π	€	©	α	¥	∑	Ω	π	€	β	≤	μ	∑	±
π	€	£	≤		€	α	≥		α	€	±	×	α ® £
®		π	≤	π	Ω	β	≠	∑	€	©		☺ π	∑
±		€	π	π	©	×	Ω	®	≠	π	≠	¥	∑	≥	∑	±	≤
Ω		π	≥	±	∑	±	β	≤	¥	π	≥	±	β	∑	α
π	α	Ω	μ	π	≤	€	©	≤	π	Ω	Ω	π	
		α	±	©	€	μ	π		β	£	α	€	α	Ω	β
¥	£	π	€	Ω	≥	±	±	¥	π	π	≤	£	±
Ω			≥	π	©	≤	α	±	∑	≤	£	☺	α	®	£
α	μ	¥	π	Ω	π	α	π	£	π	≤	≥	©	∑	α	©	≥	£
π		±	β	α	π	Ω		β	β	μ	π	±	£	π	μ	∑	
		π	¥	β	π	©		©	μ		≥	£	±	π	β	α	
		Ω	β		π	¥	≠	€		β	β	Ω	©	π	£	≠	¥
		π	¥	≥	α	¥	π	©		π	±	μ	≥	±	μ	π	β	®	β
		©	±	Ω	€	±		β	π	μ	μ	π	β	β	£	Ω	
£	α	β	π	μ	±	€	¥		≥	≤	π	±	μ	±	¥	±	
		μ	π	β	Ω	¥	Ω	β	π	©	μ	±		μ	©	π	
		£	€	β	€	£	π	α	©	μ	©	α	π	±	€	μ	
£	β	©	μ	π	©	π	μ	π	μ	±	π	€	α	Ω	π	≤	≤	π
		μ	β	π	≤	©	α	≤	π	Ω	®	μ	©	®	Ω	μ	π		
		¥	π	£	β	μ	π		≤	π		μ	Ω	©	μ	π	
±		€	α	α	±	π	μ	¥	π	μ	π	±		£	±		
		π	β	¥	π	¥	¥	β	μ	μ	β	¥	π	©			
		±	π		μ	μ	π	±	β	α	π	β	π	β	α	±	
		μ	¥	£		€	Ω	±	±	Ω	€	£	¥	α			
±		μ	β	π		±	π	μ	β		π	β	β				
π		μ		π	μ	¥	£		€		β	β		€			
€			β	π	±	β	±	±	β	π	μ	£	Ω	μ	π		
≤	π		£	β	©	Ω	π	μ	≥			£	β	Ω			
		©	≤		π	£	≥	¥	€	©	≤	Ω	β	π	μ	∑	
		α	©	≤	¥		±	∑	μ	¥	α	€	£	€	α		

TEST SHEET USED DURING VISUAL PERFORMANCE 03

Error percentage:
Score:
Time required:
Score:

QUESTION SET: C
SAMPLE NO:
SITTING POSITION OF THE STUDENT:
(BESIDE WINDOW/ MIDDLE ROW/ BESIDE CORRIDOR)

Name of the student:(/ নাম) :

Find out the symbol 'π '

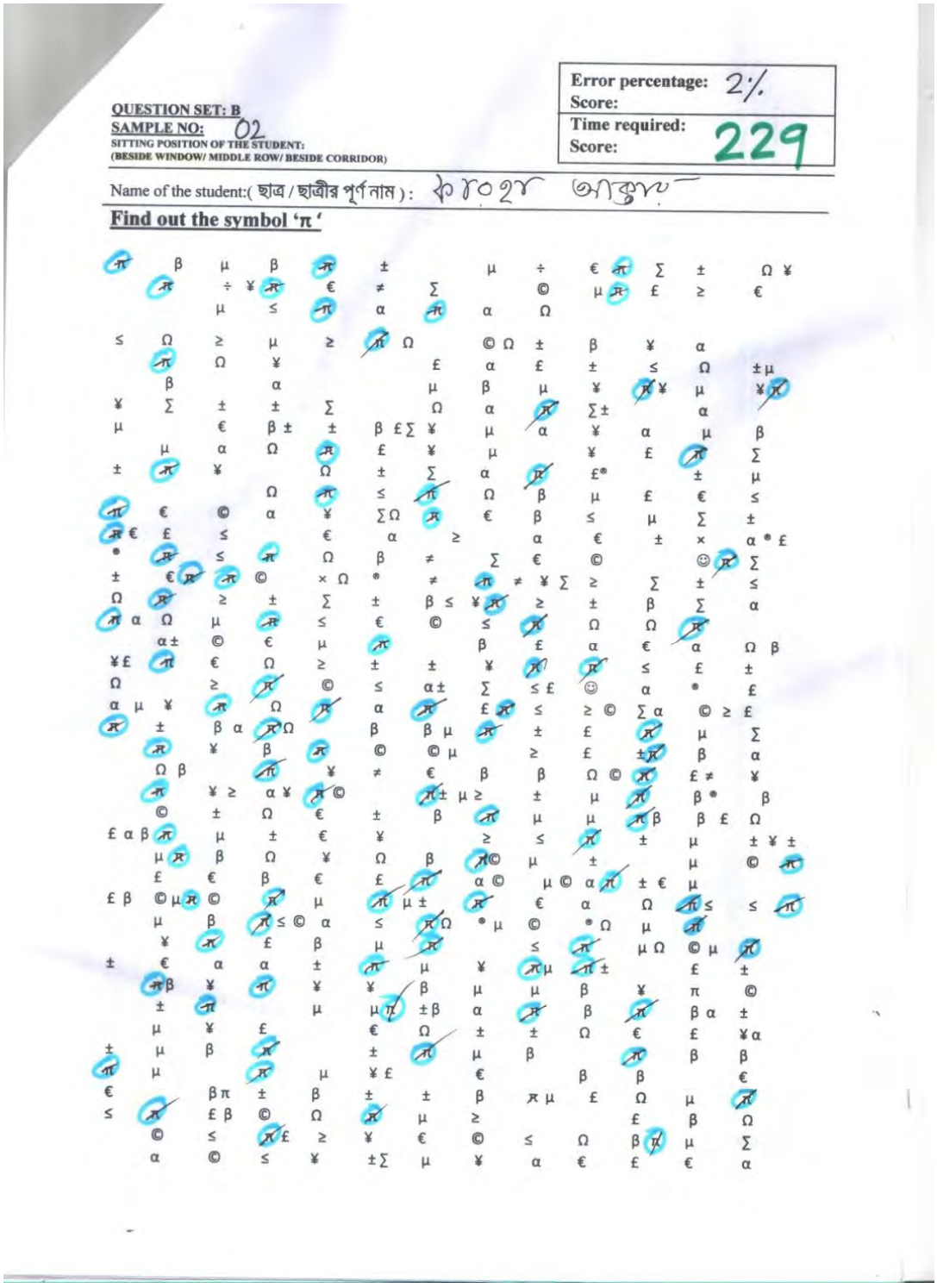
€ £ β μ β π ± μ ÷ € π ∑ ± Ω ¥ π
÷ ¥ π € ≠ ∑ © μ π £ ≥ € μ ≤
π α π α Ω

≤ Ω ≥ μ ≥ π Ω © Ω ± β ¥ α π
Ω ¥ £ α £ ± ≤ Ω ± μ β
α μ β μ ¥ π ¥ μ ¥ π ¥ ∑ ± π ∑
Ω α Ω ∑ ± α μ € β ± ± π £ ∑
¥ μ α ¥ α μ β μ α Ω π £
¥ μ π £ π ∑ ± Ω ¥ Ω
± ∑ α π £® ± μ Ω π
≤ π Ω β μ £ € ≤ π € © α ¥ ∑ Ω
π € β ≤ μ ∑ ± π € £ ≤ € α
≥ α € ± × α ® £ ® π ≤ π Ω β
≠ ∑ € © ☺ π ∑ ± € π π © × Ω
® ≠ π ≠ ¥ ∑ ≥ ∑ ± ≤ Ω π ≥ ±
∑ ± β ≤ ¥ π ≥ ± β ∑ α π α Ω μ π
≤ € © ≤ π Ω Ω π α ± © €
μ π β £ α € α Ω β ¥ £ π €
Ω ≥ ± ± ¥ π π ≤ £ ± Ω
≥ π © ≤ α ± ∑ ≤ £ ☺ α ® £ α μ
¥ π Ω π α π £ π ≤ ≥ © ∑ α © ≥ £ π
± β α π Ω β β μ π ± £ π μ ∑
π ¥ β π © © μ ≥ £ ± π β α Ω β
π ¥ ≠ € β β Ω © π £ ≠ ¥ π ¥ ≥
α ¥ π © π ± μ ≥ ± μ π β ® β © ± Ω
€ ± β π μ μ π β β £ Ω £ α β π μ
± € ¥ ≥ ≤ π ± μ ± ¥ ± μ π β
Ω ¥ Ω β π© μ ± μ © π £ € β
€ £ π α © μ © α π ± € μ £ β © μ π ©
π μ π μ ± π € α Ω π ≤ ≤ π μ β π ≤ ©
α ≤ π Ω ® μ © ® Ω μ π ¥ π £
β μ π ≤ π μ Ω © μ π ± € α α ± π
μ ¥ π μ π ± £ ± π β ¥π ¥ ¥ β
μ μ β ¥ π © ± π μ μ π ± β α
π β π β α ± μ ¥ £ € Ω ± ±
Ω € £ ¥ α ± μ β π ± π μ
β π β π μ π μ ¥ £
€ β β € € β π ± β ± ± β π μ
£ Ω μ π ≤ π £ β © Ω π μ ≥
£ β Ω © ≤ π £ ≥ ¥ € © ≤ Ω
β π μ ∑ α © ≤ ¥ ± ∑ μ ¥ α €

APPENDIX E

ANSWER SCRIPTS OF VISUAL PERFORMANCE TEST

a) Answer script of sample 2, under 500 lux above (lowest number of errors, 2%)



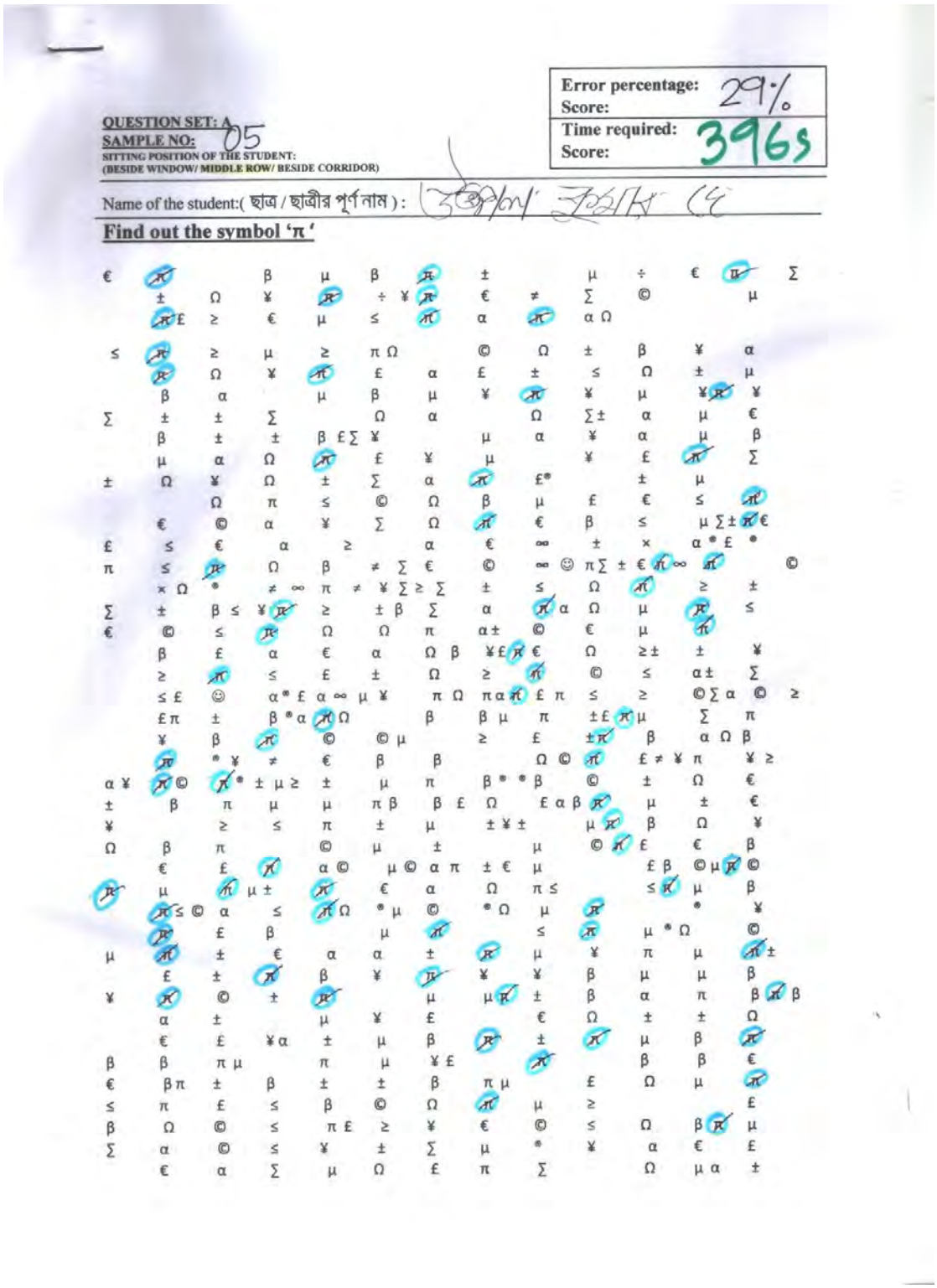
QUESTION SET: B
SAMPLE NO: 02
SITTING POSITION OF THE STUDENT:
(BESIDE WINDOW/ MIDDLE ROW/ BESIDE CORRIDOR)

Error percentage: 2%
Score:
Time required:
Score: 229

Name of the student:(ছাত্র / ছাত্রীর পূর্ণ নাম) : ফারহান আকাশ

Find out the symbol 'π '

b) Answer script of sample 10, under less than 80 lux (highest number of errors, 29%)



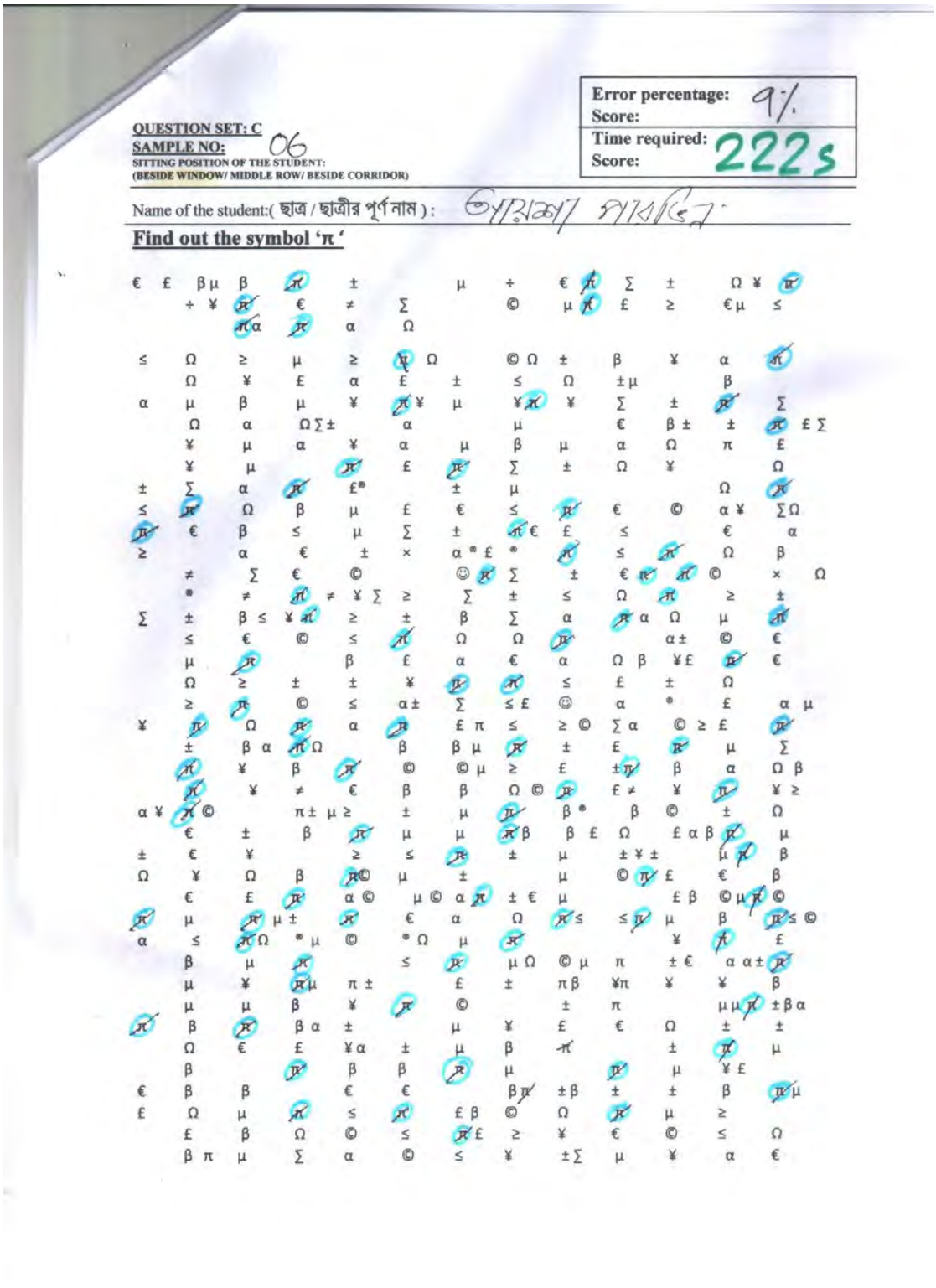
Error percentage: Score:	29%
Time required: Score:	396s

QUESTION SET: A
SAMPLE NO: 05
SITTING POSITION OF THE STUDENT:
(BESIDE WINDOW/ MIDDLE ROW/ BESIDE CORRIDOR)

Name of the student:(ছাত্র / ছাত্রীর পূর্ণ নাম) :

Find out the symbol 'π'

c) Answer script of sample 6, under 500 lux above (lowest time required, 222 seconds)



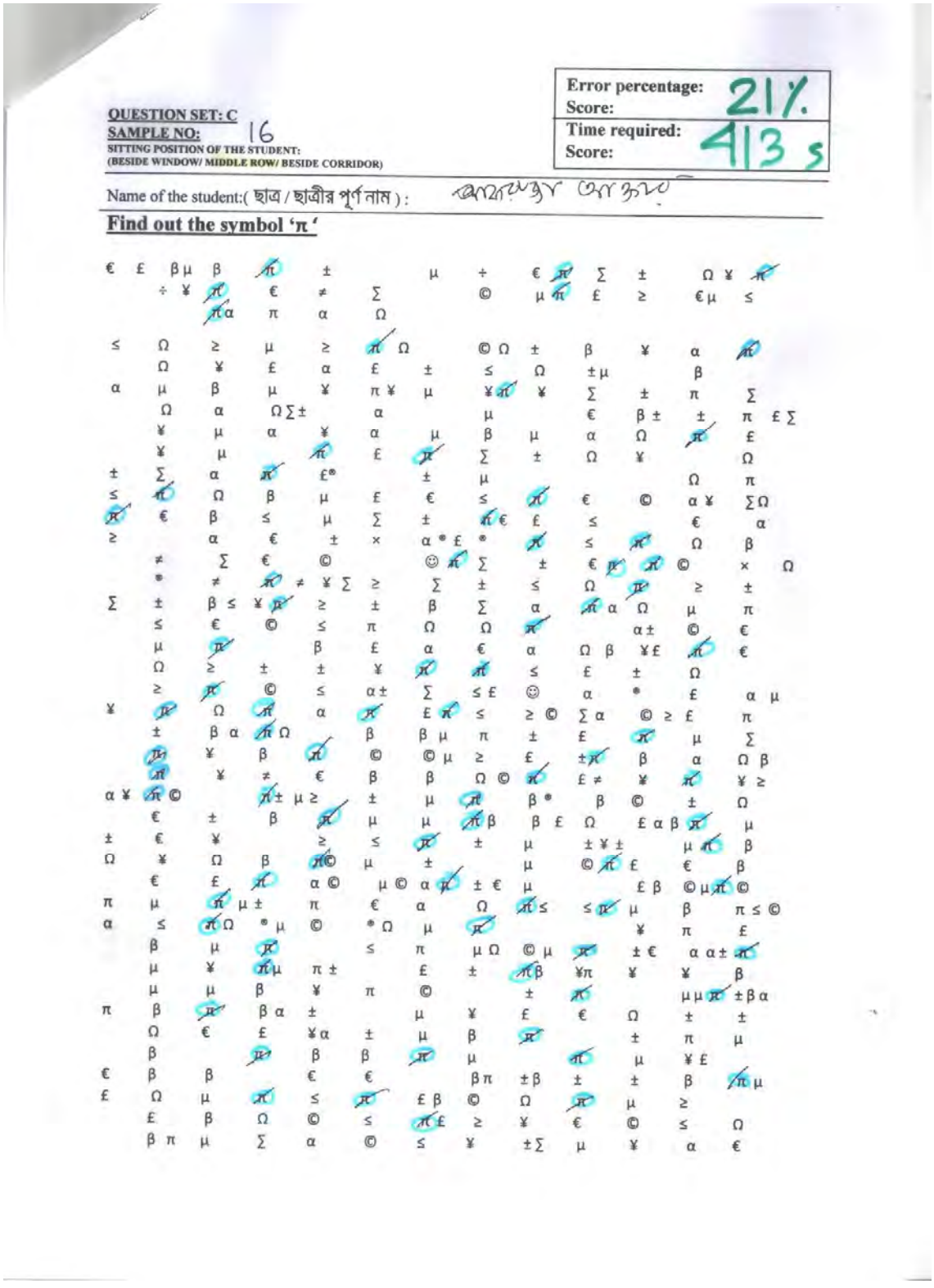
QUESTION SET: C
SAMPLE NO: 06
SITTING POSITION OF THE STUDENT:
(BESIDE WINDOW/ MIDDLE ROW/ BESIDE CORRIDOR)

Error percentage:	9%
Score:	
Time required:	222s
Score:	

Name of the student:(ছাত্র / ছাত্রীর পূর্ণ নাম) : [illegible]

Find out the symbol 'π'

d) Answer script of sample 16, less than 80 lux (highest time required, 413 seconds)



QUESTION SET: C
SAMPLE NO: 16
SITTING POSITION OF THE STUDENT:
(BESIDE WINDOW/ MIDDLE ROW/ BESIDE CORRIDOR)

Error percentage: Score:	21%
Time required: Score:	413 s

Name of the student:(ছাত্র / ছাত্রীর পূর্ণ নাম) :

Find out the symbol 'π'