Comparison of Illumination Survey Data of Field (Practical) with Developed MATLAB for Conventional and LED Lighting System in Both Open Cast and Underground Mines-A Case Study

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Abstract: The primary importance of this paper is to define the serious problems faced in mine lighting application and to provide guidance and solution of the problems. In lighting design, the primary goal is to cater a visual environment in which people may efficiently perform specific tasks and receive agreeable visual impressions. The process of design is a comparison of various alternative systems, trading off their benefits for their cost in accomplishing their goals. The Illuminating Engineering Society of North America (IESNA) has recommended some design practices for lighting. Although the eye is able to make use of wide range of light levels, there are certain conditions under which it works best. Good artificial lighting system influences the condition of seeing, which facilitates in reducing labours mental tiredness, protecting their health, eyes and nervous system, and reducing injury. These benefits tend to offset the cost economics of lighting or it may be many times greater than the cost of the lighting. A brief explanation of different LED product. By comparing the LED with Incandescent source for the distribution of luminous lux for the given area for lighting fixture at a tilt angle of 0˚ with the readings noted it is concluded that LED meets the required lux level in the surface mines as per the DGMS standards with the conservation of power. The present day LED has its features such as less power consumption, more lumen output, high efficacy and its life time is 100 times more as compared to incandescent and 10 times more as compared to CFL Light sources. Also the colour considerations for the LED gives the perfect visibility for the human eye gives the pleasant working environment with safety, increases production and reduces the accidents in the surface mines. To achieve the good requirement of illumination in mines, planed illumination is required to be enabled using suitable rules with guidelines so that effective decision can be considered in mines.

Key Words: *Glare, Reflectance, Illuminance, Horizontal and Vertical Illumination, luminaire, luminance, Reflectance, visibility.*

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I. INTRODUCTION

1.1. BACKGROUND OF THE PROBLEM

Design of Lighting system is essential for miners working inside a mine whether it is Underground or Opencast mining. Good lighting system is required in mine during dark hours for work to get progressed. an underground mine requires a very effective lighting system for continuous hours for day and night. Whereas lighting system for Haul road used inside the mine should also be effective. Thus, when a lighting system used it should follow the mining rules and regulations also it should consume minimum power with maximum light output and minimum maintenance problems [1]. A mostly conventional system used inside the mine consumes more power, high losses with high maintenance problems. In mines due to use of large machines in a workplaces identified with the critical areas where light falling should perceive for human eyes to reduce the accidents and recommendations were developed on standards for the improvement of both illumination and visibility under specific conditions. This paper also made recommendations on enhanced the visual environment to reduce hazards, and produced help for the selection, fitting and maintenance of lighting equipment [2] .

1.2. DESCRIPTION

In mines especially haul road lighting is a important concern for mines authorities. Because compared to other places of mines providing lighting for haul roads is quite frustrating and difficult in nature. This is mainly because the haul roads are regularly changing, which requires regular moving of light poles/lamps from phase to phase. Inefficient lighting losses significant financial resources every year and also poor lighting causes dangerous situation [2]. In order to provide a comfortable light level in the mines, as per the direction and guidelines [3], a fixed plan of illumination survey has to be done. In this regard, as a case study, an illumination survey was done in a mechanized opencast and in an underground gold mine of a Karnataka. In order to study the status of illumination in mines, fixed plan of illumination is required to be done using appropriate statutory guidelines, so that effective control measures can be taken. Keeping this in view, illumination study in the mechanized surface coal mine (N.Lakshmipathy et al. June, 2014) is also considered for the case study in surface gold mine in this paper.

Keeping this in view, an illumination survey the practical field data was collected in one of the open cast and underground gold mine in Karnataka. Surveying at mines at night times is risk, hard task and time consuming process as heavy trucks and dumpers will be moving for extraction of coals and ore takes place late at night also. Thus this paper supports a designed program on the MATLAB platform which gives actual time survey data of illumination in mines. An approach is made to the design a program that provides an exact time survey data of illumination in mines.

1.3 AIM OF THE STUDY

The objective of this paper is to support the advantages of LED (Light Emitting Diode) lighting system over ordinary lighting system in terms of results that were intended in energy conservation, better illumination, resistant to shock in bad and humidity conditions and should be reluctance to vibration etc. To evaluate lighting system in underground and the haul road lighting systems of opencast mines and evaluate the corresponding readings with MATLAB program. It can be achieved by the following objectives.

1.4. OBJECTIVES

The objective of this paper is to study the overall performance of LED lighting system over conventional lighting system with special particular to Mining Industry and validation of lux data collected at one of the gold mine in Karnataka.

The general goals of mine lighting are to improve safety and production. Analysis proving that mining is one of the most risky industries and it should utilize the lighting that it supports the qualities of present development method. To aware of these requirements, mine lighting system must reach the particular ambition as follows.

- A primary ambition of mine lighting is to increase the clarity of the objects which are visibly to eyes and reduce labors injuries which may happen if the dangerous are not detected.
- The important ambition of mine lighting system is to allow miners to immediately identify noticeable movement everywhere in their usual field of vision which avoids disaster[4].

But the main objectives this paper is:

- To learn the basic concepts of Illumination.
- To compare the LED lighting system with ordinary lighting system.
- To know the system of surface and underground mines and the problems.
- To find and note the illuminance level of luminaries using a digital lux meter in opencast and underground gold mines.
- To assess the adequacy of illumination in mines.
- To reduce the manpower for survey purpose.
- Validation of field measured output with respect to MATLAB obtained output.
- To ensure safe conduct of work.
- To guide a better lighting system (LED) in mines.

1.5. METHODOLOGY

The methodology for this paper is merged into several levels as shown below.

- ❖ Combining of specific objectives.
- ❖ Understanding of literature available.
- ❖ Gathering of field data from one of the Gold mines in Karnataka.
- ❖ Analysis of illumination data.
- ❖ Results showing advantages of LED over other conventional sources.
- ❖ Conclusion and recommendations.

2. FACTORS AFFECTING A VISUAL ENVIRONMENT

factors that determine the levels of illuminance are only the quality and hence safety, of a visual environment [5]. Trotter (1982) states 'seeing effectively is more complex than merely being dependant on the amount of light being shone at a target'. In coal mining, other factors that have been identified as affecting the overall quality of the visual environment[6,7,8] (after Crooks & Peay, 1981; ECSC, 1990; IES, 1993).

The following are the factors need to be considered to obtain the good and reliability of visual performance to improve safety are visual perception variables (age, visual acuity, colour vision, etc.). The requirement for selection to make use of the individuals have reasonable levels of the visual abilities required to safely undertake their job, is well recognized and should be accommodated by initial screening and periodic eyesight testing programs. Beyond this, effort should be concentrated on tailoring the visual environment to the needs of people rather than selecting individuals to cope with poor conditions.

2.1. Principle of Lighting

Comfortable vision is a highly subjective parameter, which may be difficult to ascertain. It is influenced by various factors, both physical and personal. An effective lighting installation is one, which has been designed and installed so as to provide sufficient illuminance on a visual task[9]. So while designing illumination system one must remember that it is not the machines that need light, but the men who are to operate the machines, and others who must work and move in their vicinity (N.Lakshmipathy et al. September, 2014).

2.2 Uniformity

Good lighting is not only obtaining more light but is also a requires the proper distribution of light. For example, well-lit road surfaces have to appear evenly illuminated, with no apparent dark patches and a minimum of glare. It is possible only when the distribution of light is more or less uniform throughout the length of haul road. Uniformity ratio of illuminance on a given plane is a measure of the variation of illuminance over it (N.Lakshmipathy et al. September, 2014).

2.3 Glare

Glare is often a significant problem in the coal mining industry. To reduce this, Baines (1972) suggests that it is better to have low powered lights with small distances between them, than to have high powered lights far apart [10]. The former gives an evenly illuminated roadway and the latter gives an alternate glaring light and then darkness. Good uniformity also makes for well hazard perception, as dark patches act as camouflage concealing obstacles and hazards. Trotter (1982) lists the following ways to reduce glare in the mining industry [2].

2.4. Visibility

Knowing which areas miners required to see in order to obtain their job sucessfully and safely are generally referred to as *Visual Attention Areas*. It is highly valued to distinguish between what needs to be seen from what can be seen. Lewis (1986) states that 'every year people are killed, equipment is damaged, cables are cut and roof supports are knocked down because the operators of mobile equipment cannot see due to huge blind areas happened by the design of such equipment'. Poor sightlines are common to a large range of underground mobile machinery. A study in the United States (US Department of Labour, 1980) concluded that approximately 36% of the fatalities involving underground coal mine mobile equipment between 1972 and 1979 were directly or indirectly caused by improperly designed operator compartments.

2.5 Economics of lighting

several studies have given that improved road lighting can reduce the number of night time accidents (Bell 1972, Chironis 1974, CIE 1979). Any improvement in lighting quality is an economic decision and efficient road lighting can be made economically achieved. However, in general, many other factors play a role in evaluating the cost of a road lighting installation. Among these, lamp efficiency and lamp life affect the whole economics of the lighting installation [5]. Other factors, such as lamp price, number of particular type of luminaires required, pole type and arrangement, type of gear control employed, location of the electricity supply cables, depreciation cost, rates of interest and cost of labour and maintenance, are also significant.

2.6 Haul Road Lighting

When a road is referred to as being 'evenly lit', this means that, when viewed from haul truck, the road surface appears to be 'evenly bright'. This is achieved by arranging the poles along the length of the road in such a way that the bright patches merge to cover the road area, so that objects on the road will be seen as dark silhouettes against the bright surface

Table -1: Summary of International Illumination Levels (in lux)[2]

	Shafts	Loadin g	Around Machine s	Haula ges	Hea ding s	Under ground works hop
Belgium	20-50	20	25	10		
Hungary	40-100	40-60	20-50	10-Feb		20-50
Canada (British Columbia)	21			21	53	
Poland	30	30	10	10-Feb	5-15	30
UK (British Coal)	70	30		2.5		50-150
European Coal & Steel Community	40-90	15-80		15-May	30-Oct	

West Germany	30-40	40	80	15		
Czechoslovakia	15	20	20	5		
South African Gold Mines	20-160	160		20		400

III. ILLUMINATION SURVEY IN HUTTI GOLD MINES, RAICHUR

Illumination survey was done at one of the gold mine in Karnataka. To compare the illumination standards of the mine which are tabulated in Table- 1. Both horizontal and vertical illumination readings were noted as explained in section 2.7.3. and noted by using the lux meter. The survey of field practical illumination data was noted at different places for a LED sources fitted at the working of Heavy Earth Moving Machinery, Lathe Workshop, Compressor House, etc. The quality of illumination levels when compared were found to be appropriate as per the regulations of Summary of International Illumination Levels as shown in Table-1.

3.1 Measurement of horizontal and vertical illumination reading

The readings are measured by placing the lux meter sensor at horizontal position on the point on the surface where illumination is to be measured. The horizontal reading measured is denoted as 'H' as shown in Table-3. The vertical illumination readings are measured by placing the lux meter sensor facing towards the light source at vertical position on the point on the surface where illumination is to be measured and the lux meter sensor 1m above the surface. The vertical reading measured is denoted as 'V' as shown in Table-3, during these field measurements the lights nearby this field are switched off to measurement accurate readings of the selected source.

Table- 2: Illumination levels at different working places in surface gold mine

Sl. No	Location	Height of source fitted in m	Tilt Angle in deg	Arm Extension in m	Wattage in Watts	Horizontal reading in Lux	Vertical reading in Lux
1	Sag And Ball Mill	18.6	0	0	72	44.65	-
2	Compressor House	3.234	0	0	150	92.65	-
3	LRS(Liquid Rheostat Near Ball Mill	4.88	60	0.5	72	40	-
4	Near MCC Motor Controller	9.15	45	1.525	72	9.067	6.82
5	Weigh Bridge	3.2	50	0.5	42	30	27.34
6	Belt Conveyor	2.35	75	0.305	90	158.25	178
	No-3 Line Building						
7	Inside Winding Engine Room	9.15	0	0	72	22.3	8.775
8	Plant Section Shed	9.6	0	0	90	37.34	12.2
9	Lathe Workshop	6.6	0	0	90	79.49	35.463
10	Air Compressor Near Main Gate	6.46	0	0	90	31.75	19.345

The horizontal and vertical illumination readings of table -2 and table-3 are noted at different locations in surface and underground in the Hutti gold mines as explained in section 3.1. These illuminations readings are measured in the gold mines at different locations are found to be satisfactory comparing with the international standards of illumination section table-1 and mining regulation standards.

Table -3: Illumination Readings taken in underground at 2200feet deep (Hutti Gold Mines)

SL NO	Location	Average Horizontal reading in Lux	Average Vertical reading in Lux
1	Rock Breakers	24.62	13.1
2	Pumping(Water)	729	51.98
3	Power Station	44.767	50.15
4	510 Battery Operated Opel Headlight	47.033	4.133
5	Charging Point	79.74	66.72
6	Ms-22 Crusher Single Toggle Jaw	14.9	12.9
7	Ms-22 Control Panel	35.26	61.9

3.1 Practical Field Measurement Output for single source 18 watts LED at Tilt angle 30°

Table- 3: Practical Field Output of single source LED of 18W fitted at kerb of the road at the centre of the field, Lux load data at gold mine for haul road width of 9m, the Height of the pole 4.5m, Tilt angle 30° and the Length of the measuring field 14m

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4.32H 1.47V	6.47H 2.26V	9.54H 2.78V	13.52H 3.07V	17.94H 2.47V	21.62H 1.24V	23.08H 0.94V	22.4H 1.34V	17.12H 2.37V	14.52H 2.97V	8.84H 2.68V	7.47H 2.16V	3.32H 1.57V	2.88H 1.28V
4.00H 1.49V	5.70H 2.03V	7.93H 2.48V	10.62H 2.690V	13.37H 2.93V	15.13H 2.27V	16.36H 2.47V	15.83H 2.37V	14.37H 2.83V	11.62H 2.70V	7.73H 2.48V	6.20H 2.03V	3.90H 1.49V	2.79H 1.22V
3.48H 1.37V	4.72H 1.84V	6.25H 2.20V	7.97H 2.61V	9.63H 2.70V	10.87H 2.97V	11.33H 2.73V	11.87H 3.07V	9.23H 2.66V	7.67H 2.60V	6.45H 2.10V	4.52H 1.94V	2.98H 1.47V	2.53H 1.02V
2.90H 1.22V	3.78H 1.36V	4.80H 1.71V	5.89H 2.13V	6.88H 2.48V	7.60H 2.68V	7.86H 2.75V	8.00H 2.71V	6.77H 2.48V	6.19H 2.23V	4.60H 1.91V	3.58H 1.46V	2.70H 1.24V	2.19H 0.93V
2.37H 0.98V	2.98H 1.28V	3.66H 1.46V	4.34H 1.84V	4.94H 2.13V	5.36H 2.16V	5.51H 2.20V	5.43H 2.26V	5.04H 2.03V	4.94H 1.94V	3.86H 1.46V	3.18H 1.28V	2.17H 0.98V	1.85H 0.74V
1.91H 0.86V	2.33H 0.98V	2.78H 1.24V	3.22H 1.37V	3.59H 1.49V	3.84H 1.57V	3.93H 1.77V	3.94H 1.61V	3.61H 1.49V	3.33H 1.447V	2.61H 1.34V	2.43H 0.88V	1.81H 0.86V	1.54H 0.66V
1.53H 0.66V	1.83H 0.74V	2.13H 0.93V	2.41H 1.02V	2.64H 1.22V	2.80H 1.28V	2.85H 1.29V	2.90H 1.31V	2.74H 1.22V	2.51H 1.12V	2.33H 0.93V	1.93H 0.74V	1.43H 0.66V	1.27H 0.50V
1.23H 0.49V	1.43H 0.64V	1.64H 0.69V	1.82H 0.85V	1.98H 0.90V	2.07H 0.93V	2.11H 0.94V	2.17H 0.93V	1.89H 0.90V	1.86H 0.85V	1.74H 0.69V	1.33H 0.64V	1.13H 0.49V	1.04H 0.45V
0.99H 0.43V	1.13H 0.47V	1.27H 0.51V	1.40H 0.63V	1.50H 0.66V	1.56H 0.68V	1.59H 0.69V	1.66H 0.68V	1.61H 0.66V	1.50H 0.63V	1.37H 0.51V	1.23H 0.47V	0.89H 0.43V	0.85H 0.33V

Under the section 3.1 and 3.2 The haul road in the gold mine is selected with single 18 watts LED source on the tower fitted at a height of 4.5m from the surface of the road with the tilt angle of 30°, road width 9m, the measuring field length is 12m. The readings were plotted in Table -3 gives the horizontal and vertical lux readings are measured as per the procedure explained in section 3.1 After comparing from Table-2 practical field data with MATLAB program output of Table-4 for horizontal and vertical illumination field along the road for a 18W single LED source, the error was found to be = ± 9-12 %. This error is due to the orientation of the LED light sources as these LED sources are placed in arrays in the rows and columns on the luminary. On placing these LED sources on the luminary there are possibility for variation in the orientation of the LED light sources on the luminary. Because of this reason, there will not be in uniform distribution of light as specified by the manufacturer. Also the LED sources are provided with magnifying lens which increases the intensity of light emitted by LED sources. Also there may be luxmeter calibration error and human error during measuring of horizontal and vertical illumination field readings.

3.2 MATLAB Program Output for 18 watts LED source

3.2.1 Input Data for MATLAB Program

Table-4: MATLAB Output of single source LED of 18W fitted at the center of the field, Lux load data at gold mine for haul road width of 9m, the Height of the pole 4.5m, Tilt angle 30° and the Length of the measuring field 12m.
Enter the Power of the Source in Watts = 18
Mounting height of source from ground in m = 4.5
Road width in m = 9
Measuring field length in m = 12
Enter 1: Overhanging 2: Beyond Kerb 3: Above the Kerb
2
Tilt Angle in Degree = 30
Extension of Source in m = 2
Illumination for Street Lighting Design with Single Source LED
Source Fitted at the End of Center of the Field
Utilization factor (UF) =1
Inverse maintenance factor (IMF) =1

3.2.2 Output Data Obtained through MATLAB Program

HORIZONTAL IILUMINATION FIELD ALONG THE ROAD WITH SOURCE AT THE CENTRE

y =

6.0000	5.0000	4.0000	3.0000	2.0000	1.0000	0	1.0000	2.0000	3.0000	4.0000	5.0000	6.0000	0
2.8833	4.3269	6.4799	9.5427	13.5264	17.9478	21.6265	17.9478	13.5264	9.5427	6.4799	4.3269	2.8833	1.0000
2.7945	4.0097	5.7035	7.9377	10.6206	13.3793	15.5373	13.3793	10.6206	7.9377	5.7035	4.0097	2.7945	2.0000
2.5316	3.4814	4.7251	6.2585	7.9780	9.6385	10.8751	9.6385	7.9780	6.2585	4.7251	3.4814	2.5316	3.0000
2.1972	2.9073	3.7867	4.8096	5.8933	6.8881	7.6010	6.8881	5.8933	4.8096	3.7867	2.9073	2.1972	4.0000
1.8564	2.3741	2.9847	3.6609	4.3447	4.9475	5.3666	4.9475	4.3447	3.6609	2.9847	2.3741	1.8564	5.0000
1.5434	1.9161	2.3377	2.7858	3.2219	3.5942	3.8469	3.5942	3.2219	2.7858	2.3377	1.9161	1.5434	6.0000
1.2719	1.5391	1.8308	2.1304	2.4130	2.6480	2.8046	2.6480	2.4130	2.1304	1.8308	1.5391	1.2719	7.0000
1.0441	1.2360	1.4392	1.6420	1.8284	1.9802	2.0799	1.9802	1.8284	1.6420	1.4392	1.2360	1.0441	8.0000
0.8567	0.9951	1.1380	1.2773	1.4026	1.5029	1.5679	1.5029	1.4026	1.2773	1.1380	0.9951	0.8567	9.0000

VERTICAL IILUMINATION FIELD ALONG THE ROAD WITH SOURCE AT THE CENTRE

z =

6.0000	5.0000	4.0000	3.0000	2.0000	1.0000	0	1.0000	2.0000	3.0000	4.0000	5.0000	6.0000	0
1.2811	1.5721	2.1622	2.6846	2.9752	2.3762	1.3483	2.3762	2.9752	2.6846	2.1622	1.5721	1.2811	1.0000
1.2287	1.4938	2.0305	2.4845	2.7068	2.8319	2.3762	2.8319	2.7068	2.4845	2.0305	1.4938	1.2287	2.0000
1.0224	1.3793	1.8433	2.2099	2.6144	2.7068	2.9752	2.7068	2.6144	2.2099	1.8433	1.3793	1.0224	3.0000
0.9384	1.2457	1.4694	1.9139	2.2099	2.4845	2.6846	2.4845	2.2099	1.9139	1.4694	1.2457	0.9384	4.0000
0.7427	0.9846	1.2811	1.4694	1.8433	2.0305	2.1622	2.0305	1.8433	1.4694	1.2811	0.9846	0.7427	5.0000
0.6651	0.8672	0.9846	1.2457	1.3793	1.4938	1.5721	1.4938	1.3793	1.2457	0.9846	0.8672	0.6651	6.0000
0.5074	0.6651	0.7427	0.9384	1.0224	1.2287	1.2811	1.2287	1.0224	0.9384	0.7427	0.6651	0.5074	7.0000
0.4503	0.4990	0.6407	0.6983	0.8579	0.9065	0.9384	0.9065	0.8579	0.6983	0.6407	0.4990	0.4503	8.0000
0.3328	0.4372	0.4752	0.5117	0.6349	0.6651	0.6846	0.6651	0.6349	0.5117	0.4752	0.4372	0.3328	9.0000

IV. CONCLUSIONS

Surveying at mines at night times is risk, hard task and time consuming process as heavy trucks and dumpers will be moving for extraction of coals and ore takes place late at night also. An approach is made to design a program that gives a actual time survey data of illumination in mines. The program is developed on the MATLAB platform. The provision of adequate illumination is to desire and safe visual working environment is a challenge faced by all industries, but it not possible to meet in mining. The general objectives of providing lighting and illumination are to develop safety and improve productivity. It is evident that mining is the most difficult lighting environment in the world. The LED lights are a fast improving technology, with a large potential for development in future years. LEDs can replace a large variety of lighting technologies, LEDs can replace CFLs too. The resulting energy savings range from 10% to as much as 90%. After comparing from practical field data with MATLAB program output for horizontal and vertical illumination field along the road for a 18W single LED source, the error was found to be = ± 9-12 %. This error is due to the orientation of the LED light sources as these LED sources are placed in arrays in the rows and columns on the luminary.

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