

DESIGN OF ILLUMINATION SYSTEM IN A MECHANISED OPENCAST IRON ORE MINE-CASE STUDY

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Abstract: The paper presents the results of the illumination survey being conducted in a highly mechanised opencast iron ore mine of Odisha and compares the field results with DGMS standards for illuminations to check the adequacy/efficacy at different working places viz. haul road, OB dump yard, parking area, pump station, cabin of HEMM and HEMM working area. It further includes the design of appropriate lighting system for iron ore mine to ensure the safe working of the miners and to ensure the compliance of DGMS standards to ensure energy economy using DIALux.

Keywords: Illumination, LED, Illumination survey, iron ore mine, DGMS, Uniformity Ratio, DIALux

1.INTRODUCTION

Adequate lighting is very crucial for safety and production as it affects significantly efficiency and health of the individuals working in the mine. In many studies, if a task is performed in low or poor lighting condition, it may lead to strain and physical illness in an individual. Increase in production demand and increased mechanization in mining sector demands that lighting at work places should be adequate to reduce frequency of accidents and minimize human error. Good lighting at workplaces encourages enhanced visual performance, reduces accidents and human error, improved visual communication and tasks etc. Therefore, to achieve standards of illumination, a scientific approach needs to be followed. Design of adequate illumination system is desired to address illumination deficiencies and meet illumination standards as prescribed by statutory authorities.

2. DGMS STANDARDS OF ILLUMINATION IN OPENCAST MINES

In view of the consequences that illumination and visibility can have on employees' protection and productivity, the challenges of formulating proper standards and the realistic problems of implementing them must be evaluated against the potential consequences of maintaining the present situation of these constraints. The standards of illumination in opencast metal mines have been updated in the no. 3 on November 06; 2017. This standard is now being adopted as a benchmark for comparison of various field data on mine illumination from various opencast mines. The minimum standard recommendations for opencast metal mines in India are provided in the Table 1.

Table 1: Standards for Mine Illumination for Opencast Metal Mines as per DGMS, 2017 [17]

Sl. No.	Place	Minimum Standard, (lux)
1	Heavy machinery work places	15H, 25V
2	Drilling operations	

	Drill rig work areas	25V
	Area where drill hole exists	15H
3	Areas where manual work is performed	15H, 25V
4	Places of loading, unloading of trucks/dumpers	15H, 25V
5	Machines/mechanisms operator cabins	50H
6	Trucks/dumpers Haul Roads	10H
7	Rail haulage track(pit)	10H
8	Roadways and pathways	10H
9	Permanent paths for persons	10H
10	In-pie crusher breaker	40H
11	Hand picking points	50H
	Conveyors	
12	Transfer points	40H
	Along conveyors	20H
	Coal handling points	
13	Crushing, screening, segregations and loading/unloading sections	40H
	Operations points	50H
	Other places	20H
14	Pumping station	40H
15	Electrical sub-station	100H, 50V
	Other places of operations of electrical equipment	20H, 20V
16	First aid section	50H
17	Rest shelter	30H
18	Workshop	100H, 50V
19	Parking yard	50H
20	General working areas	10H

3. METHODOLOGY

The Luxmeter HD 450 was used for collecting the luminance level in the selected opencast iron-ore mine. A 30m measuring tape is also used for measuring the distance between the poles, measuring the dimensions of the dump yard, parking area and pump station. Illumination studies were conducted at different places of work and the values were compared with recommended DGMS standards. If found inadequate/overestimated, the illumination systems were redesigned using DIALux software.

4. DESIGN OF ILLUMINATION SYSTEM IN MECHANIZED IRON-ORE MINE - A CASE STUDY

The iron ore mine is located in Jharkhand. It is a small mining town located close to the Odisha border and is being worked for winning of iron ore having a capacity to produce 10.00 million tonnes per annum of iron ore. Mechanized method of open cast mining adopted for mining iron ore in a series of 12 m high benches with the help of shovel-dumper combination.

4.1 Illumination Survey of the Mine

The places in the mine that were explored for illumination survey during the visit were Haul Road 1, Haul Road 2, Haul Road 3, dump yard, parking area, pump station and various HEMMs including dozer, dumper, shovel, motor grader and water sprinkler.

4.2 Results of the Illumination Survey

4.2.1 Illumination of haul road 1

The 1st haul road length was 2km; the inter-pole distance was 25m. There were LED bulbs on the poles throughout the road. The wattage of the LED lights was 160W. The length of the pole was 9m. The width of the road was 36m and the pole arrangement was of double arm type. The road had a curve towards the rear end. The Figure of the haul road is shown in Fig. 1.

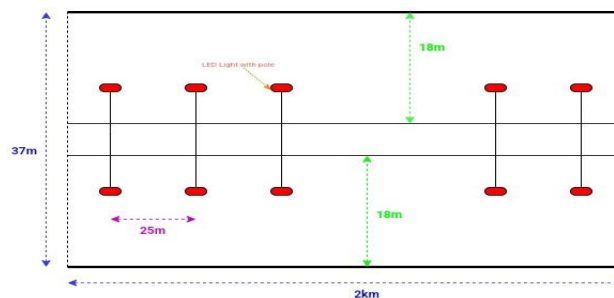


Fig.1 Position of poles in haul road 1

4.2.2. Illumination of Haul Road 2

The 2nd haul road was 800m; the inter-pole distance was 25m. There were LED bulbs on the poles throughout the road. Some of them were yellow and others were white. All of them were in working condition. The wattage of the LED lights was 160W. The length of the pole was 13m. The width of the road was 20m and the pole arrangement was of double arm type. The road was straight throughout. The Figure of the haul road is given below in Fig.2.

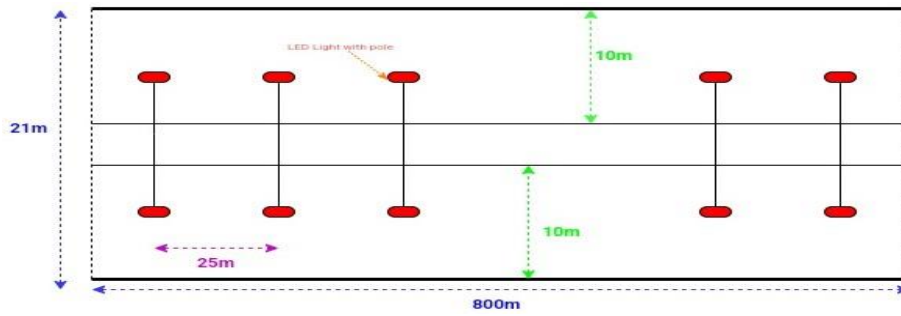


Fig.2: Position of poles in haul road 2

4.2.3. Illumination of haul road 3

The 3rd haul road was 1km; the inter-pole distance was 25m. There were LED bulbs on the poles throughout the road. Some of them were yellow and others were white. All of them were in working condition. The wattage of the LED lights was 160W. The length of the pole was 9m. The width of the road was 36m and the pole arrangement was of double arm type. The road was straight throughout. The Figure of the haul road is given below (Fig.3.):

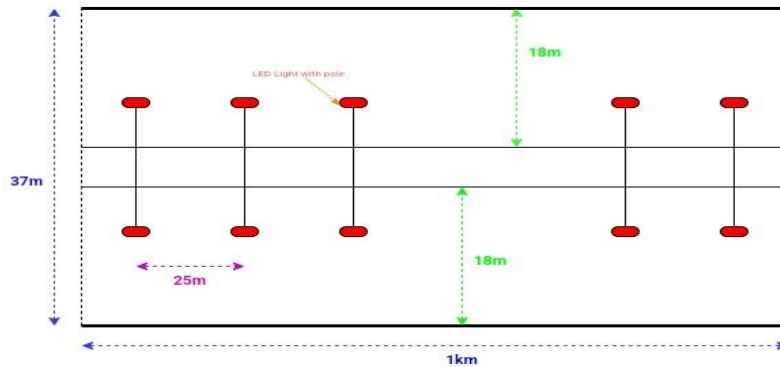


Fig. 3: Position of poles in haul road 3

4.2.4. Illumination of dump-yard (external dump)

The area of the dump yard was 150m x 200m. There was only 1 digi-light tower was installed in the dump yard. The height of the poles at the time of measurement was 6m. The bulbs used were of HPSV type having the wattage of 400W. The Figure of the dump yard is given below(Fig.4).

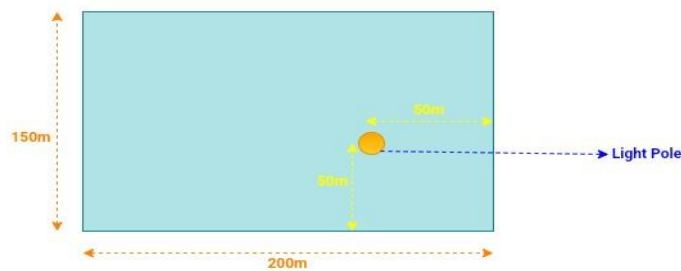


Fig. 4: Position of poles in dump yard

4.2.5. Illumination of parking area

The area of the parking area was 400m x 300m. There was only 1 high mast tower was installed in the parking area. The height of the poles at the time of measurement was 20m. The bulbs used were of LED type having the wattage of 160W. There were total 16 LED lights. The Figure of the parking area is given below:

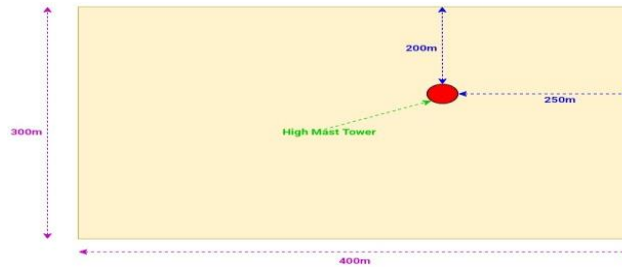


Fig. 5: Position of poles in parking area

4.2.6. Illumination of pump station

The area of the pump station was 15m x 5m. The height of the house was 8m. There are 2 types of LED lights were used having the wattage of 90 and 120W respectively. There were total 10 LED lights, 6 were of 1 type and 4 were of other type. The LED lights used were of Andura LED type. There were yellow and white LED placed randomly throughout the pump station. There were 2 rows of lights having the distance of 3.1m between 2 adjacent lights and a distance of 2.5m between the 2 rows. The Figure of the pump station is as follows:

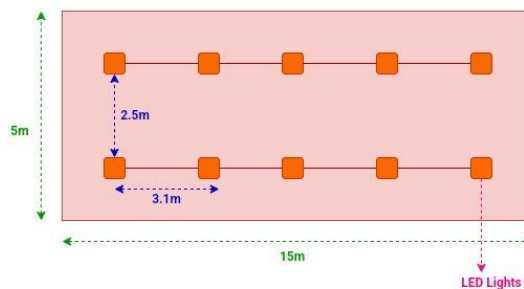


Figure 6: Position of poles in pump station

4.2.7. Illumination of cabin of HEMM

4.2.7.1. Dozer cabin

The cabin of dozer was 2m x 2m. The LED light was pre-installed in the cabin. It was of Caterpillar brand. The lux value inside cabin was 9.6 H and 3.4V. The bulbs that were used as the head lamps were of HPSV type. The cabin light was 9.6 lux

4.2.7.2. Shovel cabin

The cabin of shovel was 1.5m x 1.5m. The LED light was pre-installed in the cabin. It was of Hitachi brand. The lux value inside cabin was 40.2 H and 24V at a height of 1.5m. The cabin light was 40.2 lux.

4.2.7.3. Dumper cabin

The cabin of dumper was 1.7m x 1.8m. The LED light was pre-installed in the cabin. It was of Komatsu brand. The lux value inside cabin was 24.8 H and 11.9V at a height of 1.5m. The cabin light was 24.8 lux.

4.2.8. Discussion

It can be observed from Table 2, below that almost every place in the mine that was visited for illumination survey had lighting arrangements either unsatisfactory or higher than the required range. Haul Road 1 and Haul Road 2 had illumination level of 17.4 lux which was greater than the DGMS standards. Haul Road 3 had unsatisfactory illumination level of 9.8 lux. Dump yard had illumination level of 52.3 lux which was much greater than the DGMS standards. Parking area had unsatisfactory illumination level of 46.2 lux. Pump station had illumination level of 84 lux which was greater than the DGMS standards. The cabins of all the HEMMs had an unsatisfactory illumination level. The working area of all the HEMM had satisfactory illumination level above than 15H and 25V except for the shovel.

Since all the areas including the cabin lighting of HEMMs that were surveyed for the field study had either inadequate or higher than fixed standard illumination level therefore the new lighting system has to be designed using DIALux software in order to make the Illuminance level in accordance with the DGMS standards. For Haul Road 1, Haul Road 2, Dump yard and Pump station, the modification in the lighting system has to be done so as to reduce the Illuminance level.

For Haul Road 3 and Parking area the new lighting system has to be designed. For the cabins of the HEMMs the wattage of the LED bulbs has to be changed because it may not be feasible for new design due to space constraint. For working area of the shovel, the digi-system can be modified, but when used along with dumper gave the satisfactory results in the work face as the digi-lighting tower was also used.

4.3. COMPARISON OF THE SURVEY RESULTS WITH THE DGMS STANDARDS

The illumination (lux) values collected from the above stated places and machineries after the survey were compared with the standard illumination (lux) values set by DGMS in their 2017 circular. The comparison is shown in the Table 2 as shown below:

Table 2: Comparison of the survey results with the DGMS standards

Location of illumination survey	Minimum illumination standards by DGMS, (lux)		Average Illuminance level, (lux)		Remarks
	Horizontal, (lux)	Vertical, (lux)	Horizontal, (lux)	Vertical, (lux)	

Haul road 1	10	-----	17.5	-----	Marginally high value, modification required
Haul road 2	10	-----	17.3	-----	Marginally high value, modification required
Haul road 3	10	-----	9.8	-----	Unsatisfactory
Dump yard	15	25	52.3	26.4	Higher value, modification required
Pump station	40	-----	84	-----	Higher value, modification required
Parking area	50	-----	45.6	-----	Unsatisfactory
Dumper (cabin)	50	-----	24.8	-----	Unsatisfactory
Dozer (cabin)	50	-----	9.6	-----	Unsatisfactory
Shovel (cabin)	50	-----	40.2	-----	Unsatisfactory
HEMM working area	15	25	Satisfactory except for shovel		

The modified and the new designs using DIALux software are discussed in the following section.

4.4. MODIFIED DESIGN OF THE ILLUMINATION SYSTEM USING DIALUX SOFTWARE

4.4.1. Design of haul road 1

The new proposed design of the haul road 1 is shown in Table 3. The Isolux diagram is shown in Figure 7 and Lux value grid is shown in Figure 8:

Table 3: Output for haul road 1

Parameter	Value
Illuminance level, E_m	11.08 lux
Uniformity ratio, U_o	0.63
Optimum pole spacing	35m
Arrangement type	Middle row, double arm
No. of poles required	58
Power requirement	12296W

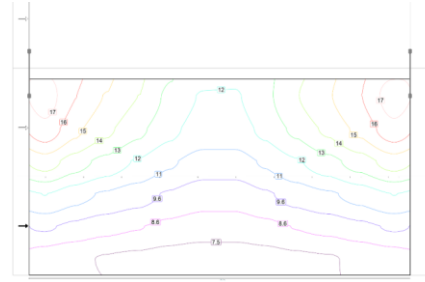
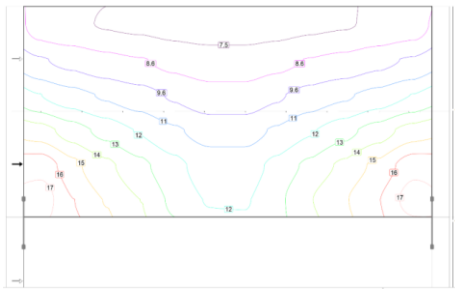


Figure 7: Isolux diagram of haul road 1

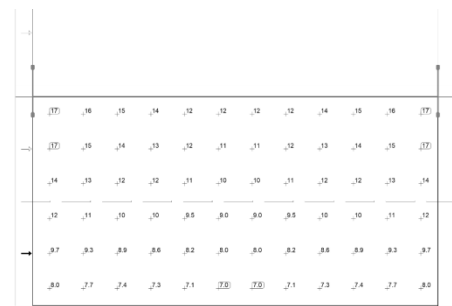
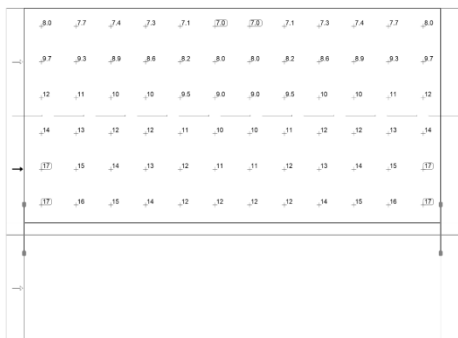


Figure 8: Lux value grid of haul road 1

4.4.2. Design of haul road 2

The new proposed design of the haul road 2 is shown in Table 4. The Isolux diagram is shown in Figure 9 and Lux value grid is shown in Figure 10.

Table 4: Output for haul road 2

Parameter	Value
Illuminance level, E_m	10.15 lux
Uniformity ratio, U_o	0.63
Optimum pole spacing	35m
Arrangement type	Middle row, double arm
No. of poles required	23
Power requirement	4876W

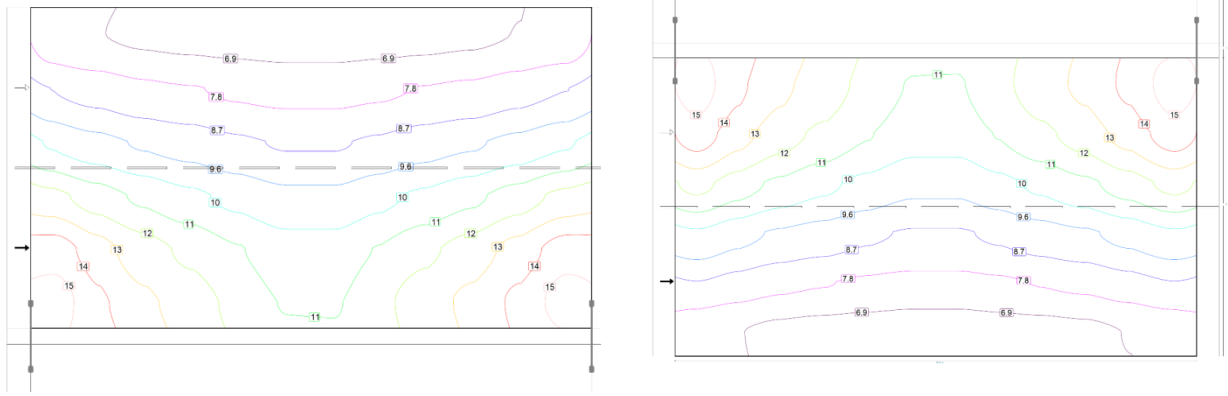


Figure 9: Isolux diagram of haul road 2

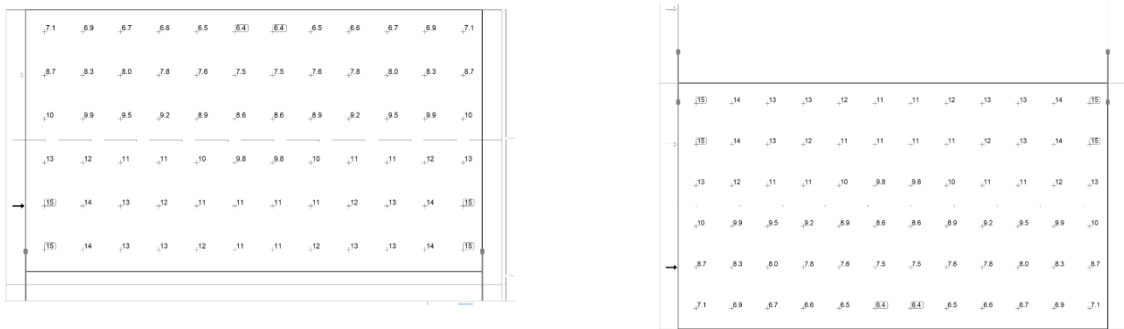


Figure 10: Lux value grid of haul road 2

4.10.3. Design of haul road 3

The new proposed design of the haul road 3 is shown in Table 5. The Isolux diagram is shown in Figure 11 and Lux value grid is shown in Figure 12.

Table 5: Output for haul road 3

Parameter	Value
Illuminance level, E_m	11.08 lux
Uniformity ratio, U_o	0.63
Optimum pole spacing	35m
Arrangement type	Middle row, double arm
No. of poles required	29
Power requirement	6148W

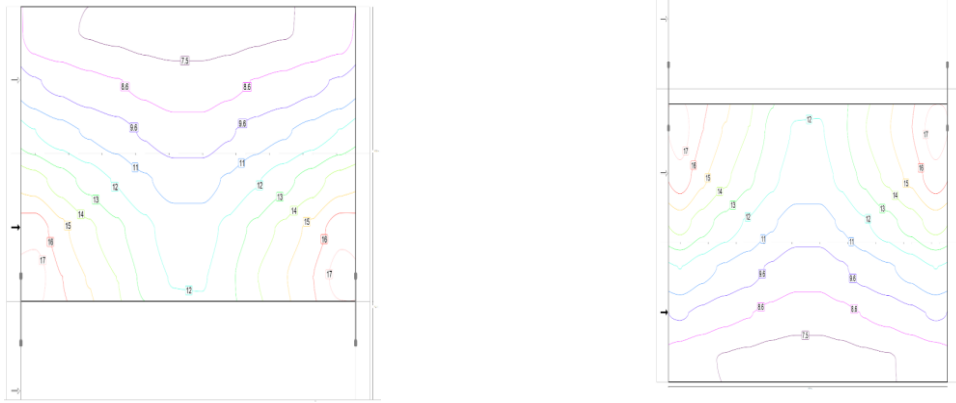


Figure 11: Isolux diagram of haul road 3

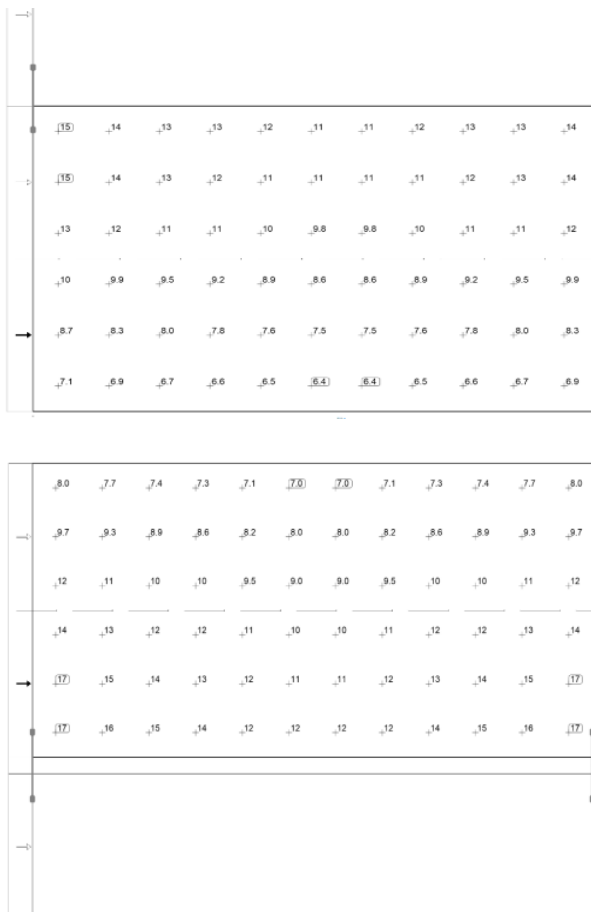


Figure 12: Lux value grid of haul road 3

4.10.4 Design of dump yard

The area of the dump yard is 200x150m. In the new design there are 21 poles having the height of 20m. The total number of luminaires used is 74. The LED type of lights is used having the wattage of 106W. The inter-pole distance in the x-direction is 30m and in the y-direction is 40m. The new proposed design of the illumination system for the dump yard is shown in Table 6.

Table 6: Output for dump yard

Parameters	Value
Average horizontal lux	16.0 lux
Uniformity ratio	0.72
Total wattage requirement	7844

The layout of the luminaire positions are shown in the Figure 13. The Isolux contour and the false colour that was produced from simulation is shown in Figure 14.

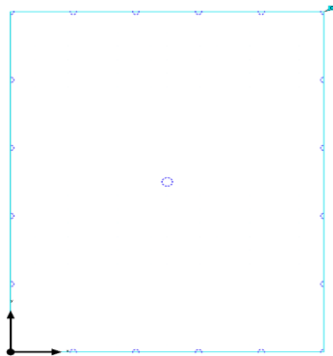


Figure 13: Luminaire position of dump yard

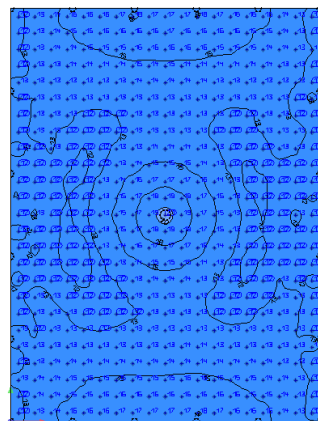


Figure 14: Isolux curve and false colour diagram of dump yard

4.10.5. Design of parking area

The area of the parking area is 400 x 300m. In the new design there are 74 poles having the height of 20m. The total number of luminaires used is 580. The LED type of lights is used having the wattage of 120W. The inter-pole distance in the x-direction is 25m and in the y-direction is 20m. The new proposed design of the illumination system for the dump yard is as shown in Table 7.

Table 7: Output for parking area

Parameters	Value
Average horizontal lux	53.5 lux
Uniformity ratio	0.004
Total wattage requirement	69600W

The layout of the luminaire positions are shown in the Figure 15. The Isolux contour is shown in Figure 16.

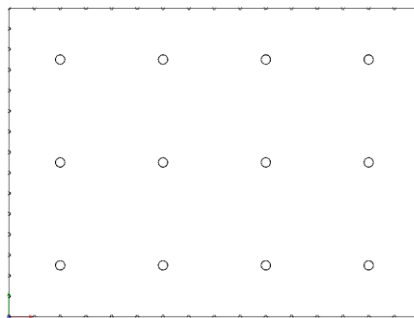


Figure 15: Luminaire position of parking area

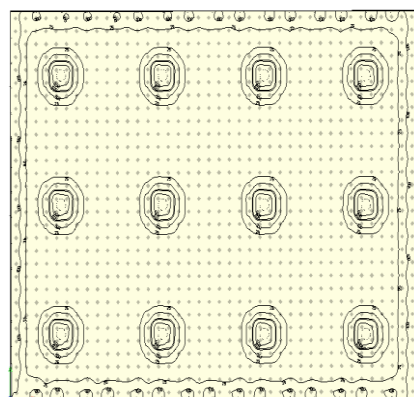


Figure 16: Isolux curve diagram of parking area

4.10.6. Design of pumping station

The area of the parking area is 15 x 5m. The height of the station is 8m. The total number of luminaires used is 10. The LED type of lights is used having the wattage of 120W. There are 2 rows of lights having the distance of 3.1m between 2 adjacent lights and a distance of 2.5m between the 2 rows. The new proposed design of the illumination system for the dump yard is in Table 8:

Table 8: Output for pump station

Parameters	Value
Average horizontal lux	45.2 lux
Uniformity ratio	0.69
Total wattage requirement	120W

The Isolux contour and the false colour that was produced from simulation is shown in Figure 17.

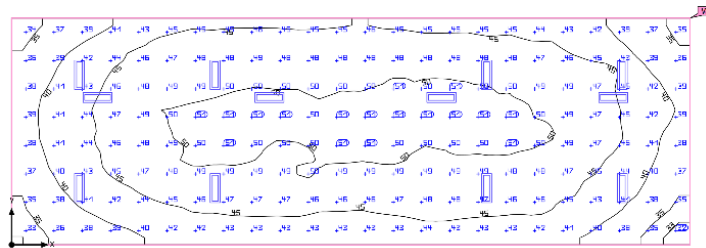


Figure 17: Isolux curve diagram of pump station

4.10.7. Illumination design in cabins of HEMMs

The following HEMMs are used in the iron ore mine:

- Dozer
- Shovel
- Dumper

The observed lux values of the cabin of all the HEMMs are unsatisfactory, therefore new design has to be proposed so as to bring the lux value to the satisfactory level i.e. 50H as specified by the DGMS in their 2017 circular. The design of the new luminaire through the DIALux software is impractical as we have the location of the luminaire inside the cabin as a constraint. Due to the limited space, only bulb type of luminaire can be used as light inside the cabin. Therefore, a theoretical approach is adopted in order to find the right wattage of the bulb that can be used as a luminaire inside the cabin. It was found that, the 15W LED bulb is selected for the cabins of all of the HEMMs stated above. This bulb can easily be fitted into the socket without making any changes to the luminaire arrangement inside the cabin. It can give lux value of 60 H and meets the DGMS requirements of 50 lux.

4.10.8 Design of HEMM working area

There was shovel-dumper combination operating in the OB face. 1 digi-light tower was also there for the illumination purpose. The results of the field survey of the digi-tower are given in the Table 4.30. The results of the field survey of the shovel and dumper are given in the Table 9.

Table 9: Survey Results of Digi-Light Tower

Pole no.	Pole height, (m)	No. of lamps	Power consumption, (W)	Illuminance level, (lux)		
				Distance across the luminaire face, (m)	Horizontal Illuminance level, (lux)	Vertical Illuminance level, (lux)
1	6	10	400	5	62.8	31.9
				10	59.6	29.8
Luminaire Type				HPSV		

The observed illumination level of working environment of shovel was 2.1H, 4.9V and of dumper was 39.4H, 82.2V. The observed illumination level of working environment of dig-lighting tower was 62.8H, 31.9V. The illumination standards for working environment of HEMM set by DGMS, 2017 circular are 15H, 25V. hence it can be concluded be that when shovel is used in combination with dumper and digi-lighting tower, then the combined illumination survey will be above the illumination standards of 15H and 25V set by the DGMS, 2017 circular.

4.11 CONCLUSIONS

Based on the Illumination survey carried out at the iron ore mine, the following conclusions can be drawn:

- Haul Road 1 and Haul Road 2 had marginally higher illumination levels as compared to the DGMS standards.
- Haul Road 3 and Parking area had inadequate illumination level as compared to DGMS standards.
- Dump yard and Pump station had higher illumination level than the DGMS standards.
- The cabins of all the HEMMs had unsatisfactory illumination level.
- The working area of all the HEMM had satisfactory illumination level except for the shovel.

Therefore, the new modified design for the lighting system in haul road, dump yard, parking area, pump station and the cabins of various HEMMs are proposed in this case study. The following light wattages are suggested for the above stated places in the mines:

- For the Haul Road 1, the poles in the road have middle row, double arm type of arrangement, having inter-pole distance of 35m, pole height of 12m, boom angle of 5° and length of 2 m. The no. of poles required is 58. 106W Philips LED lights will be used.
- For the Haul Road 2, the poles in the road have middle row, double arm type of arrangement, having inter-pole distance of 35m, pole height of 13m, boom angle of 5° and length of 2 m. The no. of poles required is 23. 106W Philips LED lights will be used.
- For the Haul Road 3, the poles in the road have middle row, double arm type of arrangement, having inter-pole distance of 35m, pole height of 12m, boom angle of 5° and length of 2 m. The no. of poles required is 29. 106W Philips LED lights will be used.
- For the Dump Yard, inter-pole distance is 30m in x-direction and 40m in y-direction, height of poles is 20m. The no. of poles required is 21 and no. of luminaries required is 74. 106W Philips LED lights will be used.
- For the Parking Area, inter-pole distance is 25m in x-direction and 20m in y-direction, height of poles is 20m. The no. of poles required is 74 and no. of luminaries required is 580. 120W Philips LED lights will be used.
- For the Pump Station, no. of luminaries required is 8. 15W Philips LED lights will be used.
- 15W Philips LED bulb proposed for cabins of all the HEMMs.

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