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Inadequate and Unsafe Temporary Lighting in Buildings under Construction: Risks, Challenges, and Solutions

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Abstract
The use of temporary lighting in buildings under construction is necessary to enhance safety and productivity of the workers. Construction sites are dynamic environments. With the constant change in environment, proper and consistent illumination is a challenge. The US construction industry has minimum guidelines for temporary lighting established by OSHA. The examination of OSHA records shows that inadequate lighting has been a contributing factor for site accidents. The question becomes whether or not construction sites in the US are meeting the minimum OSHA standards. Thirty three construction sites were visited and light readings taken inside the buildings under construction. The study showed that there are several methods, in which general contractors are providing temporary lighting for the projects, but the lighting was inadequate and most work areas did not meet the minimum OSHA standards. A discussion of possible solutions sets the groundwork for improving the temporary lighting environment.

Keywords
Temporary lighting, construction site management, safety, site accidents, quality

1. Introduction

The use of temporary lighting in buildings under construction is necessary to either maintain or enhance the safety and productivity of the workers. Lighting is multifaceted, in that a light meter can give a reading of illumination at a given point in foot-candles (*fc*) as a quantitative measure, but lighting has qualitative aspects, including brightness, glare, and contrast, which impact the quality of lighting. OSHA uses the quantitative measure of illumination to set minimum guidelines for temporary lighting for construction projects in the United States. There are other construction industry guidelines setting requirements for temporary lighting, but OSHA, as a federal regulatory body, would define the minimum requirements that all other standards would need to meet or exceed.

A preliminary study of jobsites identified several methods of supplying temporary lighting in buildings (Smith, B.W., 2006). The investigators short listed three methods that need to be evaluated. Since jobsites are such dynamic environments, in that the physical characteristics of any area in a building changes with the installation of the various building components, that makes testing lighting systems very difficult. An independent location was chosen to perform testing on several lighting methods to establish the effectiveness of each (Smith, B.W., 2007). The effectiveness was gauged on the OSHA requirements: i.e., whether the area met the requirements for temporary lighting or it did not. The selected site was a warehouse that was blacked out from all outside and natural light. There were no obstructions in the building so that the only variables tested were the lights themselves (Smith, B.W., 2007).

The testing indicated that buildings using 400 watt metal halide fixtures were able to meet the minimum OSHA temporary lighting requirements with proper spacing. One hundred and fifty (150) watt incandescent bulbs, spaced 10 feet on center (both directions resulting in 1 bulb per 100 square feet) also met the requirements. One hundred (100) watt bulbs, 10 feet on center, did not meet the minimum OSHA requirements (Smith, B.W., 2007).

A number of jobsites were visited and light readings were taken. The result of the study showed that many jobsites had inadequate lighting. The risk of inadequate lighting could lead to the risk of accidents and the risk of OSHA citations. The study, of OSHA reported accidents, shows that "poor visibility" was a contributing factor in some accidents. The study of OSHA citations shows that a significant number of citations and penalties resulted from inadequate illumination (OSHA 2007).

There needs to be a discussion on how jobsites can come in compliance with the OSHA standards, and remain in compliance during the course of the project. This discussion needs to look at the ways to overcome obstacles and to look at innovative solutions, with a brief look at the cost/benefit analysis of creating the better working environment, with the OSHA standards being only the threshold of quality lighting for the buildings under construction. These issues are investigated and discussed in this paper.

2. OSHA Illumination Requirements

OSHA standard 29 CFR 1929.56 "Illumination" clause 1926.56(a) General, states, "Construction areas, runways, corridors, offices, shops, and storage areas shall be lighted to not less than the minimum illumination listed in Table 1 while any work is in progress" (OSHA, 2004). The required illumination specified by the OSHA standard was derived from the specifications provided in the American National Standards Institute (ANSI) standard ANSI A11.1-1965, R1970 (Clark, 1991).

Table 1:- Minimum Illumination Intensities in Foot-Candles

Foot-Candles	Area or Operation
5	General construction area lighting
3	General construction are, concrete placement, excavation and waste areas, access ways, active storage areas, loading platforms, refueling, and field maintenance.
5	Indoor warehouses, corridors, hallways, and exit ways
5	Tunnels, shafts, and general underground work areas. (Exception: minimum of 10 foot-candles is required at tunnel and shaft headings during drilling, mucking, and scaling. Bureau of Mines approved cap lights shall be acceptable for use in the tunnel heading.)
10	General construction plant shops (e. g. batch plants, mechanical and electrical equipment rooms, carpenter shops, rigging lofts and active storerooms, barracks or living quarters, locker or dressing rooms, mess halls, and indoor toilets and workrooms.)
30	First aid stations, infirmaries , and offices

3. Industry Illumination Requirements

Building project specifications often address temporary lighting in Division 1: General Requirements. The CM or GC can place the duty to provide temporary lighting under the scope of work for the electrical contractor. The typical specification or scope of work could be as simple as “provide temporary lighting”. The illumination requirement may be performance based, such as the OSHA standard, or prescriptive. The Dade County Schools have a specification for construction that requires one 100-watt lamp for each 250 square feet of area, but not less than one per area (Dade County, 2005). New Brunswick has a recommended lighting level of 10 *fc* for general construction, with an example of 150 watt bulbs eight feet off the floor and thirteen feet apart (New Brunswick, 2000). The Pittsburgh AIA has set guidelines at 100 watt bulbs thirty feet on center for corridors and one lamp per 300 square feet or part thereof, with a minimum of one bulb in each space (Pittsburgh, 1987). Preliminary studies have shown that the prescriptive requirements of Dade County, New Brunswick, and the Pittsburgh AIA do not meet the OSHA performance standard (Smith, B.W., 2006 and 2007).

The United States Department of Energy (DOE) recognizes the lack of specific guidelines for temporary lighting, and in reference to the topic states “Construction design documents define the contractor’s responsibilities during construction, but they typically focus on the design elements of the finished product. They rarely set environmental guidelines to be followed during the construction phase. The design team should work with the construction contractor to adopt environmental guidelines to be followed during construction.” (U.S. DOE, 2004)

4. Fundamentals of Lighting and Illumination

Temporary lighting, for this paper, will be defined as the process and the equipment used to provide artificial illumination in a work area. Natural light may also provide illumination, and it is the combination of the two that provide the construction illumination. Illumination is the amount of light falling on a surface and is measured in foot-candles (*fc*). A foot-candle is the measurement of the light falling on a square foot of surface (Lechner 2001, Smith, B.W., 2006).

The measurement of light is multidimensional in that there are several factors that impact the amount of illumination measured at a given point. First, the light source can vary in type, color, distance, and intensity. The reflectance (RF) of surrounding surfaces also impacts the measurement of light. Reflectance is the proportion of light that a surface reflects compared to the amount of light that falls on that surface. Dark, matt and/or textured surfaces absorb a lot of light and have low reflectance values. Light, glossy and/or smooth surfaces reflect most of the light that falls on them and have high reflectance values. All colors have a reflectance value between 0 and 100. If a surface has an RF of 60, 60% of the light hitting the surface will be reflected. The texture and shape of surfaces also impact the reflectance (Lechner, 2001).

The OSHA standard for a construction area in a building is a minimum of 5 foot-candles. The measurement of illumination is one dimensional and lighting is multidimensional. The one dimension is the quantity of illumination. Other aspects, such as brightness, contrast, and glare help define the quality of illumination.

Brightness and illumination are very similar. Illumination is the objective measurement of light, while brightness refers to the perception of the human observer. “The perception of brightness is a function of the object’s actual illumination, the adaptation of the eye, and the brightness of adjacent objects” (Lechner, 2001).

Contrast is the difference in brightness of two areas (Lechner, 2001). Black ink lettering on a white page makes it easy to read. There is high contrast between the two areas. Road signs on interstates have white letters on a dark green background. The brightness ratio is the comparison of the brightness of objects or areas and gives a quantitative comparison of the two areas.

Glare is the extreme brightness caused by a light source. Direct glare is caused by a light source that is bright enough to cause annoyance, discomfort, or the loss of visual performance (Lechner, 2001). Indirect glare is caused by the reflection of a light source off a shiny surface, such as glass or stainless steel. The severity of glare depends on the brightness of the light source and the background. A bright light will produce more glare when on a black background than on a white background (Lechner, 2001).

The examination of temporary lighting requires both the quantitative measurements of illumination and the qualitative analysis of the lighting environment because lighting is based on human perception. The eyes can adjust to low light levels in a museum or extremely high light levels at the beach. It is the combination of brightness, contrast, glare, and the task performed that determine the quality of lighting (Smith, B.W., 2006).

Table 2 shows some light readings in different conditions and will help illustrate how much illumination is present and the impact on the eyes when moving or looking from one area to another. Several measurements were taken in each location and averaged. The readings were taken 36 inches off the floor to reflect the common task height.

Table 2: Miscellaneous Light Readings
(Smith April 2006)

Location	**Light Meter Readings (fc = foot-candles)**
Outside on a sunny day	4000 *fc*
Parking deck	3 *fc*
Shopping mall common area	56 *fc*
Department store	53 *fc*
Sporting goods store	60 *fc*
Jewelry store	33 *fc*

5. Project Lighting Investigation

An early study of three projects resulted in all three projects substantially non-compliant to the minimum OSHA standard. The first project was a hospital addition, eight stories tall, with a cast-in-place concrete structure. The temporary lighting system was comprised of 400 watt metal halide fixtures 60 feet on center. The surfaces were dark and non reflective, and there was little natural light. The light meter readings showed that 78% of the building were under 5 *fc* (Smith, B.W., 2006).

The second building was a two story school addition. The structure was steel frame with CMU interior walls and CMU back-up block on the exterior walls. The ceilings were corrugated steel in the first floor and white gyp on the second floor. There was some natural light on the perimeter of the building. The temporary lighting was 100 watt bulbs spaced unevenly throughout the building. The only area in the building that had sufficient light was near the windows on a sunny day. The interior areas were all below 5 *fc* (Smith, B.W., 2006).

The third building was engineered steel on steel building. The temporary lighting consisted of 150 watt bulbs, about 20 feet off the floor, and 20 feet on center. Other than natural light through the windows and openings, the temporary lighting was inadequate to meet OSHA standards in all interior areas (Smith, B.W., 2006).

The three buildings examined identified the problem, but did not give a broad enough view of temporary lighting. Buildings vary in shape, size, materials and a multitude of other factors. More buildings were examined and the results summarized.

Several other sites were also investigated during this study. It was found that most of the smaller projects such as multifamily residential units had no temporary lighting. Observations indicated that eleven investigated sites did not have any temporary lighting, one used metal halide fixtures, one used clusters of four halogen bulbs, and the remainder used 100 watt incandescent bulbs. Where temporary lighting was provided, only the 400 watt metal halide bulbs and the halogen bulbs provided enough illumination to meet the OSHA guidelines. There was no area in any building that, without natural light, met OSHA standards with only 100 watt incandescent lighting.

The buildings were all located in Alabama and Tennessee, and all locations were examined in May and June on sunny days. The results showed that natural lighting was heavily relied on at many of the locations. It was estimated that 41% of the building area examined did not meet the minimum of 5 *fc* with the natural light. Without sufficient natural light, such as early morning starts, short daylight hours in the winter, and cloudy days, the non-compliant area of the combined buildings could reach 75%.

6. Risks

When OSHA developed standards for the construction industry, lighting was one of the safety aspects of construction projects addressed. The writers of the standard realized that some level of lighting was necessary to provide workers with a safe environment. Although proper lighting is required by the OSHA standards, few accidents reported to OSHA since 1987 have been attributed to poor visibility or inadequate lighting. Several accident reports note that there was poor visibility at the time of the accident, such as OSHA Accident Report #0950623, where an employee fell through an opening in the floor. The cited cause of the accident was the unguarded opening, but the report read, “The lighting in the auditorium was poor and the opening was unguarded…” (OSHA, 2007).

The number of citations issued by OSHA (not including state programs) for SIC code 1500, Building Construction General Contractors and Operative Builders, and SIC code 1700, Specialty Trade Contractors, were researched. During the period from October 2005 through September 2006, twenty-four citations were issued for “Illumination” violations. These violations had a total penalty amount of $10,600 (OSHA, 2007). The number of citations is small compared to the total of citations for the period of 11, 211, with penalties of over $7.5 million, but the impact on any one contractor could become significant.

The risks involved in poor illumination include the risk of accidents, the risk of citations, and at some level, the risk of poor quality and productivity. The risks have human and monetary implications. The inability to quantify all the aspects of risks limits the conclusions that can be drawn from improvement techniques. However the mitigation of risks is the main goal that should be considered.

7. Challenges

OSHA has created a minimum standard for buildings under construction to have a minimum illumination of 5 *fc*. Some industry standards exist, but those standards must meet or exceed the OSHA standards. The investigation into current lighting practices on several projects shows that many projects are not in compliance. The study of OSHA accidents and citations shows there is some degree of risk associated with having illumination which does not meet the OSHA standards. The question that follows is why so many projects not in compliance are.

One answer is that contractors and owners do not realize that they are not in compliance. The second, and perhaps the more important issue, is that attaining compliance and maintaining compliance is difficult and could become expensive. Construction sites are not like other industries. The working environment changes constantly. The very nature of construction calls for additional materials and system becoming part of the building every day. Ductwork, piping, and walls are installed that block natural and temporary lighting. The dynamic nature of the process calls for dynamic solutions to lighting. The solutions need to take in account numerous variables, such as shadows, reflection of light, glare, brightness, and contrast.

8. Analyzing Current Practices

The ability to analyze solutions started with analyzing current practices. Attempting to analyze different lighting solutions is difficult on the jobsite. The numerous variables mentioned above make comparisons difficult. The following is a discussion of a lighting study where all variables were eliminated, except for the source of the illumination. The complete study is currently under review as a submission to the International Journal of Construction Education and Research. The following is an overview of that paper (Smith, B.W., 2007). The testing was conducted in a closed warehouse, with dimensions of 60 feet by 28 feet by 12 feet tall. A grid was laid out on the floor, 5 feet on center each way, to give 55 points where the light readings were taken (five rows of 11 points). The lighting fixtures were hung at 11 feet above the floor. The walls, floors and ceiling were of similar material, color, and texture as would be found in a concrete masonry building or a cast-in-place concrete structure.

Three primary current lighting systems were analyzed to see if they meet OSHA standards. The systems were modified a bit to find a system that would meet the minimum illumination standard. The following is a summation of the testing.

8.1 Four hundred (400) watt metal halide fixtures 30 feet on center

The spacing found on jobsites was closer to 60 feet on center, but light readings showed that this was inadequate. Preliminary test showed that 30 feet on center would provide the minimum required lighting (5 *fc*) on the majority of the area. The test on the 400 watt system showed that the illumination ranged from 23 *fc* to 11 *fc*. All points in the test area were above the 5 *fc* minimum. The fixtures could have been spaced further apart. The test area was too small for a complete test at different spacing, but an examination of the light levels with one fixture on showed that the light levels drop significantly after 15 feet from the fixture, so 35 to 40 feet on center would be the maximum spacing. The downside of the lighting was the deep shadows that resulted from few, very bright lights. When there was an obstacle in the test area blocking one of the lights, the point was under the 5 *fc* minimum. On the qualitative aspects for the lights, there was a lot of glare, deep contrast, and brightness issues. The lights were not comfortable to work in for long period.

8.2 One hundred (100) watt incandescent bulbs 10 feet on center

The Dade County requirement was one 100 watt bulb for 250 square feet. Pre-built light strings are 10 feet on center so 10 feet on center (100 square feet) was chosen for testing. The 100 watt lights, 10 feet on center had a maximum reading of 3.2 *fc* and a minimum of 1.2 *fc*. There was no point in the tested area that met the OSHA standard of 5 *fc*. The Date County requirement, which requires less than half the fixtures, would not meet the minimum OSHA requirement. The lights were not so bright as to be uncomfortable, and although the light was dim, the area was relatively uniform visually in illumination. Shadows were not a problem.

8.3 One hundred and fifty (150) watt incandescent bulbs 10 feet on center

New Brunswick required 150 watt bulbs 8 feet off the floor and 13 feet on center. Since most buildings have ceiling heights over 8 feet, the spacing was changed to 10 feet on center. The 150 watt lights, 10 feet on center, had a maximum reading of 6.1 *fc* and a minimum of 2.5. The area under the 5 *fc* was on the perimeter of the test area. Interpolating the results over a larger area, the majority of the points would be in compliance with the OSHA standards. With some additional lighting on the perimeter, the entire area could become compliant. The shadows were not a problem. The lights were brighter than the 100 watt, but not so much to cause the eye discomfort as experienced with the metal halide bulbs.

8.4 24 Watt florescent bulbs

A forth system was tested that used 24 watt florescent bulbs in the same fixtures as were used for the incandescent bulbs. The fixtures were placed 10 feet on center. The results showed the same illumination as the 150 watt bulbs with the visual brightness of the 100 watt bulbs.

9. Proposed Solutions

Choosing a lighting system for the temporary service of a building can become as rigorous as the selection of the final lighting system. Each area of the building needs to be individually examined as to the needs of the area based on the environment and use. Those areas with highly reflective surfaces will respond differently than those with a low reflectance number. There is also the challenge of understanding the sequences in system installation so the temporary lighting facilitates the construction process without frequent modification.

Each room needs to be analyzed for the location of piping and ductwork that would conflict with the fixture. Once the locations are identified, the proper light fixture can be chosen. The most light is usually necessary when the gyp installation, finish, and painting are taking place. If sufficient lighting is supplied for the most light intensive process, there should be enough light for all other processes.

Hallways are often a difficult area for the installation and maintenance of temporary lighting. The above ceiling cavity often contains large ductwork, plumbing, electrical, and communication components. Lighting that is placed on the ceilings early in the construction process is covered up, moved, or removed. One answer is to have good lighting immediately on each side of the hallway to properly maintain light for the area. Before the gyp is installed, additional lighting would need to be installed. In some cases, the final fixtures may be installed and energized.

Stairways are often difficult to light because of the lack of any natural light, dark concrete walls, and high ceilings. One option is to plan on installing the final light fixtures as temporary lighting as soon as possible. Stairways often have a minimum of mechanical interference.

The lighting fixtures need to be chosen based on the requirements of each area of the building. The qualities of the lighting fixture need to become part of the decision process, such as the amount of light, the brightness of the fixture, the glare from the fixture, and the contrast created by the fixture. The efficiency of the lighting system can become a factor in the decision process on large sites where power demands and costs are significant. Small offices require smaller light fixtures than larger areas, but more of them. High ceilings and large areas require larger, more intense lights. When lights are higher off the floor, more light is required and glare becomes less of an issue. The variety of lights that can be used in construction areas needs to be expanded. Two or three options may not be enough to satisfy the industry needs.

Installing final fixtures could become a viable option in large areas, such as atriums, warehouses, auditoriums, gyms, cafeterias, etc. The fixtures may need to be protected from paint and dust during the construction process. Extra globes and fixtures may be necessary to replace damaged units.

10. Conclusions

The pathway to change is difficult. The construction professionals need to become aware of the problem. No changes will take place until there is the acceptance of the need to change. Along with the need for change comes the understanding of the value of change. Resources need to be allocated to make the change. The resources include the planning of the temporary lighting system and the additional funds to implement the system. Different solutions need to become available to accommodate the differing needs of jobsites, and the lighting methods need to be analyzed to assure the effectiveness in providing illumination and mitigating glare, brightness, and contrast.

Inadequate temporary lighting is a potential risk on construction sites. OSHA sets minimum requirements for the level of illumination on construction projects. The OSHA minimum guidelines are the minimum to establish a safe working environment. The ability for employers to reach the level of safety is hampered by the dynamic nature of the construction site. The environment on construction sites changes daily with the installation of building components, such as piping, ducts, and walls. Natural light is a part of construction lighting, but natural light is limited by daylight hours which may be shorter than working hours during winter and/or cloudy conditions. Adequate lighting is required any time when there are workers present. Temporary lighting, in many cases, is required and that lighting must be OSHA compliant. The testing of lighting methods showed that 100 watt bulbs are inadequate to provide the minimum lighting requirement when the lights are 11 feet off the floor. The study of various jobsites revealed that sites using 100 watt bulbs were non-compliant with the OSHA minimum standards. There are challenges to installing and maintaining temporary lighting, and some current lighting solutions are unable to meet OSHA standards. The solution can vary to meet individual jobsites requirements, but these solutions involve incorporating the temporary lighting into the design and planning of a project. The temporary lighting design to take into account the placement of final walls and mechanical systems that could conflict with the placement of lighting fixtures. Each area of the building needs to be analyzed to assure that the lighting is adequate for all stages of the work progress, to avoid additional modifications to the sightings systems that could have been avoided. Additionally, the lighting systems should not only provide adequate illumination to meet the OSHA standards, but the lighting systems should also be chosen to minimize brightness, glare, and contrast.

Future studies of temporary lighting could include the examination of productivity, cost/benefit analysis of lighting systems, experiments with different lighting systems, and the development of new lighting fixtures that are especially designed for the construction industry and not an adaptation of industrial or task lighting for building illumination.

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