TUNNEL AND UNDERPASS LIGHTING PRACTICE IN THE U.S.A.

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Introduction

In offering this review of the lighting of vehicular tunnels and underpasses in the United States, the authors have attempted to present a brief report covering the illumination methods which have been used in recent years and are presently being used for new facilities either under construction or being designed. There has been little if any organized research in this country directed to the special problems which the tunnel lighting designer frequently encounters in trying to provide safe and comfortable seeing conditions for the motorist.

Relatively few developments have occurred during recent years in the art of tunnel lighting. With the exception of new underpass luminaires, the same general type of lighting equipment is being used today as was employed 20 years or more ago. Where equipment modifications have been made they have generally been minor in nature, despite the fact that traffic conditions in many of our new multi-lane, high speed, high volume freeway tunnels are substantially different from the conditions which existed in the two-lane, bidirectional tunnels built before World War II. Our impression is that tunnel lighting as a specialized field of illumination has been relegated to a very minor role in lighting developments and the possibility for improving design techniques has been largely unrecognized or avoided.

The unusual requirements necessary to provide proper visibility in our new tunnels raises a pertinent question - should a study be undertaken to determine the proper illumination conditions which should prevail, along with an exploratory investigation intended to develop new methods and equipment which would more efficiently and economically answer tunnel lighting needs? The authors believe that such a study would be beneficial.

General Practice

The established practice in this country is to provide fixed lighting in the covered portions of streets and highways which either carry an appreciable volume of vehicular traffic only or where there is a combination of both vehicular and pedestrian traffic. On main traffic routes, all structures which have sufficient length that they are considered to be tunnels rather than underpasses are normally lighted 24 hours per day, even though the adjacent sections of outside roadway may not be continuously illuminated at night. This situation could exist with a tunnel located in a rural area.

Very short tunnels and structures usually referred to as underpasses are frequently unlighted, particularly when there is no problem of visibility through the structure during daylight hours. For the night condition when the adjacent roadway sections are unlighted there is usually no need for fixed lighting within an underpass. In the continuously lighted roadway situation, the need for supplementary lighting in an underpass depends on whether luminaires immediately outside the structure will give sufficient light penetration to make supplemental lighting unnecessary. Underpasses up to about 75 feet in length usually do not require supplemental lighting.

Long Tunnels

The basic method of lighting most long tunnels utilizes fluorescent lamps within an enclosed luminaire designed to provide mechanical protection for the electrical components and to control the direction and intensity of the light. In some cases, the enclosure merely provides mechanical protection and a support for the lamp and its auxiliary devices, with no provision for controlling the light.

The fluorescent lamp is a linear light source and lends itself readily to the establishment of continuous lines of light throughout the length of the tunnel. The continuous rows of lights are considered to be a desirable feature for long tunnels since flicker effect is minimized and excellent longitudinal lighting uniformity results. Consequently, fluorescent lamps have been the most widely used light source for new tunnels and for some of the older tunnels in which the original lighting system was replaced during recent years.

Enclosed fluorescent luminaires intended especially for tunnel applications are commercially available. They vary in size to accommodate from one to three lamps and are equipped with ballasts to operate each lamp at a predetermined wattage and light output. By the use of automatic switching or dimming equipment it is possible to obtain variations in the level of illumination to meet most of the prevailing needs. For example, all lamps in the entrance section may be operated at their maximum light output to give the higher brightness required for eye adaptation on a sunny day. Step reductions in the lighting are brought about by reducing the number of lamps or changing the light output of the lamps in successive sections as the motorist proceeds through the tunnel. For night operation the controls and circuits are arranged to operate the lighting system at a low level of illumination, usually one lamp in each luminaire at minimum light output throughout the entire length of the tunnel.

The controlled light output type of fluorescent tunnel luminaire often employs an optical system consisting of an internal reflector and a translucent front cover which in some cases includes a refractor for more precise light control. Luminaires are usually surface mounted along the walls or ceiling of the tunnel.

Another frequently used type of luminaire has the fluorescent lamp mounted inside a hardened, heat resistant glass tube. The tube provides mechanical and thermal protection for the lamp but gives no directional control of the light. In such cases it is important that the tunnel walls have a high coefficient of reflection for best utilization of the available light. The associated electrical equipment required for these glass tube luminaires permits dimming of the fluorescent lamps, affording a means for either automatically or manually varying the prevailing level of illumination in accordance with a predetermined schedule.

A special fluorescent luminaire was developed by the California Division of Highways and has been used for a number of tunnels in that State during the past ten years. It has features which contribute to the development of good uniformity of wall and ceiling brightness. Auxiliary reflectors are used for lamp shielding and the electrical control system allows the luminaire to be operated at reduced brightness during the night period when low levels of illumination are adequate.

For the lighting of long tunnels it has been the custom in this country to use only one type of light source for each installation. There have been few instances in which two different sources have been employed in the same tunnel. Yet, in the opinion of the authors, there are good reasons why a combination of sources may be advantageous. For example, a high intensity source such as mercury in combination with a basic fluorescent system may be used to build up high levels of illumination to meet the daytime lighting requirements in the entrance zone. With an arrangement of this kind the total number of lamps and possibly the number of luminaires may be reduced substantially. The combination of fluorescent and mercury equipment has been successfully utilized in the tunnel leading to the eastbound lower level roadway of the George Washington Bridge.

Two and three lane tunnels can be satisfactorily lighted by one or more rows of luminaires along each side, located near the junction of walls and ceiling. For very narrow tunnels one row is sufficient, but this condition rarely is encountered except for entrance and exit ramps. When the structure exceeds three lanes in width the usual practice is to provide supplemental rows of luminaires on the ceiling over the traffic lanes to provide additional illumination in the center portion of the tunnel.

Lighting designers perfer to locate the lighting equipment near the sides of the tunnel whenever possible to facilitate maintenance work and reduce the possibility of accidental damage to surface mounted luminaires.

The new mall tunnel now being built in Washington, D.C. will have a minimum wall-to-wall width of 66 feet to accommodate four lanes of traffic on each directional roadway. In some sections the width increases to over 80 feet where ramp connections occur within the structure. Because of the extreme width a maximum of nine longitudinal rows of fluorescent luminaires will be used for some zones of each roadway, with a minimum of five rows required for the main tunnel exit zone. All luminaires will be operated at maximum output during daylight hours and dimming controls are provided to reduce the illumination level during the night hours. In addition, some of the rows will be turned off at night to provide the relatively low illumination condition desired at that time.

Level of Illumination

A review of tunnel lighting in this country would not be complete without some comments concerning the prevailing levels of illumination. Limited amounts of test data are available which in most cases represent actual light measurements made in tunnels before the facilities were opened to traffic. It must be recognized that these data are for initial conditions and do not, therefore, represent the illumination which will prevail at any specific time in the operational life of the lighting system. Experience and common sense dictate that the light depreciation factor may be fairly high in many cases and dependent on the frequency and thoroughness of the cleaning and relamping program.

Based on the limited test information and on some engineering design calculations, it seems safe to say that maintained horizontal roadway illumination at night in many of the long tunnels constructed during the past six or seven years will range from a low of about 3 average footcandles to a high of about 20 footcandles, with a majority of the tunnels having from 5 to 8 footcandles. Roadway illumination in the zone of maximum daytime lighting will range from about 50 average footcandles to 100 average footcandles with most of the installations falling in the 50 to 75 footcandle category.

Brightness measurements have been made in a few tunnels but the available data are so limited that any conclusions which we might attempt to draw from these results would have little significance.

Sun Shields

There has been little application in this country of sun shields or louvres for gradually reducing the natural daytime brightness levels at tunnel entrance approaches. A system of this kind was installed a number of years ago at the original Caldecott Tunnel in California but the new tube of this tunnel which was completed about 1964 does not have sun shields. We are aware of two other tunnels in this country which have made limited use of sun shields, namely the Baltimore Harbor Tunnel and the two tunnels of the Chesapeake Bay Bridge-Tunnel Crossing. We recognize that there are valid objections which can be raised to the use of sun shields, two of which are the added initial cost and the problem of snow and ice accumulation in areas having severe winter conditions. Nevertheless, we feel that they should be considered as a means of reducing entrance zone lighting requirements, particularly where the tunnel approach roadways are depressed.

Underpasses and Short Tunnels

The decision to install fixed lighting in underpasses and short tunnels depends largely on the location and geometrics of the structure. In rural areas underpasses are not usually lighted. For structures longer than about 75 feet located in urban areas supplementary lighting is generally used, particularly when the outside roadway has night illumination. Urban freeways frequently have short tunnels varying in length from about 200 to 500 feet and it is normal procedure to install fixed lighting in these facilities, the lights being operated on a 24 hour schedule. In urban areas, lighting is usually necessary if an underpass has provisions for pedestrian traffic regardless of the structure length.

The development during recent years of low wattage mercury luminaires designed for wall mounting has resulted in a strong trend to these units for underpass and short tunnel illumination. Luminaires of this kind are commercially available from various manufacturers. The luminaires usually have prismatic glass covers for accurate light control and are so designed that the driver does not experience objectionable brightness at the necessarily low mounting height. They use either the 175 watt or the 250 watt lamp and are spaced as required to achieve the desired level and uniformity of illumination. Typical of new locations which will use these luminaires are two short freeway tunnels in Minneapolis, one 450 feet in length and the other 390 feet long. Some of the luminaires will use 175 watt mercury lamps operated on a 24 hour basis and supplemented during the daytime hours with additional 250 watt units. The calculated roadway illumination for daytime is 35 average footcandles maintained. The expected average to minimum uniformity ratio is 2:1.

Fluorescent luminaires have also been used for underpasses and short tunnels, mounted either on the walls or suspended from the overhead structure. Mercury luminaires suspended overhead have been utilized in some locations with satisfactory results, but their application is now quite limited. The long lamp life, good light control and low maintenance cost of the small wall mounted mercury luminaires are primarily responsible for their increasing popularity as preferred items for lighting underpasses and short tunnels.

Conclusion

Evidence exists that tunnel lighting in this country has improved somewhat in recent years as a result of the need to light many of the tunnels and underpasses on our expanding highway system. The authors believe, however, that there is a need for research to develop more definite lighting criteria and better equipment for tunnel illumination. A study of this kind, properly oriented, should be of considerable value.