A STUDY OF ARTIFICIAL LIGHTING IN RESIDENTIAL BUILDINGS

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ABSTRACT

A survey of night time artificial lighting was carried out in residential buildings to check the prevailing levels of illuminance and also the present practice in lighting design so as to evolve rational design guidelines regarding the number, location and mounting height of light point as well as the suitability of lamp wattages for different situations. It was observed that the lighting in homes is generally unsatisfactory due to inappropriate location of light points, inadequate wattage of lamps used and poor maintenance of lamps and reflectors. The work plane illuminance was found to vary from 10 to 100 lux whereas the required illuminance for any critical work has to be above 100 lux. The commonly used lamps in homes are 20 and 40 watt bare fluorescent tubes and 25, 40, 60 and 100 watt clear incandescent lamps with enamelled reflectors. The direct illuminance due to these lamps were measured in the laboratory and the inter-reflected illuminance was computed for different room sizes. The results of survey, laboratory measurement and analysis are presented in this paper alongwith recommendations for improving the lighting of residential buildings.

1. INTRODUCTION

Good artificial lighting forms an important aspect of the functional design of buildings. After sunset one has to solely depends upon artificial lighting for different activities in a building. An adequate level of lighting is required for performing any visual task with efficiency and ease. In residential buildings the common visual tasks are reading, writing, cooking, dining, conversation and circulation etc. The recommended values of illuminance for these tasks are given in the Indian Standard Code of Practice[1] for interior illumination under the category 'hotels, restaurants, shops and homes'. These are shown in Table 1 for relevant spaces in residential buildings.

TABLE 1

Recommended Illuminance Values for Different Spaces in Residential Buildings

Particular Spaces	*Illuminance Lux*
Study Room	150
Bed Room	100
Kitchen	200
Dining Room	100
Store Room	100
Bath Room	100
Toilet	100
Stairs	100
Corridor	70
Garage	70

For more exerting tasks such as sustained reading and sewing/darning the recommended illuminance values are 300 Lux and 700 Lux respectively.

A suitable provision of artificial lights for satisfactory performance of different visual tasks should be the aim of lighting design of residential buildings. It is a general experience that the artificial lighting in residential buildings is not based on any rational design consideration. The location and the number of light points are mostly decided arbitrarily. The occupants concern about the cost of lamps that they have to buy and the monthly bill of electricity which they have to pay seems to be the main reasons for the continuing provision of low wattage and use of incandescent lamps for lighting in homes. Earlier studies[2] have established that fluorescent tubes are economical in the long run and can provide higher level of lighting than incandescent lamps. There is a growing conciousness amongst users for improving the lighting in their homes. The use of fluorescent tubes for home lighting has an increasing trend now despite a much higher initial cost of fluorescent tube fixtures than incandescent lamps. Howerve, the information about adequacy of light in and the homes design guidelines to achieve the same are lacking. Attempts made in the recent part to provide

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general guidelines[3,4] for lighting of residential buildings are far from being practicable in this country, as the proposed solutions envisage several light points in any room with a much higher wattage for lighting than that being used presently. To investigate the problem of home lighting thoroughly, with the objective of bringing out rational and economic design solutions a research project has been taken up at Central Building Research Institute, Roorkee. A survey was carried out to study the present practice in artificial lighting of residential buildings. Measurements of illuminance due to incandescent lamps and fluorescent tubes commonly used in residential buildings were and in the laboratory to compare the results of survey with the calculated values. The data obtained from the survey of artificial lighting in homes and the measurements in the laboratory are presented in this paper. These data will enable the estimation of illuminance from commonly used incandescent lamps and fluorescent tubes for rooms of different sizes.

2. DETAILS OF SURVEY

A survey of artificial lighting was carried out in the staff quarters of CBRI, IRI* and UOR* and also in some private houses in and around Roorkee. Details of rooms, the number of light points and their location, mode of mounting and mounting heights, type of lamps and reflectors were noted in each case. Measurements of illuminance were taken after dusk in the evening with the help of a Lux Meter on a horizontal plane at 0.85 m above floor below the lamps, in the room centre and near the walls along the central lines. Illuminance levels were also measured on study tables and cooking platforms. Wherever, there were more than one lamps in a room the measurements were taken with individual lamps on as well as with all the lamps on. The wattage of lamps in use in different spaces were also noted down.

The maintenance condition of luminaires was categorised as good, medium or poor by visual assessment depending upon whether a luminaire was absolutely clean, yellowish or darkish in appearance due to dirt collection. The reaction of the occupants to general lighting of rooms was recorded as good, satisfactory or poor according to their subjective appraisl. The subjective preference of the occupants for all mounted and pendant type of fittings was also recorded.

3. LABORATORY MEASUREMENTS AND COMPUTATIONS

It was found from the survey that the most commonly used lamps in residential buildings are 20 and 40 watt bare fluorescent tubes and 25, 40, 60 and 100 watt clear incandescent lamps with enamelled conical reflectors. The actual illuminance due to these lamps was measured upto a distance of 3 m on a goniophotometric bench set in a dark room so that the measured values can be used to determine the direct illuminance due to these lamps for mounting heights upto 3 m. The measurements were made for new lamps after 100 burning hours. The reflectors used with incandescent lamps were also new and absolutely clean. The mains voltage was stablized at 220 volts for all these measurements. The measured values are therefore maximum direct illuminance for different distances at 220 volts under very clean conditions lamps and reflectors.

Inter-reflected illuminance in a room due to a light source depends upon the input flux of light, the room size and the reflectance of room surfaces. The methods of computing average inter-reflected illuminance in a room have been discussed in an earlier publication[5]. Here Arnd's[6] formula, which assumes the room as an integrating sphere with reflectance equal to the average of the room surface reflectances has been employed. The ceiling height, has been assumed to be 3 m and the common room size upto a floor area of 25 sq.m. have been considered, The luminous output[7] of incandescent and fluorescent lamps employed for the computation of the average Inter-reflected illuminance is given in Table 2.

TABLE 2

Lnminous Flux of Incandescent and Fluorescent Lamps

S.No.	*Lamp Type*	*Lamp wattage watt*	*Luminous Flux Lumen*
1.	Tungsten Incandescent (GLS)	25	220
2.	-do-	40	425
3.	-do-	60	720
4.	-do-	100	1380
5.	Cool Daylight Fluorescent Tube	40	2440
6.	-do-	20	970

The average inter-reflected illuminance due to these lamps has been computed for different room sizes assuming a reflectance of ceiling walls and floor as 0.7, 0.5, and 0.3 which represents white, off white and medium grey finish respectively. The reflectance of curtains on doors and windows has been taken equal to that of walls.

4. RESULTS AND DISCUSSION

Important spaces which are common to almost all categories of houses are drawing room, bed room and kitchen. Where a living room and dining room is not provided the corresponding activities are formally carried out in bed room and kitchen respectively. Drawing rooms are generally used for casual reading and entertaining guests and therefore the illuminance requirement of drawing room should be considered as that of a study room. Mostly there is no provision of a separate study room in a house. Accordingly, a part of the drawing or bed room is used for studies. Sometimes the dining table is utilised for reading purposes.

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* *University of Roorkee.*

The range of workplane illuminance and the wattage of lamps employed in drawing rooms, bed rooms and kitchens as observed in the survey are depicted for a few cases in Figs. 1, 2, and 3 respectively. The use pattern of lamps of different wattage are given in Table 3.

TABLE 3

Percentage Distribution of the use of Different Wattages of Incandescent and Fluorescent Lamps in Drawing Rooms, Bed Rooms and Kitchens

Particular spaces	*Tungsten Incandescent Lamps*			*Fluorescent Tubes*		
	100 W	*60 W*	*40 W*	*25 W*	*40 W*	*20 W*
Drawing Room	30	20	15	0	30	5
Bed Rooms	46	30	12	0	12	0
Kitchens	27	40	27	6	0	0

Table 3 shows that the most commonly employed lamps are 100 W, 60W and 40W incandescent lamps for drawing rooms, bed rooms and kitchens respectively. 40 W fluorescent tubes are largely used in the drawing rooms. About 45% of the incandescent lamps were without reflectors and the tubelights were all bare fluorescent tubes. About 70% incandescent lamps and all the fluorescent tubes were found to be mounted on the walls and only 30% of the incandescent lamps were suspended from the ceiling. The mounting heights varied from 2.1 m to 3.0 m above the floor.

The levels of illuminance that are important for different activities in houses are 200 Lux, 150 lux, 100 lux and 70 lux as seen from Table 2. The percentage of cases in which the maximum workplane illuminance in drawing rooms, bed rooms and kitchens exceeded these typical levels are given in Table 4.

TABLE 4

Percentage Cases for which the Maximum Workplane Illuminance (E) Exceeded a Particular Value

Particular spaces	*E⩾200 Lux*	*E⩾150 Lux*	*E⩾100 Lux*	*E⩾70 Lux*
Drawing Rooms	NIL	31	33	73
Bed Rooms	NIL	NIL	7	45
Kitchens	NIL	NIL	13	20

From Table 4 it clear that in most cases the illuminance levels observed in homes do not satisfy the minimum requirement. None for the kitchens have the recommended illuminance of 200 Lux on the cooking platforms and only 13% of the drawing rooms satisfy 150 Lux on a table top 0.85 m above the floor level. Similarly, only 7% of the bed rooms satisfy the requirement of 100 lux. Even the level of 70 lux which corresponds to circulation activity is not satisfied in most of the cases. The level of illuminance in kitchens is found to be very poor which is also corroborated by the subjective reaction of the occupants.

The poor lighting levels observed in residential buildings are due to low lumen output and inadequate wattages of lamps employed, improper mountin heights and poor maintenance of lamps and reflectors. In view of desirable economy and energy conservation the Lumen method of design as given in the part I of the I.S. Code[1] is neither practicable nor advisable for residential buildings. A rational design approach for homelighting should be that of spot lighting of specific areas in a room where a particular visual task is most likely to be performed. The general illumination of a room should however, be such as to satisfy the brightness ratio of 1:10 of the general surrounds and the task. The measured direct illuminances that are possible at different distances below incandescent GLS lamps and fluorescent tubes are given in Fig. 4. The corresponding values of average inter-reflected illuminance, which represent general illuminance of the surrounds, are given in Fig. 5. It can be seen from Fig. 4 that a good level of lighting is possible when the mounting height approaches 1 m above the workplane. Since the mounting height of 2.1 m above floor has been observed in a few cases in the survey and it corresponds to the usual door height, it should be possible to easily adopt it in practice. For usual workplane of 0.85 m above floor and cooking platform of height 1.0 m the effective mounting height above these workplanes will be 1.25 m and 1.1 m respectively. The expected illuminance for an effective mounting height of 1.25 m above the workplane (or 2.1 m above floor level) is given for different wattages of incandescent lamps and fluorescent tubes for rooms of floor area between 10-15 sq. m. The calculated values are in good agreement with the available measured data. It may be seen that a 60 watt lamp and a 100 watt lamp will provide an illuminance of 70 lux and 150 lux respectively at a distance of 1.25 m from the lamp. The later will also provide an illuminance of 200 lux at a distance of 1.1 m from it. The Lumen output of these lamps will satisfy the required ratio of brightness between the task and the surrounds for floor area 10 sq. m. A 40 watt fluorescent tube will provide the same order of task illuminance as a 100 watt incandescent lamp, but the general illuminance due to fluorescent tube will be much better than that due to incandescent lamp. The provision of a fluorescent tube alongwith an incandescent lamp is desirable to avoid shadows due to direct light and also to increase the work area satisfying the illuminance requirement.

The location of light points should be in the vicinity of the fan because most of the activity areas are likely to be located near the fan. Where a single point is to be provided it should be along the centre of a longer wall. If two light points are provided they may be pendant type on either side of the fan along the room length or of centre on longer walls away from each other. However, the subjective preference was more for wall mounting than pendant type. In kitchens the direct light should be provided from a side wall to illuminate the cooking platform and a general light may be provided to mitigate the shadows. A study table should be located just below the lamp and a table lamp may be used for fine work.

5. CONCLUSIONS

1. Levels of lighting in homes are generally poor and are inadequate for cooking and study tasks.
2. Lighting of areas meant for specific visual activity in rooms can be improved by suitably locating the light points.
3. Workplane illuminance will be effectively improved by bringing down the mounting height to the level of door height.
4. The poor maintenance of lamps and reflectors is one of the major factors responsible for poor levels of lighting in residential buildings. Therefore a periodic schedule for cleaning of lamps and reflectors need be followed so as to wash in keep them absolutely clean.
5. White wash should be preferred over a colour rooms and kitchens.
6. Study tables should be located just below the lamps tables lamps need be used for fine work.

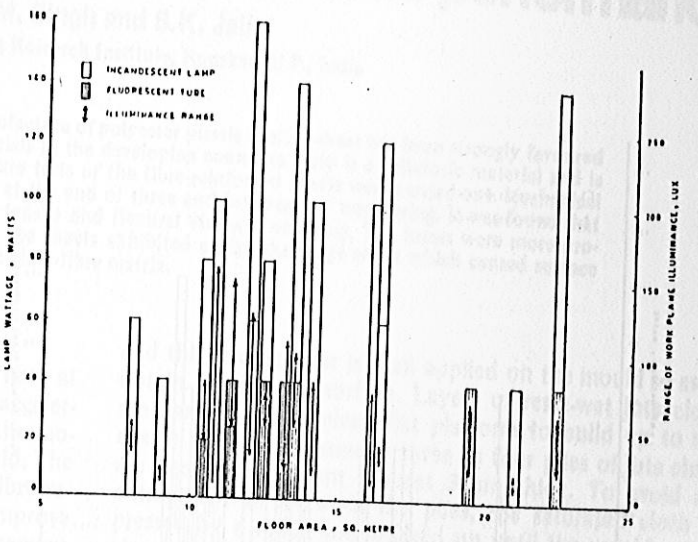

FIG.1 LAMP WATTAGE AND ILLUMINANCE RANGE IN DRAWING ROOMS OF DIFFERENT SIZES

ACKNOWLEDGEMENT

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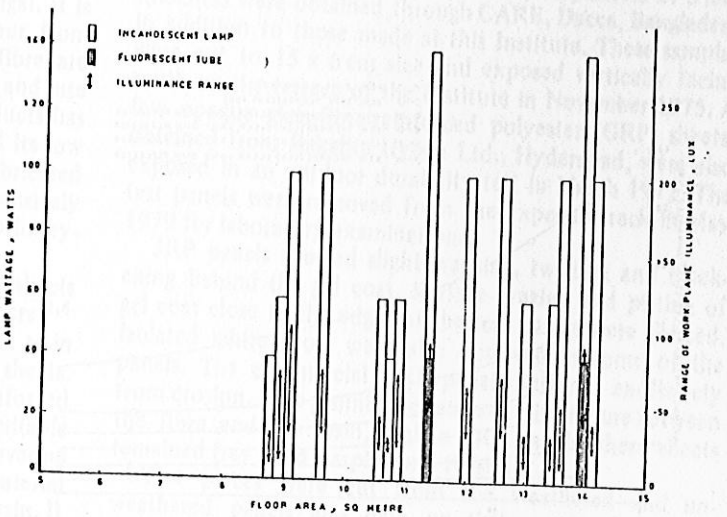

FIG.2 LAMP WATTAGE AND ILLUMINANCE RANGE IN LIVING ROOMS OF DIFFERENT SIZES

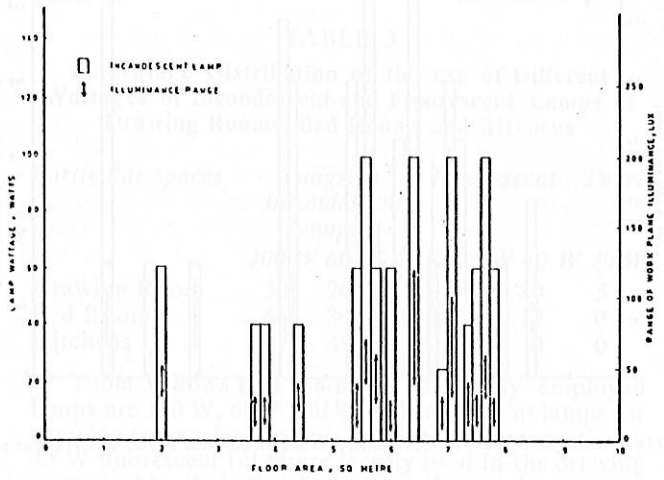

FIG 3 LAMP WATTAGE AND ILLUMINANCE RANGE IN KITCHENS OF DIFFERENT SIZES

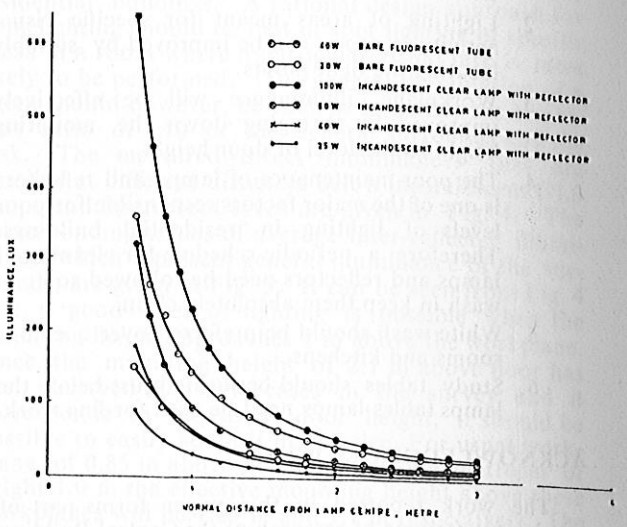

FIG. 4 MEASURED VARIATION OF ILLUMINANCE WITH DISTANCE FOR LAMPS COMMONLY USED IN RESIDENTIAL BUILDINGS

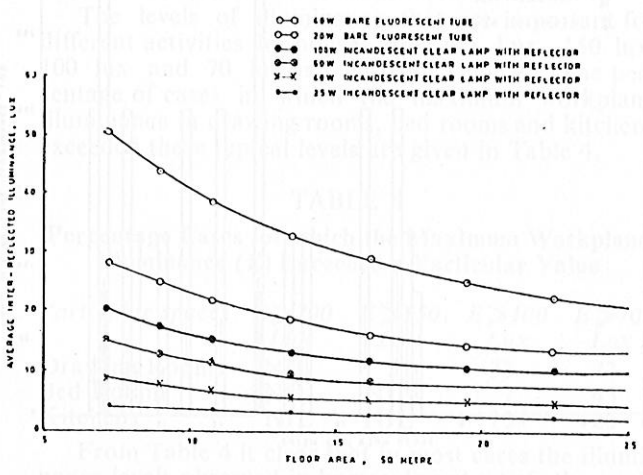

FIG. 5 COMPUTED INTER-REFLECTED ILLUMINANCE FOR ROOMS OF DIFFERENT SIZES

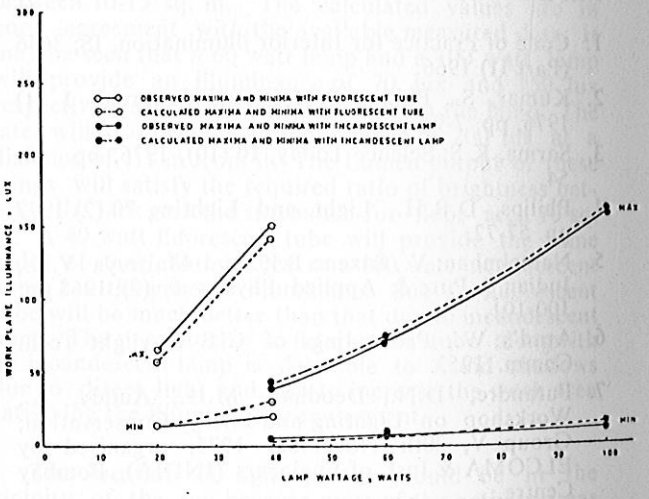

FIG. 6 ILLUMINANCE MAXIMA AND MINIMA FOR ROOMS OF 10 TO 15 SQ METRE FLOOR AREA