Estimation the performance of solar fiber optic lighting system after repairing the glass Fiber Cables in a South Korean Residential Building

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ABSTRACT

The solar fiber optic lighting system consists of the solar ray concentrating apparatus, the tracking control, lighting transmission and emission parts. This system was installed on a 20-storey apartment building in South Korea. Many residents had concerns about its long-term maintenance. The most common maintenance difficulties are sun tracking problems and damaged glass fiber cables. Sometimes fiber optic lighting systems should not be repaired with splices. Splicing glass fiber cables often results in decreased system efficiency and further cable damage. In this study, the cost of replacing the cables was prohibitive; hence, the drop in efficiency of the damaged cables was answered by repairing through splicing. These damaged cables were repaired by specially process of cutting and polishing. Results showed that the luminous intensity ratio improved by 0.391%, though this was still lower than the recommended guideline of 0.725%. Accordingly, on average 55% of luminous intensity was increased.

INTRODUCTION

The solar fiber optic lighting system consists of the solar ray concentrating apparatus, the tracking control, the lighting transmission and emission parts. The concentrating apparatus uses a Fresnel lens, whose focal point is the terminal of fiber optic lighting cable. Using total reflection, the cable transfers the concentrated solar lighting through the fiber optic cable. Fig.1 shows the schematic diagram of the solar fiber optic lighting system. The system's primary benefit is that natural solar lighting is more conducive to the health of the elderly, children, and hospital patients. A secondary benefit is that plants can be grown indoors and even underground.

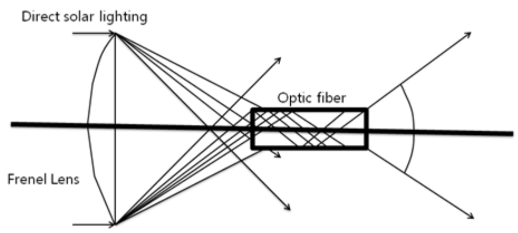


Fig. 1 The schematic diagram of the solar fiber optic lighting system

In 2002 this system was installed on the roof of a 20-storey residential building in South Korea. After a few years, many residents raised concerns about its long-term maintenance. The most common maintenance difficulties are sun tracking problems and damaged glass fiber cables. In the latter case, splicing glass fiber cables often results in decreased system efficiency and further cable damage. Thus it's generally preferable not to splice but to replace the fiber optic cable entirely. The practice of splicing exists solely as a cost-cutting measure. Table 1 lays out the problems with the lighting system and how they were addressed.

Table 1. Problems and improvements

Item	Problem	Improvements made
Body	corrosion, waterproof defectiveness	waterproofed the body
Dome	dust covered	cleaned
Lens	dust covered; deformed	cleaned; changed
Control box	inaccurate control	replaced sensors
Concentration part	inaccurate focus	adjusted focus
Transmission part	damaged optic cable	repaired (by splicing) the cable

The damaged cables in this study were repaired due to a drop in efficiency. They were not replaced due to budget limitations. These damaged cables were repaired by a special process of cutting and polishing. Before and after comparisons are made in section 4. Fig. 2 is a picture of the solar ray concentration apparatus and the dirt covering it. Fig. 3 shows the body's corrosion due to its being constructed from steel. Fig. 4 shows the sensor installation for the sun tracking.

Fig. 2 Dirty of Concentration part

Fig. 3 Corrosion of the body


Fig. 4 Exchange of sensors


Fig. 5 Cleaning inside

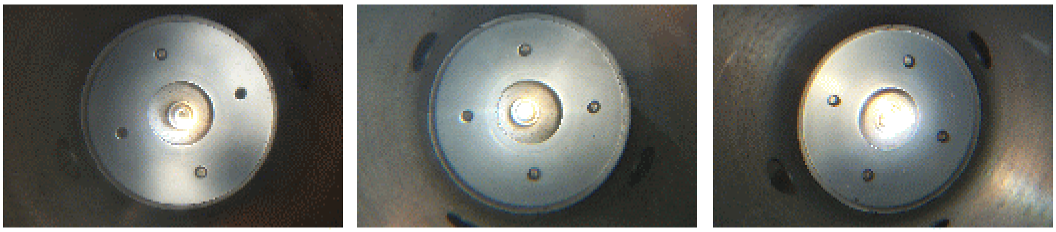


Fig. 6 Sample of focusing shape at the terminal of cables in concentration part

EXPERIMENTAL METHOD

The experiment was performed in May of 2003 (5/16 - 5/30) in Seoul, South Korea. The equipment used in this experiment were the following: illuminance meter (IM-3), outdoor illuminance sensor (ML-101S), indoor illuminance sensor (Ml-101S-I), luminance meter (LS-100), pyrheliometer/ sunshine duration meter (MS-091), pyranometer (NP-62), spectrometer (CA-1000).

Fig. 7 shows the apparatus for recording the weather data. Fig. 8 shows the apparatus for measuring the luminous intensity distribution in a residence. After repairing the system we measured two points of luminance intensity; one was 0.5m beneath the emission point and the other is 1.2m from the floor. Simultaneously we measured the outdoor luminance intensity, so we could get the ratio of indoor and outdoor values. We also measured the light brightness on the ceiling, walls, and floor.

Fig. 7 Weather recording apparatus

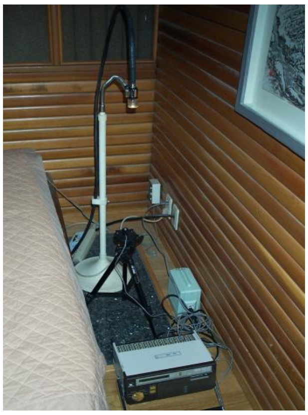


Fig. 8 Apparatus for measuring luminous intensity distribution in a residence

REPAIRING WORK

We adjusted the focus of solar concentration. In cases where there was no increase in efficiency, we surmised there must be damage to the fiber optic cable. In such cases we looked for damage at the terminal and solar concentration points. When damage was observed the cables were repaired. In one cable there are about 42 glass fibers. If at least ten fibers showed signs of damage, the cable was repaired. Repair work can be seen in Figures 9-14. In Figure 14, the worker has ground off the end of the fiber optic cable and is splicing each fiber with a piece of stainless steel.

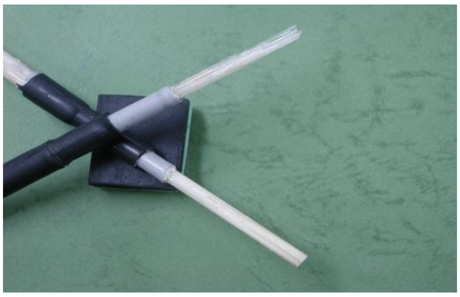


Fig. 9 Comparison of good and damaged cable ends (upper one is damaged)

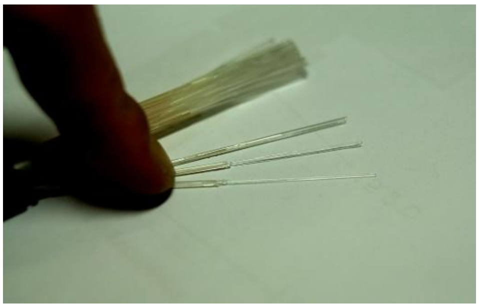


Fig. 10 Fiber Optic Cable has double covers

Fig. 11 Inspection of the status before repairing

Fig. 12 Checking line status before and after repair

Fig. 13 Attach cap at the emission part after repairing

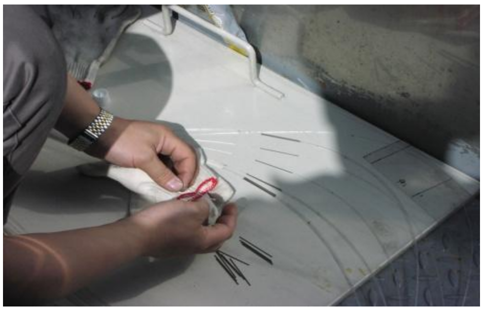


Fig. 14 Connecting individual fibers

RESULTS AND DISCUSSION

Wavelength and Luminous Intensity Distribution (Before and After)

Fig. 15 is a before and after graph of the wavelength distribution of the light emitted. The dark line on the graph indicates the wavelength following the repair. Initially, the wavelength shows a spectrum ranging from white to red. The visible rays are subdivided, according to wavelength, into red (750-620nm), orange (620-585nm), yellow (585-575nm), green (575-500nm), blue (500-445nm), dark blue (445-425nm), and violet (425-390nm). We find that light from the emission point falls mainly within the red spectrum; this is due to an improper focal distance at the concentration part. Fig. 16 displays, for one particular apartment, the distribution of luminous intensity from mid-morning to mid-afternoon. The left axis indicates the indoor luminous intensity while the right axis indicates that for outdoors.

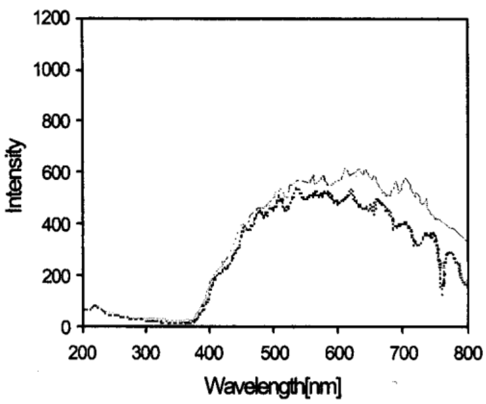


Fig. 15 Results of spectrum analysis

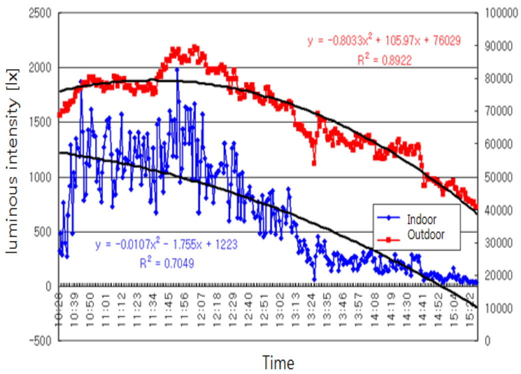
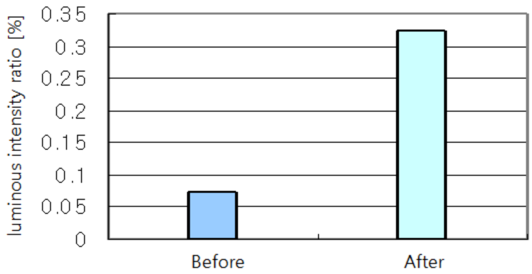


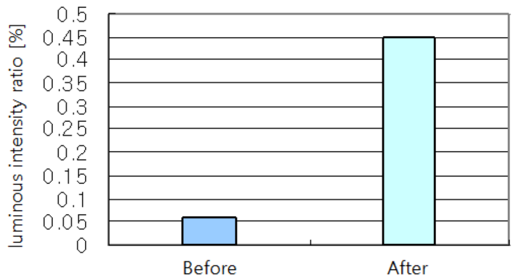
Fig. 16 Distributions of luminous intensity for indoor and outdoor (one sample)

Comparisons of Luminous Intensity Ratio Before and After Repair

Following the repairs, the luminous intensity ratio made it evident that an increase in efficiency had been achieved. And because of the now accurate focus, the color of emitted light shifted from red to white. Fig. 17 shows that the luminous intensity ratio before the repairs was between 0.06 and 0.07%; after repairs the value rose to between 0.323 and 0.447%. This is to say, the luminous intensity ratio increased at least seven-fold.



(a) Bottom floors (cable length is less than 50m)



(b) Top floors (cable length is less than 20m)

Fig. 17 Comparisons of luminous intensity ratio in winter season

Comparisons of Luminous Intensity and The Guideline Value

After repairs were made, the measured value of luminous intensity ratio, at 3 meters from the light source, fell short of the recommended guideline of 0.725%. The repairs, however, enabled a 55% increase in luminous intensity. By adjusting the sun-tracking apparatus the focal point on the cable terminal was 96% more accurate. Fig. 19 shows the average luminous intensity ratio of all rooms that were measured; the average of which was 0.391% compared to the recommended guideline of 0.725%.

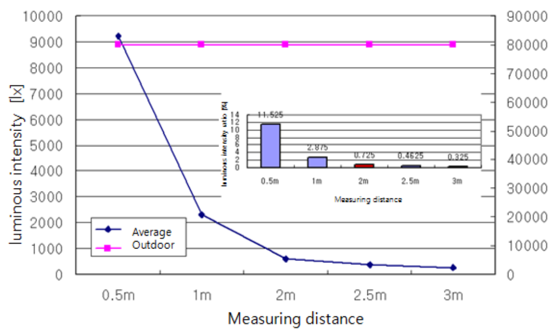


Fig. 18 Average luminous intensity guideline when outdoor luminous intensity is 80000lx

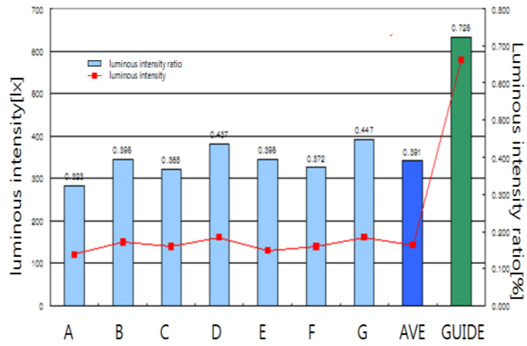


Fig. 19 Comparisons of luminous intensity ratio at sample house in winter season

Fig. 20 Lighting environment before repair

Fig. 21 Lighting environment after repair

Results of Brightness Testing

At enclosed residential room, from the surface under the lighting stand the brightness represents 21.2 cd/m^2 - 9.24 cd/m^2, at the walls the brightness represents 1.3 - 1.84 cd/m^2. This means that all areas satisfied the brightness index because all detected data were covered by the recommended guidelines. The guidelines give the following ratios: 1) at 1 meter the brightest luminous value has less than a 1:3 ratio to the dimmest luminous value and 2) at twice that distance the ratio becomes less than 1:10.

CONCLUSION

In 2002 we began repairing a fiber optic lighting system in a 20-storey building in South Korea. In 2004 we gathered all the experimental data from the last two years. Following repairs the efficiency of the fiber optic lighting system jumped 50%. Before the repairs the natural solar light entered indoor space using only 2 - 20 lines. After the repairs, such light entered using 38 - 40 lines. Due to the increase in quantity of solar light, the main wavelength entering the indoor space shifted in color from red to white. By enhancing the sun tracking's performance as well as the focal accuracy the luminous intensity ratio rose from 5% to 40%.

REFERENCES

Kribus, A., Zik, O. and Ka, J. 2000. Optical fibers and solar power generation. *Solar Energy Vol. 68, No. 5, pp. 405–416*

Li, D., Lam, J. 2000. Evaluation of lighting performance in office buildings with day lighting control, *Energy and buildings, 33 793-803*

Franzetti, C., Fraisse, G., Achard , G. 2004. Influence of the coupling between daylight and artificial lighting on thermal loads in office buildings, *Energy and Buildings 36 117–126*

Whang, A., Chen, Y., Wu, B. 2009. Innovative design of cassegrain solar concentrator system for indoor illumination utilizing chromatic aberration to filter out ultraviolet and infrared in sunlight, *Solar Energy 83 1115–1122*

Feuermann, D., Gordon, J., Huleihil, M. 2002. Light leakage in optical fibers: experimental results, modeling and the consequences for solar concentrators, *Solar Energy Vol. 72, No. 3, pp. 195–204*

Feuermann, D., Gordon, J. 1999. Solar fiber-optic mini-dishes: a new approach to the efficient collection of sunlight, *Solar Energy Vol. 65, No. 3, pp. 159–170*

Feuermann, D., Gordon, J., Huleihil, M., 2002. Solar fiber-optic mini-dish concentrators: first experimental results and field experience, *Solar Energy Vol. 72, No. 6, pp. 459–472*

Yin , L., Huang, H., Chen W., Xiong, K. Z., Liu, Y.C., Teo, P.L., 2004. Polishing of fiber optic connectors, *International Journal of Machine Tools & Manufacture 44 659–668*

Schlegel, G.O., Burkholder, F.W., Klein, S.A., Beckman, W.A., Wood, B.D., Muhs, J.D., 2004, Analysis of a full spectrum hybrid lighting system, *Solar Energy 76 359–368*

Kandilli, C., Ulgen, K., 2009. Review and modeling the systems of transmission concentrated solar energy via optical fibres, *Renewable and Sustainable Energy Reviews 13 67–84*

Han, H., Kim, J. T., 2009. Application of high-density daylight for indoor illumination, *Energy xxx 1–13*