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EFFECT OF DUST ON THE OPTICAL PROPERTIES OF GLAZING MATERIALS OF SOLAR COLLECTORS: A CASE STUDY

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Abstract*- Interest in renewable energy resources, particularly in solar energy resource, is increasing day-by-day around the globe. Therefore, solar power plants are more often being installed in arid, desert-like areas, where the solar irradiance is very high, but the land could be rarely used for other purposes. Solar energy is either transmitted through glass cover of a solar panel or a solar heater, or reflected by mirror or concentrator of a concentrating solar collector. Therefore, the overall energy performance of a solar collector directly depends on the optical performance of the glass or mirror of the collector. An experimental investigation is currently underway on the rooftop of the EME building of CUET to find a year-round effect of dust and dirt on glass transmittance and mirror reflectance. The finding will facilitate to calculate the energy potential of a certain solar collector at the location. Regardless the orientation of the glass and mirror samples, the investigation, so far, shows that dust and dirt cause an adverse effect on their actual optical properties.*

Keywords: renewable energy, solar collectors, dust effect, optical efficiency

1. INTRODUCTION

Interest in renewable energy resources, particularly in the solar energy resources, around the globe is increasing day-by-day. In order to get high solar irradiance, most of the solar power plants in the USA, the UAE, Australia, North Africa, Saudi Arabia, Chile, and India, are being installed in arid and desert like areas [1]. Solar energy is either transmitted through glass cover of a solar panel or a solar heater, or reflected by mirror or concentrator of a concentrating solar collector. However, soiling or scaling from local dirt and dust on these optical materials', glass and mirror, surfaces could have detrimental effect on their optical performances, which, ultimately could reduce overall energy performance the collector. Depending on the location and its environment, typical dust particles are sized within 10 µm [1]. The effect of scaling on mirror reflectance or glass transmittance was investigated by many researchers all over the world.

Richard Pettit et al. [2] recorded 6.5% to 24 % reflectance losses for silvered glass mirrors. They recorded the solar averaged specular reflectance loss to be 0.78±0.04 times higher than that measured at 500 nm light spectrum for the same mirror. After 33days of observation, J. Hee et al [3] measured that the average transmission of a plain glass was reduced from 90.7% to 87.6%; while that of the upper and lower halves of the glass were reduced to 88.7% and 87.9% respectively. Hottel and Woertz [4] in Boston, Massachusetts, examined the effect of dust accumulation on a 30° tilted solar panel in an industrial area near a four-track railroad for three months. An average of 1% loss of incident solar radiation was resulted from accumulated dust on its surface, while the highest degradation was observed to be 4.7%. In Iran, Tehran, Soleimani et al. [5] found that polluted air covered the surface of a PV panel and obstructed the sunlight that resulted in more than 60% reduced power output of the panel. A study by Kimber et al. [6] in California, United States indicated that soiling on large grid-connected PV panels in rainless dry weather could reduce energy efficiency on average 0.2% daily, and 1.5% to 6.2% annually depending on the location of the PV plant. M. Vivar et al. [7] measured 9%, 11% and 64%cumulative transmittance loss due to soiling in the first, second and third consecutive months respectively. However, an average loss in transmittance and reflectance was recorded 20% from soiling on PV panels. In Abu Dhabi, UAE, Tahboub [8, 9] reported nearly 100W photovoltaic energy drop because of dust accumulation on the PV on a single day in April 2009. When the test PV was not cleaned, about 15% drop in energy per month could occurred [10].

Soiling by dust and sand in arid and desert-like areas is a serious issue that affects the efficiency of solar plants. The deposition of dust in these areas is high and it can be increased by night dew as the dust and sand sticks to wet surfaces. At the day time the accumulated dust dries out and baked on by the sun and the next night more accumulates on the dew-damp surface, and the process repeats until the formation of a thick layer of dust block the sun completely. So the system fails in transmitting or reflecting radiant energy effectively, and the collector efficiency reduced significantly. That is the reason dust build-up is the greatest technical challenge facing a viable solar industry. Therefore, the foregoing literature demonstrates the negative effect of scaling on mirror reflectance and glass transmittance for a certain location. The selected site for this investigation is the roof-top of EME building of CUET, Chittagong. Such study, by the author's best knowledge is the first time in Bangladesh.

2. METHODOLOGY

2.1 Test facilities

2.1.1 (20+2) Glass and mirror samples

For this experiment 22 pieces of 10×10 cm^2 glass and mirror samples were cut from their respective large sections. Two pieces of the glass and mirror samples are stored carefully in the laboratory that are used as reference samples, and the rest of the cut samples are used as the test samples. The loss of transmittance and the reflectance of the test samples are compared with that of the reference samples.

2.1.2 LASER lite

A lite is used as a source of LASER.

2.1.3 Lux meter

"Mastech" digital lux meter is used to measure the intensity of the incident light on the samples. It gives output in three ranges 0-1999, 2000-19990, 20000-50000 lux with 5% tolerance using one silicon photo diode with filter operating at 9V.

2.1.4 (2+2) Test samples exposers and carriers

Two timber frames, as shown in Fig. 1, were fabricated, which has four 45° inclined sides and one horizontal side. Each of the sides has two slots to hold and expose the test samples to outdoor condition at the investigation site.

On the other hand, in order to ensure precautious handling of the test samples between the laboratory and the investigation site during data collection, two timber carriers with ten slots each were fabricated as shown in Fig. 2.

2.1.5 Two dark boxes

Two dark boxes (boxes with top covers) were used for glass and mirror samples to collect data in dark condition. The schematic of the boxes are shown in Fig. 3 and Fig 4 respectively. There are slots to attach the LASER lite, Lux meter and the test samples inside the boxes. Top cover of the box ensures no interference between the Lux meter and the external light.

Fig. 1. A typical timber frame to expose the test samples at outdoor condition.

Fig. 2. A typical carrier to carry the test samples between the sample exposer and the laboratory during data collection.

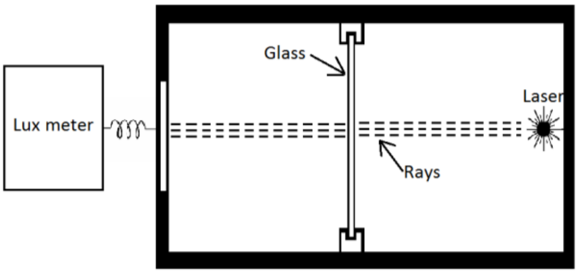

Fig. 3. Schematic diagram of experimental setup for glass transmittance measurement (top view)

2.2 Data collection and analysis techniques

All of the test samples are exposed to the environment using their exposers (see Fig. 1) on the roof-top of three storied EME building at CUET. Three sides of the building are surrounded by heavy greens, while the other side is exposed to a construction site of a new twelve storied academic building.

Data was collected for the last two months, and the weather was mostly rainy. It is ensured always that a certain side of the test samples is exposed to the environment to match the real condition. Every time of data collection, at first the transmittance and the reflectance of the reference glass and mirror are measured respectively, and treated as reference value for the respective test samples. Then the same properties of the test samples are measured and compared with the reference values. The properties are measured applying the techniques as shown in Fig 3 and Fig. 4 respectively inside the dark box.

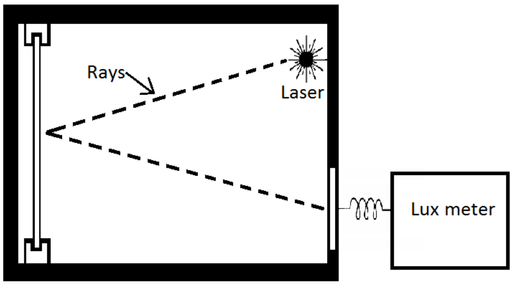

Fig. 4. Schematic diagram of experimental setup for mirror reflectance measurement (top view)

For instance, one glass test sample is placed inside the respective dark box (see Fig. 3) keeping the power connection of the LASER source and the lux meter at ON state. The intensity of the transmitted LASER is measured using the lux meter and recorded. Similarly two other data for the same sample is measured varying the LASER incident location on the sample. Average of these three data gives the transmittance of that particular sample. The transmittance of the test glass samples is normalized dividing the value by the same of the reference glass sample in order to calculate the percent reduction or loss in the transmittance because of dust or scaling on the test sample surface. Since, there are two test samples at each inclined or horizontal direction (see Fig. 1), a normalized transmittance of glass sample of certain direction at a certain day refers the average of six data altogether.

The process is repeated for all of the test samples and the reference glass to measure their transmittance. Similarly the normalized reflectance of the mirror samples is measured applying the technique as explained in Fig. 4.

Once the data collection has been accomplished, the samples are put back to their respective exposer immediately. The global and local orientations of each sample are kept identical to ensure continuity of dust accumulation on the same surface of each sample for the total period of investigation.

3. RESULTS AND DISCUSSIONS

The normalized transmittance of the glass samples, and the normalized reflectance of the mirror samples over time are plotted as shown in Fig.5 and Fig. 6 respectively. Critical analysis shows that the resultant transmittance and the reflectance profiles (or the loss patterns) are exactly the similar. Moreover there is no remarkable directional effect on these properties could be found, though a very marginal effect of dust on these properties could be seen for the horizontal test samples. However, the loss of glass transmittance was found more than 22%, while that of the mirror reflectance was found less than 20%. The reason of this less effect of dust on the mirror reflectance is attributed to the reflection of the LASER on the dust also. But in case of glass, LASER reflection on dust impedes the transition. Data fluctuation patterns for both of the transmittance and reflectance are the same, which is also attributed to the intermittent rain during the investigation. Rain washout and clean some of the dust from the test surface samples. However, without rain, the effect of dust may be cumulative and linear, and requires further investigation in dry seasons.

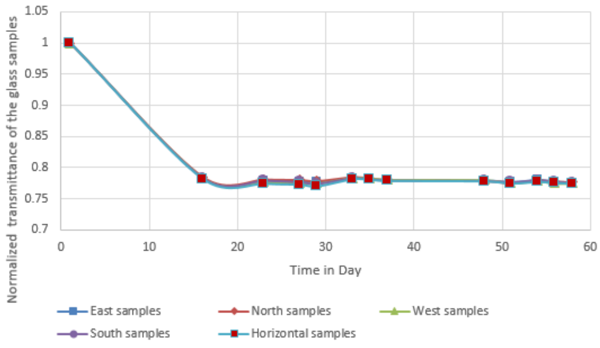

Fig. 5. Normalized transmittance of glass samples in consecutive days

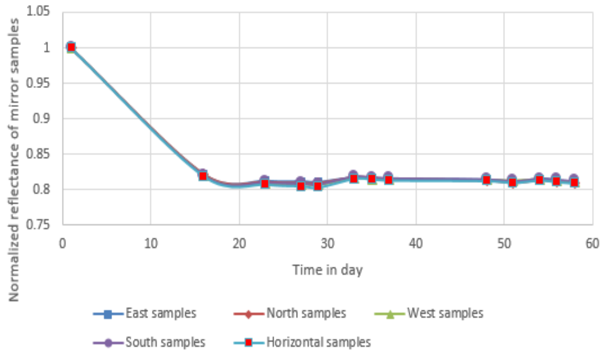

Fig. 6. Normalized reflectance of mirror samples in consecutive days

4. CONCLUSIONS

4.1 Summary

An experimental investigation is currently underway to develop a local year round profile or loss pattern of glass transmittance and mirror reflectance because of dirt and dust at CUET in order to calculate the solar energy potential of a certain solar collector. The glass and mirror test samples are placed at outdoor condition. The process is reviewed overtime, and the data is collected periodically. The findings of this project are as below:

- The reflectance of mirror sample is decreased to 81%, and the transmittance of glass sample is decreased to 78% with respect to their reference samples. That is the reflectance loosed by 19%, and the transmittance by 22%.
- The transmittance and the reflectance profiles or their loss patterns because of the dust are exactly the similar.
- Lower loss in mirror reflectance over the glass transmittance is attributed to the reflection of light (here the LASER) on dust particles.

- The fluctuations in the profiles are attributed to intermittent rain during the investigation.
- The effect of dust on the horizontal test samples is found marginally higher than that of the inclined samples. Otherwise, there is no effect could be seen because of global orientation of the test samples.

As a significant effect of dust on the optical properties of the glazing materials (glass and mirrors) of solar collectors could be found, it is strongly recommended to clean the surfaces of the materials periodically to achieve natural optical efficiency followed by the overall energy efficiency of the collectors.

4.2 Limitations and further research

Coincidently the presented data in this article is collected at rainy season, and the actual effect of dust could not be found. Therefore, data is still collected to see the yearly effect of dust on the optical properties of the glazing materials.

The LASER is extremely intensive than the visible light. So, the accumulated dust on the tested surface may cause local effect to the used LASER instead of an average effect as it would be seen with ordinary visible light. Therefore, a LED torch as a visible light source is now being used instead of LASER in measuring optical properties of the test samples.

Currently there is no radiometer available to measure the energy intensity of the transmitted or the reflected light. Instead an available lux meter is used to measure the light intensity.

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