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Study of Optimum Inward Glass Tilt Angle for Window Glass in Different Indian Latitudes to Gain Minimum Heat into Buildings

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Abstract

Modern buildings use glass materials for building enclosures. Extensive use of glass in building envelopes increases the heat gain, which in turn increases the energy demand to maintain the building at comfortable conditions. This paper presents experimentally measured spectral optical properties of four different glass materials such as, clear, bronze, green and reflective glasses. The solar optical properties were computed using spectral optical properties. The effect of inward glass tilts to gain minimum heat into buildings for different latitudes of India with four different glass materials for energy efficient glass window design was studied.. The optimum glass tilt for different Indian latitudes such as, 9^0, 13^0, 17^0, 21^0, 25^0 and 29^0 in all orientations of the window glass (E, W, N, S, NE, NW, SE and SW) were computed. From the results it is observed that at 9^0 and 17^0 N latitudes minimum heat gain is found to be in south direction for the vertical position of all the glasses. For 13^0 N latitude, 4^0 inward tilt of the glass is observed to be optimum in south direction. For latitudes 21^0 and 25^0 N, 2^0 inward tilt of the glass is efficient in south orientation. 29^0 N latitude requires an inward tilt of 6^0 for glass materials to eliminate solar radiation passing through the glasses in south direction.

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Keywords: green glass; optimum glass tilt; spectral optical properties; solar optical properties

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Nomenclature			
α_s	Solar absorptance	$\Delta\lambda$	wavelength interval (nm)
α_λ	Spectral absorptance	τ_s	Solar transmittance
		τ_λ	Spectral transmittance

1. Introduction

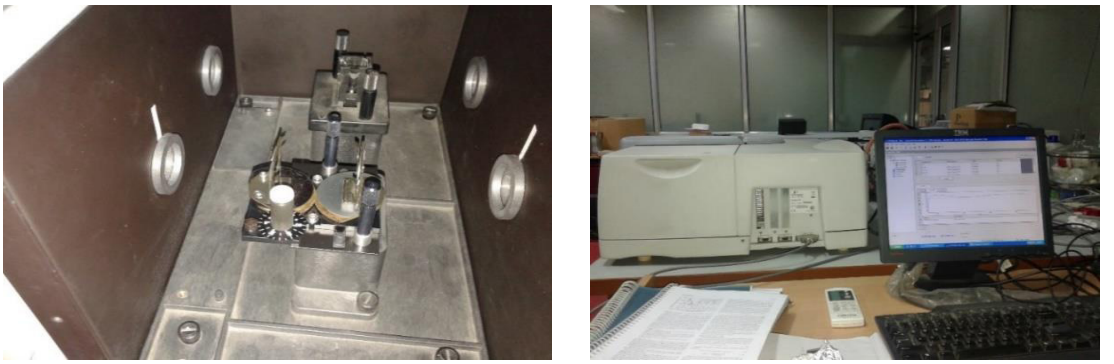
Buildings are responsible for about 40% of total energy use in the world [1]. With the recent boom in the construction sector, there has been a sudden increase in energy consumption, especially in countries like India. Glass has been a major building component for commercial buildings. Glazing is the opening to provide visual interaction between outdoor and indoor environment. Glass is used in building envelopes to provide day lighting either side lighting using windows or top lighting using sky lights. Earlier, radiation passing through clear glass for Delhi climatic conditions was reported [2]. Glass window affects the building not only in terms of heat transmission, but also in terms of thermal comfort. Most of the solar radiation enters into the buildings through windows only. Solar radiation through windows depends upon solar optical properties of the glass materials used for the window. Earlier, researchers have also concentrated on numerical computations of design of windows to reduce solar radiation into the buildings with clear and brown glass materials [3] and the evaluation of thermal and optical properties of glazing [4]. The present study focuses on the effect of inward glass tilt on direct solar radiation passing through the four different glass materials (Clear, Bronze, Green and Reflective).

2. Experimental methodology for spectral optical properties of the glazing materials

The Perkin Elmer Lambda 950 Spectrophotometer experimental setup was used to find the spectral optical properties of different glass materials [5]. To assess the quantity of direct solar radiation entering inside through windows, spectral optical properties of glass materials are required. The experiments were conducted with four different glass materials of thickness 6 mm at different angle of tilt of the glasses from 0^0 to 80^0 and at various angle of incidence wavelengths ranging from 320-2500 nm. The spectral optical properties such as Transmittance, Absorbance and Reflectance of clear, bronze, green and reflective glass materials were measured using a Perkin-Elmer Lambda 950 Spectrometer as shown in Fig.1 (a). The data for transmittance and absorptance at corresponding wavelength are obtained using UV-Win lab software in PC interfaced with the spectrophotometer as shown in Fig. 1 (b). From the measured spectral data, the solar optical properties are determined using the British Standard method [6]. These spectral optical properties were used to evaluate the solar optical properties and to evaluate the direct solar radiation passing through glazing at different Indian latitudes [7,8,9]. The solar transmittance and absorptance factor for single glazing can be evaluated from the relation as follows.

$$\tau_s = \frac{\int_{320}^{2500} S_\lambda \tau(\lambda) \Delta\lambda}{\int_{320}^{2500} S_\lambda \Delta\lambda} \quad (1)$$

$$\alpha_s = \frac{\int_{320}^{2500} S_\lambda \alpha(\lambda) \Delta\lambda}{\int_{320}^{2500} S_\lambda \Delta\lambda} \quad (2)$$



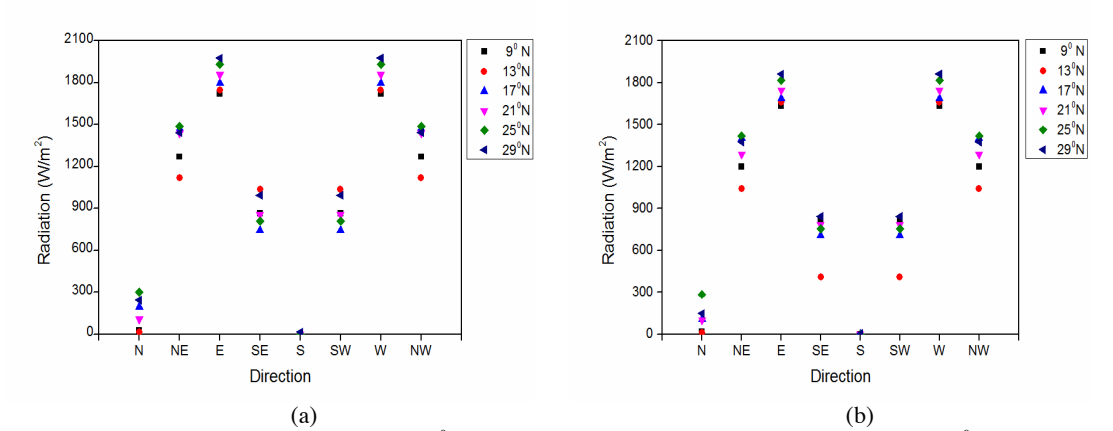
(a) (b)

Fig. 1. (a) Perkin Elmer Lambda 950 Spectrophotometer; (b) Spectrophotometer with UV Win Lab software

3. Results and Discussions

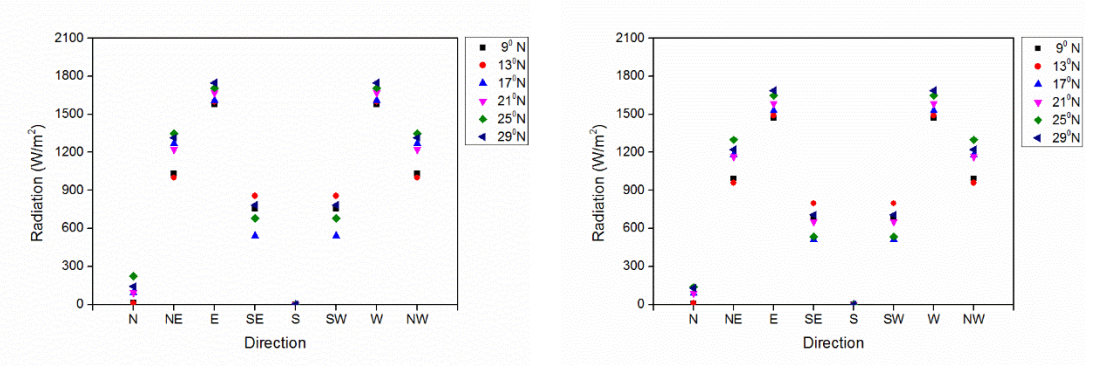
3.1 Effect of glass tilts on Solar Radiation through Clear Glass material

Referring to Fig. 2 and Fig. 3, it is observed that the solar radiation passing through the glass is reduced in south direction due to a higher angle of incidence in south direction. Solar radiation passing through the glass mainly depends upon Transmissivity of the glass, angle of incidence, tilt of the glass, position of the sun and latitude of the place. The more is the angle of incidence, the least will be the solar radiation passing through the glass material and vice-versa.



(a) (b)

Fig. 2. (a) Solar radiation through clear glass at 0^0 tilt from vertical; (b) Solar radiation through clear glass at 2^0 tilt from vertical

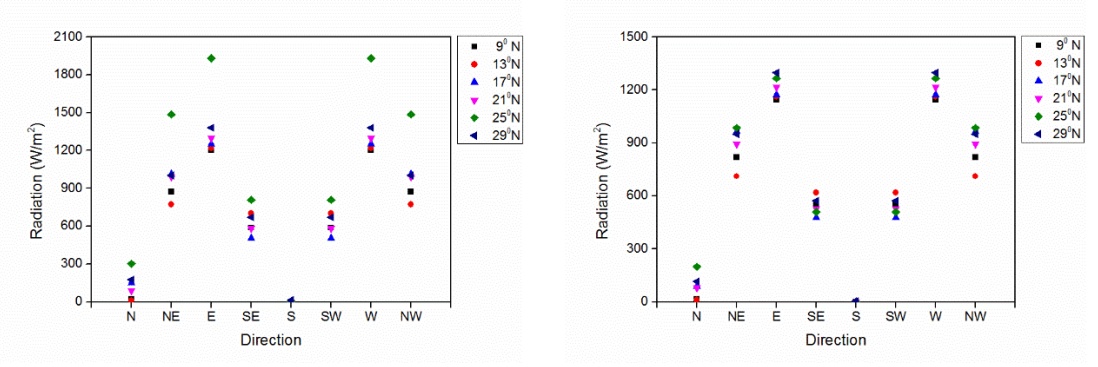


(a) (b)

Fig. 3. (a) Solar radiation through clear glass at 4^0 tilt from vertical; (b) Solar radiation through clear glass at 6^0 tilt from vertical

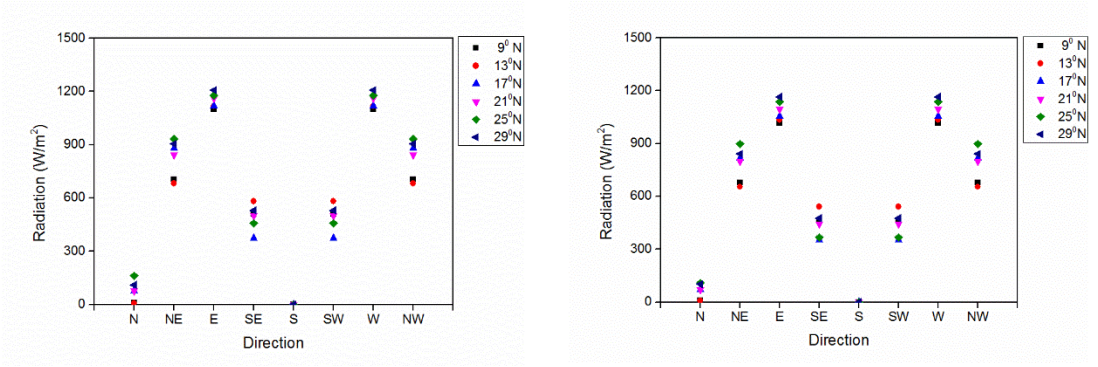
3.2 Effect of glass tilts on Solar Radiation through Bronze Glass material

From Fig. 4 and Fig. 5, it is observed that for bronze glass material the solar radiation passing through the glass is less than the clear glass in south direction due to its higher angle of incidence value compared to the clear glass.



(a) (b)

Fig. 4. (a) Solar radiation through bronze glass at 0^0 tilt from vertical; (b) Solar radiation through bronze glass at 2^0 tilt from vertical

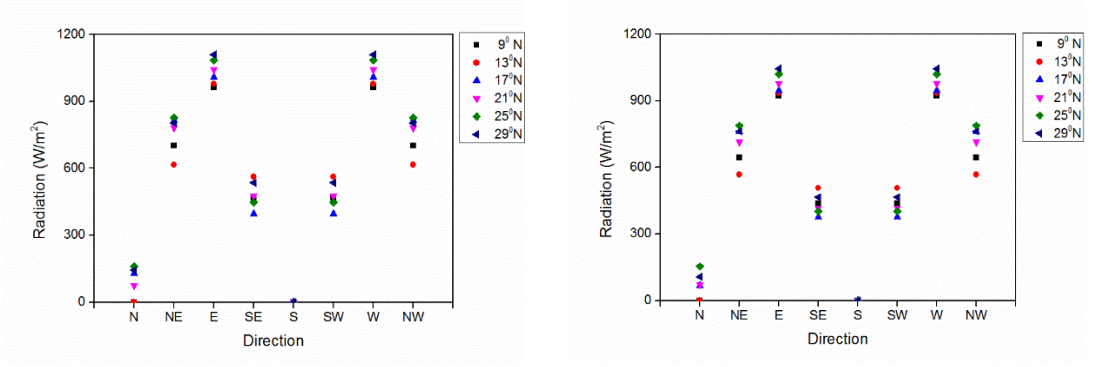


(a) (b)

Fig. 5. (a) Solar radiation through bronze glass at 4^0 tilt from vertical; (b) Solar radiation through bronze glass at 6^0 tilt from vertical

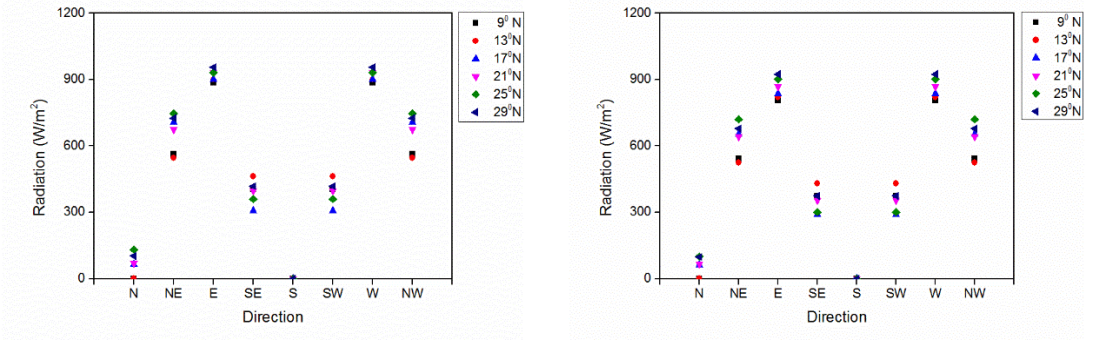
3.3 Effect of glass tilts on Solar Radiation through Green Glass material

Fig. 6 and Fig. 7 show that the solar radiation passing through the green glass is less in south direction than the clear and bronze glass due to its higher angle of incidence values compared to both clear and bronze glasses.



(a) (b)

Fig. 6. (a) Solar radiation through green glass at 0^0 tilt from vertical; (b) Solar radiation through green glass at 2^0 tilt from vertical

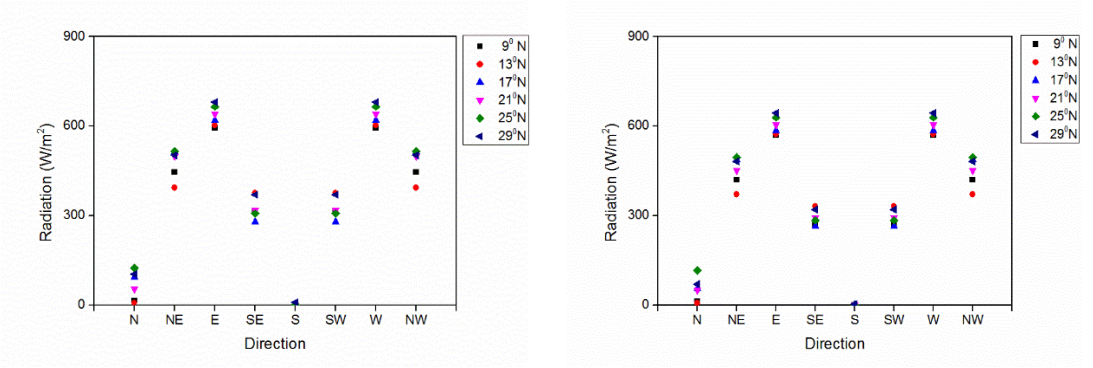


(a) (b)

Fig. 7. (a) Solar radiation through green glass at 4^0 tilt from vertical; (b) Solar radiation through green glass at 6^0 tilt from vertical

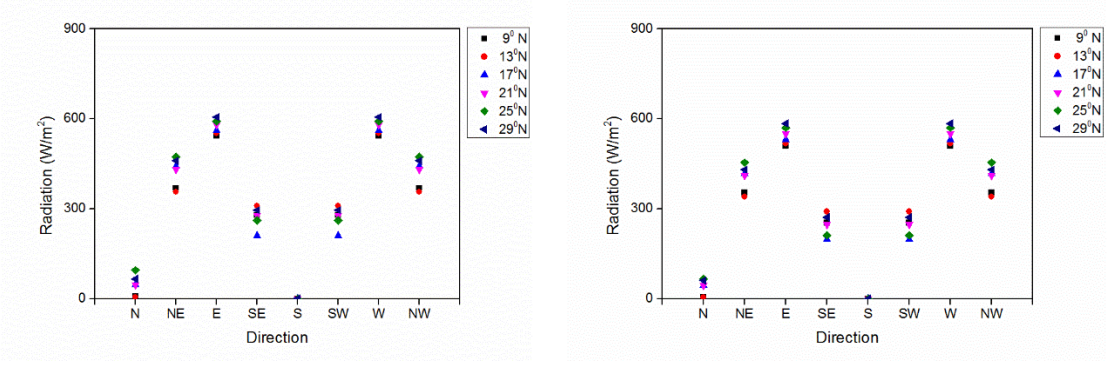
3.4 Effect of glass tilt on Solar Radiation through Reflective Glass material

Referring to Fig. 8 and Fig. 9, it is obvious that the solar radiation passing through the reflective glass is less than the any other studied glass materials (clear, bronze and green glasses) in south direction due to its highest angle of incidence compared to the other three glass materials (clear, bronze and green glasses). From the results it is clear that, for the vertical position of the glass at 9^0 and 17^0N latitudes, the solar radiation passing through the glass material is depleted in south direction. This is due to more angle of incidence in south direction. In 13^0N latitude, 4^0 tilt of the glass is required, In 21^0 and 25^0N latitude regions, 2^0 tilt of the glass is recommended and In 29^0N latitude places, 6^0 tilt of the glass is mandatory to avoid solar radiation through window glasses in south orientation. It is also suggested to place window glasses in North, South-East and South-West orientations after south orientation for reduced radiation through glasses. East, West, North-East and North-West are observed to be the worst orientations for placing glass windows for reduced solar radiation due to the lower angle of incidence.



(a) (b)

Fig. 8. (a) Solar radiation through reflective glass at 0^0 tilt from vertical; (b) Solar radiation through reflective glass at 2^0 tilt from vertical



(a) (b)

Fig. 9. (a) Solar radiation through reflective glass at 4^0 tilt from vertical; (b) Solar radiation through reflective glass at 6^0 tilt from vertical

4. Conclusions

The present research work to find the direct solar radiation through glazing at different Indian latitudes with different glass materials. It is observed that solar radiation passing through glass in south direction is minimum. After the south direction and it is also observed that the solar radiation passing through the glass is least in North, South-East and South-West directions, when compared to other directions. Among all the studied glass materials reflective glass material is the most energy efficient glass due to its lower solar optical properties. The following glass tilt angles are recommended for different latitudes: vertical glass location is enough for latitudes 9^0 and 17^0N, for 13^0N latitude, 4^0 tilt of the glass is required, In 21^0 and 25^0N latitudes, 2^0 tilt of the glass is recommended and in 29^0N latitude places, 6^0 tilt of the glass is mandatory to avoid solar radiation through window glasses in south orientation.

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