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"EFFECT OF HEIGHT AND TYPE OF ROOF ON AIR MOTION IN INDUSTRIAL BUILDINGS"

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Synopsis

Investigations concerning influence of height and shape of roof of industrial buildings on wind-induced air motion indoors are described. It is shown that height of industrial buildings with sky light type roof openings can be brought down to about 4 m (13 ft) without sacrificing much of the ventilation performance of the buildings. In case of factories devoid of roof openings air motion at working level is almost independent of the building height. It is also found that in comparison to flat roof buildings, pitched roof and sawtoothed roof-type buildings perform better in respect of air motion indoors.

Introduction

Provision of high ceilings in industrial buildings is necessitated due to two factors, viz. (i) to accommodate crane and other equipment employed in the industrial processes, and (ii) to reduce heat stress on the workers due to the radiation from the ceiling. When the industrial processes do not involve use of high equipment, the selection of ceiling height is governed by comfort considerations only. Therefore, it is desirable to examine the effect of ceiling height on the various parameters which have a bearing on the thermal comfort indoors. Earlier investigations pertaining to heat flow through roofs conducted at this Institute[1] have established that once the roof is insulated, lowering of ceiling height does not significantly affect the thermal conditions indoors. As air motion is a valuable contributor to thermal comfort, the present investigations were undertaken to determine the influence of ceiling height on air motion in industrial buildings with various roof types.

Experimental Set-up

The investigations were conducted on 1/30 scale models of industrial buildings. These models consisted of four bays each having 24 cm width and 96 cm depth. Five numbers of identical openings, each 3 x 5 cm were provided at 3 cm above the floor on the opposite walls of each bay. Thus the total area of wall opening was about 6.5% of the floor area. Four such models with sawtooth roof having 23° pitch and ceiling heights 10, 12, 14 and 16 cm were used to study the effect of ceiling height. The models were tested in the air stream of a low speed wind tunnel[2] (Fig. 1) used for studying ventilation problems. The windows on side walls were made to face the incident wind and the roof openings were always technical to the wind direction. The plane of observations coincided with sill level. Wind speeds were observed with the help of an omnidirectional hot wire anemometer at six symmetrically spaced points along the central line of each bay. To examine the influence of roof-shape, similar measurements were also made in 12 cm pitched-roof and flat-roof models having fenestration sizes and locations identical to those of the sawtoothed roof model. The study covered two cases, (i) without roof openings and (ii) with 3 cm roof opening running along the entire length of the bays.

Effect of ceiling height

The availability of air motion at a particular point in a building depends, in part, upon the wind forces acting on the air stream as it passes through the inlet opening, and, in part, on the volume of indoor air to be entrained. Both these factors are affected by the height of building. As such, the height of an industrial building has a bearing on the air motion at the working level indoors. Fig. 2 depicts the influence of building height on the distribution of wind speeds at normal working level in a sawtoothed factory building with no roof openings. It is seen that the air motion in the middle bays increases near the inlets with the increase in the height of the building. In other parts of the building, available wind speeds do not seem to change systematically with ceiling height. However, overall variation in available wind speeds is rather small for practical purposes.

Provision of openings in the roof lights also governs the development of air flow patterns indoors. In such a case, the effect of height on the distribution of indoor wind speeds is shown in Fig. 3. It is observed that as the ceiling height increases from 10 to 12 cm, available wind speeds increase almost over the entire working area. Further increase in ceiling height adds only a little to air motion at a few points indoors. To explore the overall effect of ceiling height, the average values of indoor wind speed were determined for the entire working area. It is found that (Fig. 4) air motion in buildings with openings in roof lights increases from say, 18% of outdoor wind speed, by increasing the ceiling height from 10 cm to 13 cm in models (these values correspond to 3 and 3.9 m in the actual). Further increase in ceiling height does not appear to produce appreciable changes in the average wind speed indoors. It is also found that when buildings are devoid of roof openings, the average wind speeds are not affected much by variations in ceiling height.

Effect of shape of roof

The wind flow patterns around buildings as also the development of wind pressures on various parts of the building envelope depend upon the shape of the roof. For a given building height, the volume of enclosed air also changes with the type of the roof. Therefore, the available wind speeds indoors are governed by the architectural design of the roof. Industrial buildings normally have sawtoothed, pitched or flat types of roof. A study of their influence for buildings with *no* roof openings (Fig. 5) revealed that available wind speeds in buildings with pitched and sawtoothed type roofs are almost identical over the major portion of the occupied zone. However, the velocities in flat roof buildings are found to be less in the windward half and higher in the leeward zone. It is also seen (Fig. 6) that lower wind speeds are achieved over a larger part of the working zone when the openings are provided in the monitor of flat roof buildings. The influence of shape of roof on average indoor wind speed is shown in Fig. 7. It is found that when openings are provided in roof lights, the air motion in pitched and sawtoothed type roof buildings is much higher than in a flat roof buildings. In buildings without roof openings, air motion is not influenced much with the shape of the roof. It is interesting to note that provision of roof openings as shown by earlier investigations also[3,4] enhances air motion in pitched and sawtoothed roof buildings, whereas such openings retard air flow in flat roof buildings. Similar effect of roof openings is also seen in case of sawtoothed building with height around 10 cm (Fig. 4). In these cases the reduction in indoor air motion is attributable to the fact that the resistance to air flow through roof openings diminishes as their height above the side windows decreases, consequently the outdoor air entering through the windows escapes through the roof opening. Thus the flow is short-circuited and major part of the working zone remains unventilated.

Conclusions

1. Air motion in buildings having openings in roof lights increases considerably with increase in the height of the building upto about 3.9 m; beyond that, effect on air motion is practically insignificant.

2. In buildings having no roof openings, variation in building height does not produce any significant change in the available wind speeds indoors.

3. For a given height, the available wind speeds in flat roof buildings are lower than those in pitched and sawtoothed roof buildings; in the latter cases wind speeds are nearly equal.

4. In flat roof industrial buildings with low ceiling height, provision of monitor roof openings results in reduction in air motion at working level.

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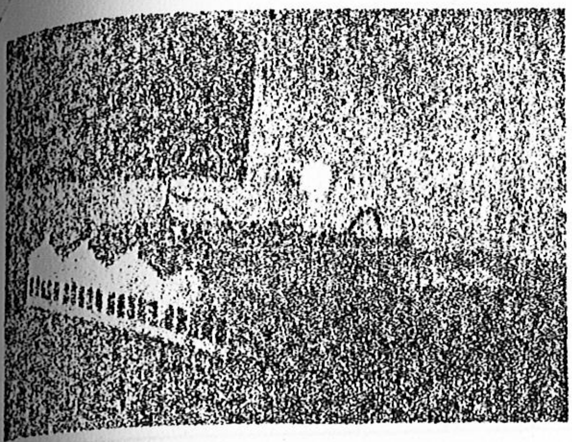


Fig.—1.

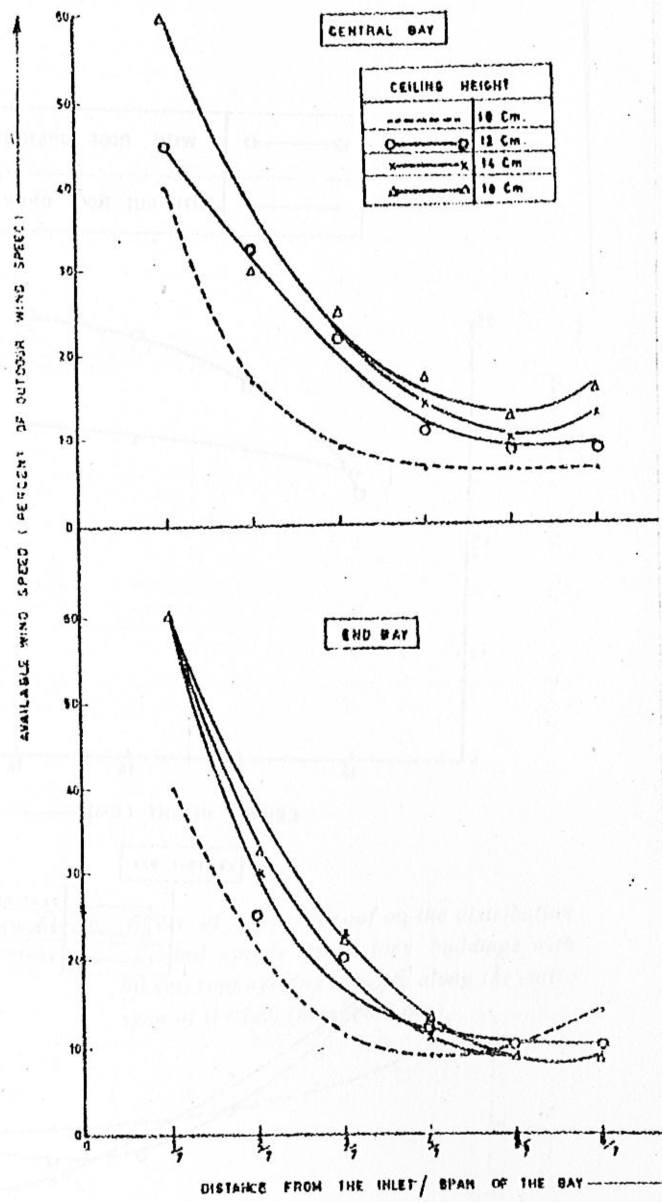
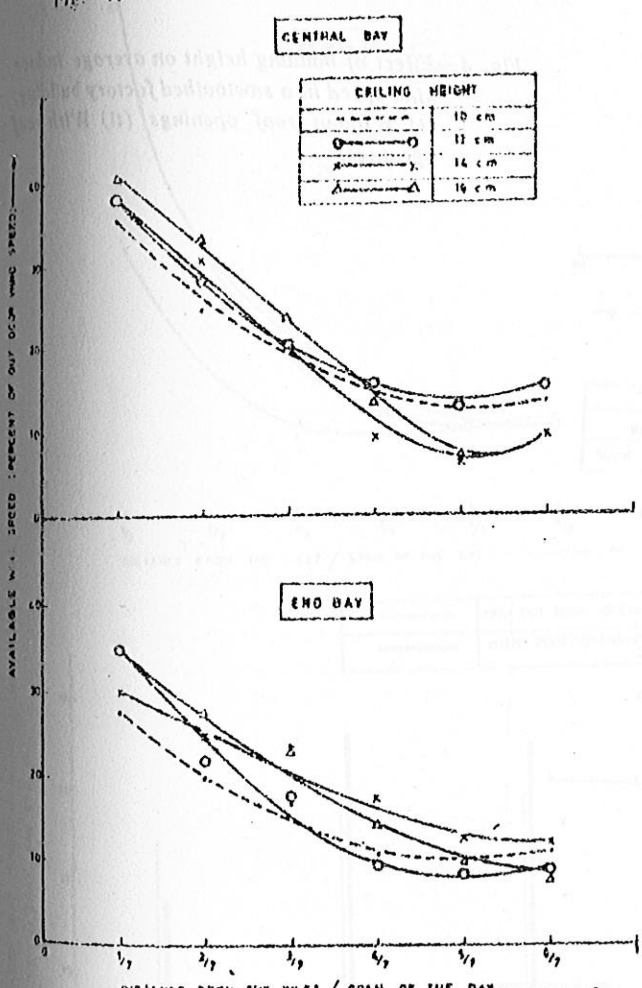


Fig. 3—Effect of height on the distribution of wind speed in a sawtoothed factory building with 90 cm. roof openings running along the entire span of the bay.



←*Fig. 2—Effect of building height on the distribution of wind speeds in a sawtoothed factory building with no roof openings.*

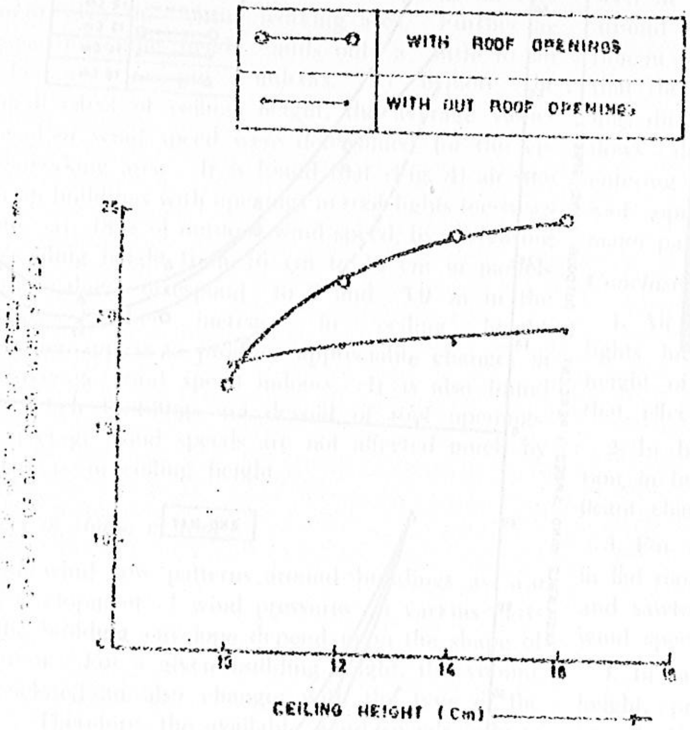


Fig. 4—Effect of building height on average indoor wind speed in a sawtoothed factory building: (I) Without roof openings (II) With roof openings.

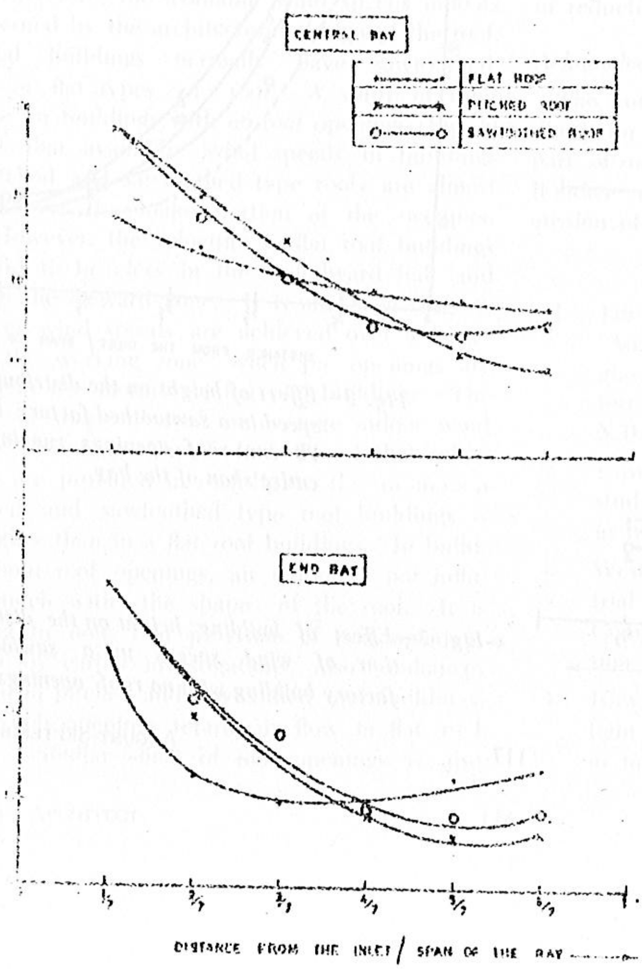


Fig. 5—Effect of shape of roof on the distribution of wind speeds in factory buildings with no roof openings (height=3.6m).

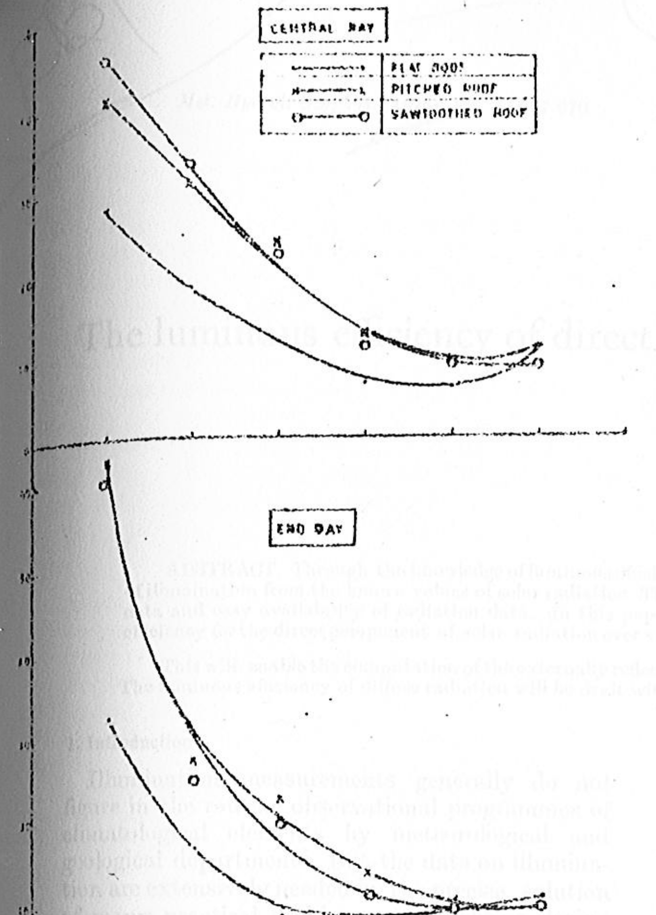


Fig. 6—Effect of shape of roof on the distribution of wind speeds in factory buildings with 90 cm. roof opening running along the entire span of the bay (height = 3.6m).

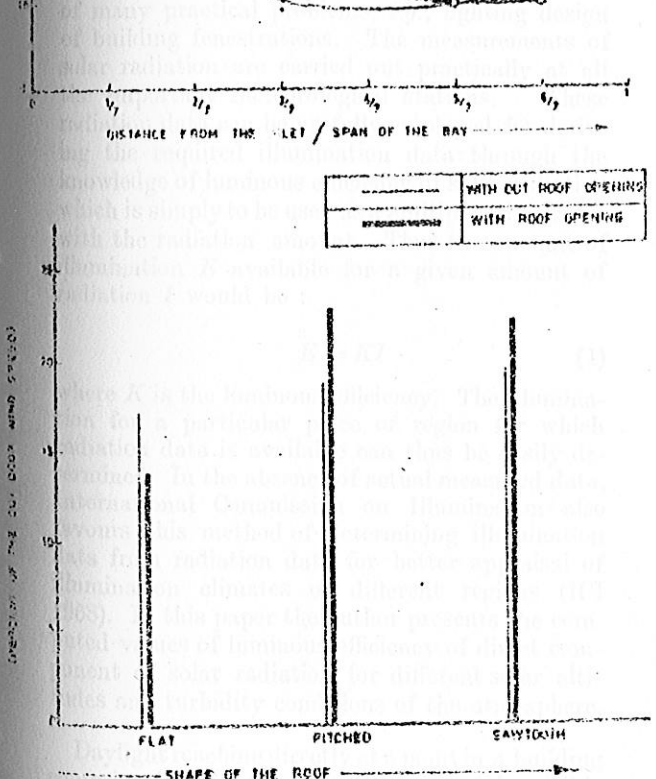


Fig. 7—Effect of shape of roof on average wind speeds in factory buildings (i) With no roof openings (ii) With roof openings.