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Better Utilization of Wind Through its Escalation over Dam

Dr N C Varshneya, *Non-member*

Dr Ishwar Chand, *Non-member*

This paper describes an experimental study of the flow profile of wind over escarpments, ie, over sloping dams. It is found that enhancement in wind speed atop the dam is maximum at levels close to half the height of the dam. If one envisages an earthen dam with 10 m height and 30° slope on the upstream side, and installs windmills on its top, then the wind speed for windmill operation will be 50 per cent higher than the speed reported as meteorological data at the same height without the dam; this amounts to 3.38 times enhancement in power generation. An example of rural wind power generation, making use of these results is described to illustrate how the construction and maintenance costs can be reduced to a great extent.

INTRODUCTION

Studies on flow of wind over hills, ramps and escarpments has been of interest to several investigators[1-3]. Their studies were generally aimed at collecting design data for estimation of wind loads on buildings and structures.

The present study was made in the context of wind-power. It was conceived that the wind, escalated over a streamline-shaped dam or an escarpment, following the Bernoulli's flow pattern, would get accelerated, and, since the power flow per unit area in wind is proportional to the cubic power of its speed, the power available for a windmill installed at the top of the dam will considerably increase. This method of using wind through windmills installed over an escarpment, therefore, should be a better and economical way to harness wind power, particularly in plains and rural areas.

Following this line of thought laboratory investigations were made on models simulating dams or escarpments which are feasible to construct under conditions prevailing in rural areas.

EXPERIMENT

The investigations were carried out on models in a low speed wind tunnel[4]. A rectangular model, 60×15 cm, and 5 cm high with longer side perpendicular to the air stream was mounted on the working table in the test chamber of the tunnel. Thus the flow of wind over the central portion of the model was almost two-dimensional. The slant surface of the escarpment was simulated by a piece of plywood sheet placed in an inclined position on the upstream side of the model. A micro-mini vane anemometer was used for wind speed measurements. Wind velocities were recorded at various heights in a vertical plane passing through the centre of the upstream edge of the rectangular model. Measurements were taken for 10°, 20° and 30° slopes of the inclined surface. Simultaneous record was also made of the velocities at equivalent heights over the flat surface.

RESULTS

The wind velocities obtained at different heights above the dam were expressed in terms of the corresponding available velocities at equal heights over a horizontal terrain. The variation of this ratio with the height expressed as a fraction of the height of the model is shown in Fig 1 which shows that in general, the winds over the escarpment are more than their values at corresponding heights without it, *ie*, in plain terrain. The typical enhancements (for a 30° slope) are 1.35 at the top level of the dam, increasing gradually upward. It reaches its maximum value at a height about half the dam height after which it again falls off. A windmill installed over the dam should therefore have its centre of vertical-extent situated at this height.

The effect of sloping angles of the escarpments on the acceleration of wind is also shown in Fig 1. There is a marked enhancement from 10° to 30°. But from 20° to 30° it is very small and beyond 30° (not shown) the effect is negligible. Thus keeping the economic considerations in view a slope of 30° should be considered as a good slope for design purposes.

The wind profile over a plain terrain is shown in Fig 2 (curve A). Usually, the value of the wind speed mentioned in meteorological data is its value at a height about 12.19 m (40′), and this value is taken into calculation for assessing wind power potential at the place in question. The actual gain in wind speeds due to escarpment should therefore be with respect to these values, Fig 2. It is seen that the actual maximum gain in speed by escarpment is 1.5, and therefore, the power gain is $(1.5)^3 = 3.38$.

Dr N C Varshneya is with University of Roorkee, Roorkee and Dr Ishwar Chand is with Central Building Research Institute, Roorkee.
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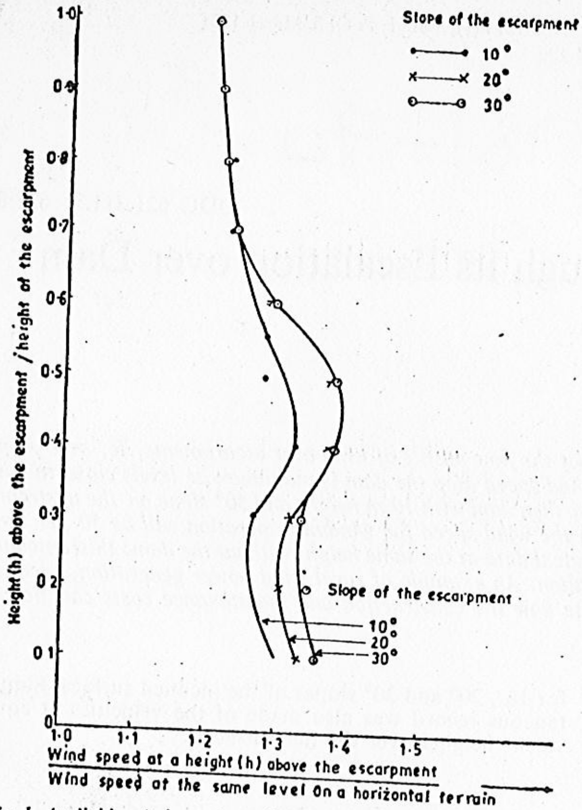

Fig 1 Available wind speeds at different heights over the escarpment

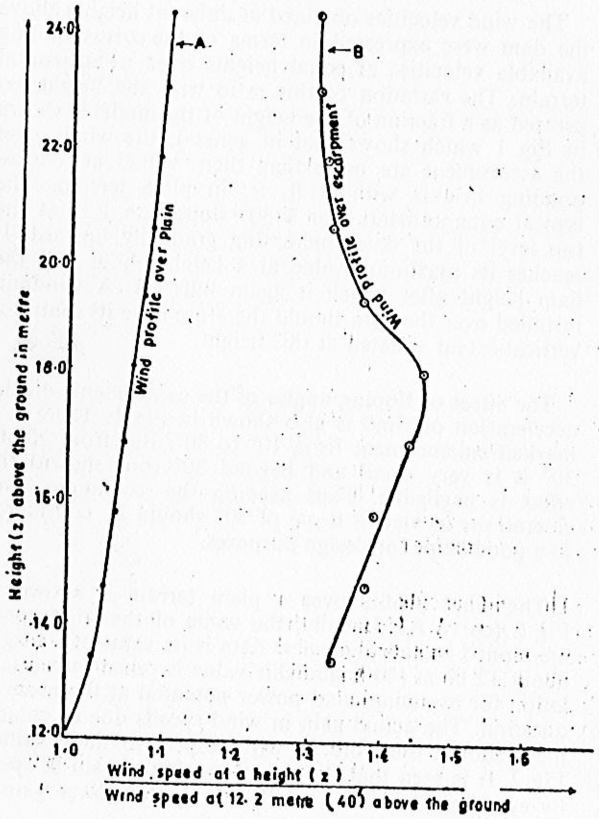

Fig 2 Wind speeds at different elevation

(A) Over plain ground

(B) Over an escarpment with 12.2 m (40') height and 30° slope on upstrean. side

APPLICATION IN WINDPOWER UTILIZATION IN RURAL AREAS

The incident wind power, P, on a unit surface area normal to its direction is

$$P = \frac{1}{2}\rho v^3 = 0.65 v^3$$

where ρ is the air density (1.3 kg/m³) and v its speed.

In wind applications, this power is converted into useful work through windmills either directly, say, by pumping water, or via conversion into electrical energy. With improved wind-mill designs, like Savonius S-rotor design and others, the efficiency of extracting work can be up to 40%.

The usefulness of the results of the experiment in better utilization of wind power, especially in rural areas, is illustrated by a typical example. It is supposed that the region under consideration is such that during the useful season, the wind keeps its direction and the dam is constructed to intercept it normally. A modest village of 500 families with ample flat terrain surrounding it is considered. The annual power requirement of this village can be of the order of 6×10^5 kWh. A single windmill, of wind-facing area of 80 m², running at an average wind speed of 5 m/s, and reckoning that the wind blows 8 hr a day, can generate about 7.5×10^3 kWh annually.

In practice, it is assumed that only about one-half the power requirement of the village is met through wind. Then 50 windmills should be installed; and, with the present practice, each windmill must be put on about 20 m high steel structure. The prospects of 50 such steel structures and 50 windmills is not particularly attractive if the construction costs are considered.

The experiment and results reported in this paper show that if an earthen dam of a typical 10 m height be constructed and windmills installed on it then, since the windspeed is enhanced by a factor of 1.5 and so the power by a factor of 3.38, only $\frac{50}{3.38} = 15$ windmills will now generate the same amount of power. These 15 windmills necessitate the 10 m high dam to have a span of about 160 m. Thus to generate the same amount of power the needs are not 20 m high, 50 steel structures and 50 windmills, but a 160 m span, 10 m high, 30° slope earthen dam and only 15 windmills. This reduces the construction and maintenance costs to a great extent. In Fig 3 the dam with windmills and the corresponding wind profiles are shown schematically. An actual project based on these considerations, if undertaken, can only prove fruitfulness of this study.

ACKNOWLEDGMENTS

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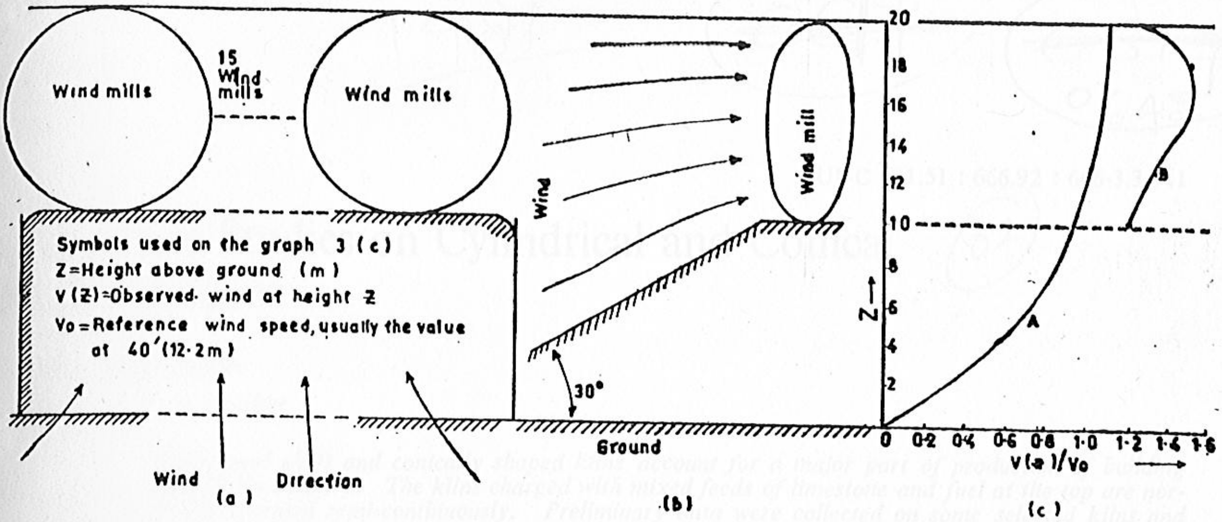

Fig 3 Schematic diagram of the dam (a) section perpendicular to the wind direction, (b) section along the wind, (c) wind profiles without dam (a) and over the dam (b)

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DISCUSSION

M C Johery (*Fellow*)

Has the proposed arrangement been tried at a prototype level ?

Ishwar Chand (*Author*)

It has not yet been tried. However, the proposal is under consideration for field trial at the University of Roorkee, Roorkee.