DISCUSSION

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This paper investigates the flow effects on an array of roughness elements projecting from a smooth surface into a turbulent boundary layer. The number of variables in this kind of study is large; for an element height \( H \), an upstream boundary layer height \( H_b \) and a fetch of roughness elements \( R \), the results are obviously affected by parameters such as \( R/H \) and \( H_b/H \) as well as the orientation and arrangement of elements in the array, and the upstream structure of the turbulent boundary layer.

To be applicable to low rise housing, the ratio of \( \delta/H \) should be in the range to 50 to 100, so that the present values between 2 and 5 make direct application impossible. As a more fundamental study, the res its will be affected by the shape and structure of the upstream boundary layer, particularly at low roughness density, and we have only this boundary layer's nominal thickness \( \delta \). The use of \( R/H = 14 \) for all tests is questionable, particularly at low densities, as the authors point out. However the overall picture which emerges, division into isolated element, wake interference and skimming flow regimes, is very useful and helps to broadly categorize our knowledge of the complicated effects involved.

For low roughness density, the work of Dvorak [15] should be noted since it correlates other measurements over two-dimensional roughness elements. The work of Marshall referenced in the present paper, has been put into broader context in the later paper by Wooding, Bradley and Marshall [16], who also note the uncertainty in the von Karman "constant" used in all logarithmic laws.

Finally, for fully rough flow, usually taken as \( (U_*H/v) \approx 70 \), the viscosity is of no importance, essentially all the drag occurring on the roughness elements by pressure rather than shear forces. In the present studies, values of this parameter are above 500 so that the use of the viscosity in the plot of Fig. 11 is misleading. The problem arises because the other parameter \( \Delta U/U_* \) used in Fig. 11 is itself not appropriate for fully rough flow since it is dependent, by definition, on \( (H_0U_*/v) \). A more appropriate parameter here is a roughness function \( f(\lambda) \) used by Dvorak and defined by:

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\begin{align*}
 f(\lambda) &= \Delta U/U_* \frac{1}{\lambda} \ln \left( \frac{H_0U_*/v}{\lambda} \right)
\end{align*}
\]

This is independent of viscosity for the fully rough case.

Because of the growing variety of correlations, constants and parameters used to describe rough wall boundary layer results, a review of the best experimental data and analysis is urgently required for these fundamental flows.

Additional References


Authors’ Closure

The authors would like to thank Professor Gartshore for his interesting and helpful discussion of their paper. Some of the points he raises with regard to the values of the parameters used in the test series described in the paper have also concerned the authors, and further tests in a 1.2 \( \times \) 1.2 m wind tunnel, which are currently proceeding, should provide further definitive information. The aims of the current tests are not only to repeat some of the work in a more rigorous atmospheric boundary layer simulation, but to include variations of height, frontal aspect ratio and plan aspect ratio for three-dimensional element layout patterns.

Taking the particular issues raised by Professor Gartshore, the ratio of the physical thickness of the rough wall boundary layer to the element height is 9.5. While the authors would agree that this does not represent a literal scaling, it may well be considered for some purposes to be an acceptable compromise for wind tunnel testing purposes. This is particularly true in the case of the wake interference and skimming flow regimes, where it has been shown that the mean forces on the roughness elements are dominantly influenced by the growth of an internal layer over the particular roughness layout pattern and not the incident flow itself. With regard to the description of the incident boundary layers, the smooth wall flow has a power law index of 0.15 and the rough wall flow an index of 0.18. Professor Gartshore's comments on Fig. 11 are correct. This figure results from the inappropriate comparison of our data with the strong adverse pressure gradient data of Perry, et al. [2], [3]. The roughness function of Dvorak, \( f(\lambda) \), has been evaluated but does not indicate the trend of flow regime characteristics displayed by other parameters. A more complete description of the tests described in this paper can be found in Soliman.4

The authors welcome Professor Gartshore's call for a review of rough wall boundary layer flows.

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