ANNEX D

(*Clauses* 7.4.2.2, 7.4.3.2 *and* 7.4.3.3)

WIND FORCE ON CIRCULAR SECTIONS

D-1 The wind force on any object is given by:

$F = C_f A_e p_d$

where

C_f = force coefficient,

A_e = effective area of the object normal to the wind direction, and

p_d = design pressure of the wind.

For most shapes, the force coefficient remains approximately constant over the whole range of wind speeds likely to be encountered. However, for objects of circular cross-section, it varies considerably.

For a circular section, the force coefficient depends on the way in which the wind flows around it and is dependent upon the velocity and kinematic viscosity of the wind and diameter of the section. The force coefficient is usually quoted against a non-dimensional parameter, called the Reynolds number, which takes into account of the velocity and viscosity of the flowing medium (in this case the wind), and the member diameter.

Reynolds number, $Re = D\overline{V}_d/\nu$

where

D = diameter of the member

$\overline{V}_d$ = design hourly mean wind speed

ν = kinematic viscosity of the air which is 1.46 × 10^{-5} m^2/s at 15°C and standard atmospheric pressure.

Since in most natural environments likely to be found in India, the kinematic viscosity of the air is fairly constant, it is convenient to use $D\overline{V}_d$ as the parameter instead of Reynolds number and this has been done in this code.

The dependence of a circular section's force coefficient on Reynolds number is due to the change in the wake developed behind the body.

At a low Reynolds number, the wake is as shown in Fig. 16 and the force coefficient is typically 1.2. As Reynolds number is increased, the wake gradually changes to that shown in Fig. 17; that is, the wake width d_w decreases and the separation point denoted as sp, moves from front to the back of the body.

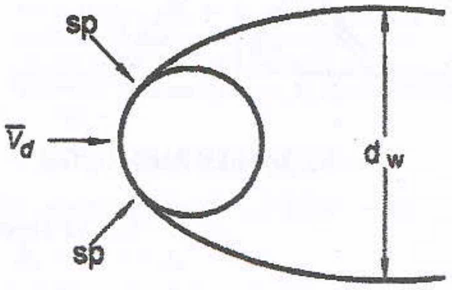

FIG. 16 WAKE IN SUB CRITICAL FLOW

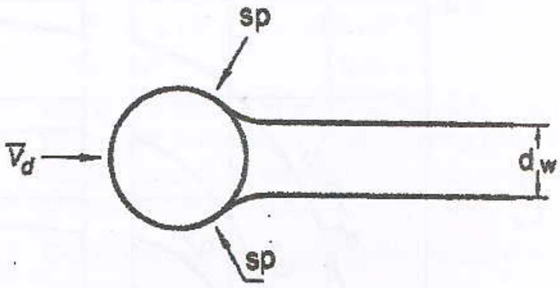

FIG. 17 WAKE IN SUPER CRITICAL FLOW

As a result, the force coefficient shows a rapid drop at a critical value of Reynolds number followed by a gradual rise as Reynolds number is increased still further.

The variation of C_f with parameter $D\overline{V}_d$ is shown in Fig. 5 for infinitely long circular cylinders having various values of relative surface roughness (ε/D) when subjected to wind having an intensity and scale of turbulence typical of built-up urban areas. The curve for a smooth cylinder (ε/D) = 1 × 10^{-5} in a steady air stream, as found in a low-turbulence wind tunnel, is also shown for comparison.

It can be seen that the main effect of free-stream turbulence is to decrease the critical value of the parameter $D\overline{V}_d$. For subcritical flows, turbulence can produce a considerable reduction in C_f below the steady air-stream values. For supercritical flows, this effect becomes significantly smaller.

If the surface of the cylinder is deliberately roughened such as by incorporating flutes, riveted construction, etc, then the data given in Fig. 5 for appropriate value of $\varepsilon/D > 0$ shall be used.

NOTE — In case of uncertainty regarding the value of ε to be used for small roughness, ε/D shall be taken as 0.001.

Refer extract 1 for Figure 5.