CHAPTER VI

CONCLUSIONS

The experiments were taken with three sizes of the Blaine's air-permeability apparatus having the manometer of 0.40 c.m., 0.80 c.m. and 2.0 c.m. inside diameter. The results from the experiment compared with the sedimentation method or typical value of soil[18] showed that the specific surface value obtained was independent of the dimensions of the u-tube manometer. The advantages of using different sizes of manometer were the ability to save the testing time in measuring the surface area of different sizes of soils. The coarse grained soil should be tested with the larger manometer and the fine grained soil should be tested with the smaller manometer. The Blaine's air-permeability apparatus should be used to measure the specific surface of soil from the range of silt size particles and over $(>5\mu)$. The accuracy of this method was in range of ± 5 %. The sedimentation method based on the assumption of particle diameter expressed as the sphere of the same density and falling velocity, defined by Stoke differs from the assumption based on the length of the cube's side of the same volume, defined by Andreasen. The Andreasen dimension was 0.8061 times the spherical dimension. In the range of silt size the Stoke's assumption was satisfactory but in the sand size range the Andreasen's assumption would give a close agreement with the experimental results. The specific surface value was independent of porosity when tested in the 'normal range' and the corrected specific surface should be accepted in this range. For uniform equi-dimensional particles the 'normal' porosity range was E = 0.40-0.50 and for non-uniform particles, it can be less and for acicular, platy or skeleted particles it can be considerably higher.

The gas adsorption techniques provide the best means for determining the total surface area of very fine particles but this method is not well suited to aprticle size above 1μ in diameter. In all cases, the area measured by the gas adsorption method was significantly larger than that measured by the air-permeability method. Part of the discrepency in the case of the finer particles may be explained by inadequate compaction of the permeability beds but this does not explain the results obtained with coarse particles. In some cases, there may be a real difference in the area measured by the adsorption and permeability methods. It is likely that some of the particles possessed an appreciable internal surface which was not measured by the permeability technique.

Table 3 Range for Best Application of Method[20]

Method	Range		
	Particle radius (u)	Surface area (m^2/gm)	Pore radius (u)
Liquid sedimentation	0.5-300	-	-
Air-permeability (Permeametry)	-	up to 10	100 and up
Nitrogen-adsorption	-	0.5and up	0.001-0.03

Recommendation For Future Study

When the mean free path of molecules of a gas is many times greater than capillary diameter[6] 'molecular flow' is obtained. This has been studied both theoretically and experimentally by Knudsen[10] (1950), who obtained the law

$$\frac{Q}{t} = \frac{8}{3}\sqrt{\frac{2RT}{\pi M}} \cdot \frac{A^2}{P} \cdot \frac{\Delta P}{L}$$

Further, it has been shown experimentally by Knudsen and also by others that when the ratio of mean free path to capillary diameter approaches unity and smaller values the rate of flow can be expressed in the form

Rate of flow = Poiseuille term + σ x Knudsen term

The dimensionless factor σ is a complex function of the mean pressure p, which has so far not proved susceptible to a theoretical treatment. The application of equation above to flow in porous media was first carried out by Adjumi[10] (1937) but he was unaware of the Kozeny equation for viscous flow in such media. Arnell[10,12] (1948) realized that the equation should take the form,

Rate of flow = Kozeny term + σ x modified Knudsen term

When the ratio of capillary diameter to mean free path is large, σ approaches another limiting value which is constant for a given system but which depends both upon the particular gas and upon the material of the capillary wall. Generally this limiting value lies between 0.7 and 0.9. If σ = 0.9 the modified Knudsen term take the form

$$\frac{Q}{t} = \frac{A\Delta P}{S_v LP} \, 0.96 \, \frac{E^2}{(1-E)}\sqrt{\frac{RT}{M}}$$

Substituting Kozeny term and modified Knudsen term in equation introduced by Arnell ( ), then

$$\frac{QLP}{tA\Delta P} = \frac{PF_1}{5\eta S_o^2} + \frac{0.96F_2}{S_o}\sqrt{\frac{RT}{M}} \qquad (12)$$

when $F_1 = \frac{E^3}{(1-E)^2}$ and $F_2 = \frac{E^2}{(1-E)}$

As above equation is a quadratic in S_o the direct solution would give a very clumsy expression for S_o. It was found better to break up the calculations from the experimental data into the following stages. First, if one ignores the slip term, a specific surface S_k is obtained, this being the 'uncorrected surface' obtained with the normal Kozeny equation,

$$\text{i.e.} \quad S_k^2 = \frac{tA\Delta P}{Q\ LP} \cdot \frac{F_1P}{5\eta}$$

Next, if the Kozeny term is ignored, a specific surface S_m is calculated, which would be the correct specific surface if pure molecular flow occured in the plug,

$$\text{i.e.} \quad S_m = \frac{tA\Delta P}{QLP} \; 0.96\, F_2\sqrt{\frac{RT}{M}}$$

Equation (12) now takes the form

$$1 = \frac{S_k^2}{S_o^2} + \frac{S_m}{S_o}$$

whence

$$S_o = \frac{S_m}{2} + \sqrt{\frac{S_m^2}{4} + S_k^2}$$

Now in the experiments of Pechukas and Gage[22] (1946) the pressure on one side of the plug (P_1) was atmospheric and that on the other (P_2) was usually small, while the volume measured was Q_1 (the volume at pressure P_1). Thus it follows that for most of their data

$$Q = \frac{Q_1 P_1}{P}$$

Replacing Q by Q_1 for the purposes of Pechukas and Gage method one obtains.

$$S_k^2 = \frac{tA\Delta P}{Q_1 L P_1} \cdot \frac{F_1 P}{5n}$$

and

$$S_m = \frac{tA\Delta P}{Q_1 L P_1} \quad 0.96\, F_2 \sqrt{\frac{RT}{M}}$$

The main advantage of modified Pechukas and Gage apparatus is that it is very simple, and gives direct readings of volume of air passing through the plug for very small rates of flow under a constant pressure-head. This method permits determinations for materials having mean surface diameters down to about 0.1μ. Therefore, most of clay minerals can be determined by Pechukas and Gage method and this apparatus should be developed to find the specific surface of more various soils than the ability of Blaine permeability apparatus.