PERMEABILITY AND SALT-FILTERING PROPERTIES OF COMPACTED CLAY

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EXTENDED ABSTRACT

The ability of some compacted clay materials to restrict the passage of sodium chloride relative to water when subjected to flow with sodium chloride solutions has been demonstrated by Kemper (1960) and by McKelvey and Milne (1962). Continued experimental work on this phenomenon, directed toward an understanding of the effect of variables such as the type of clay material, porosity, hydraulic permeability and solution concentration has been stimulated by the possibility that salt filtering occurs in the subsurface as a result of the movement of brines in response to compaction and other sources of hydraulic pressure.

The apparatus in which experiments have been carried out has been described in the paper by McKelvey and Milne. A clay sample, in the form of a dry powder or water slurry is compacted in a nylon-lined steel cylinder between monel pistons capped with porous monel filter discs. The piston-cylinder assembly is bolted between steel plates to maintain the compaction pressure.

The input piston has two openings, one of which enters a circular groove near the edge of the piston face while the other enters the center of this face. The second piston has a single opening at the center of the face. The two openings in the input piston permit a bypass circulation to carry away the salt rejected by the clay filter. Flow through the bypass is controlled by a suitable restriction in the bypass line beyond the input piston. The salt filtration efficiency in a particular case is expressed as the percentage of salt removed from a solution in passing through the clay filter. The concentration of the solution at the input face of the clay filter under flow conditions must necessarily rise above that of the source solution. Since the clay filter must be supported by a metal filter, this concentration is dependent on the efficiency of mixing and flushing within the pore space of the metal filter. Filtration efficiencies which have been, in practice, calculated from the concentrations of solutions emerging from the bypass and the throughput lines are likely therefore to be less than the true values. Certain experiments involving measurement of filtration efficiencies at various pressures and others in which salt has been accumulated in the input metal filter and finally flushed through the bypass system, have suggested that true filtration efficiencies are much higher than those which have been obtained from the concentrations of throughput and bypass solutions.

A sample of recent mud from the Mississippi River, compacted such that it contained 14 per cent water, has shown a filtration efficiency of 60 per cent with a 0.5 normal solution of sodium chloride and a decline to 30 per cent at a concentration of 5 normal. These filtration effects were obtained under a hydraulic pressure of 10,000 psi.

A mixture of bentonite from Clay Spur Wyoming and amorphous silica in equal parts by weight, compacted under 10,000 psi shows a filtration efficiency of 30 per cent in the 0.1 normal concentration range at relatively low hydraulic pressure (1000–2000 psi). The high water content probably explains the low efficiency. The efficiency is pressure dependent, declining to zero at 8500 psi.

A compacted mixture of bentonite and alundum powder in the ratio of 2: 1 by weight, with a water content of 16 per cent gives filtration efficiencies up to 70 per cent over a range of hydraulic pressures from 1000 to 10,000 psi. Maximum filtration occurs in the vicinity of 2000 psi. The decline in filtration at lower pressure undoubtedly involves the limit imposed on salt filtration by osmotic pressure. A pressure of approximately 700 psi is required to maintain a concentration difference of 1 normality unit across a perfect membrane. Thus with membranes which are imperfect, a decline in salt filtration would appear under lower hydraulic pressures. The high pressure decline cannot be explained so easily. It is possible that the flushing system at the input face of the clay filter becomes less effective at higher pressures and flow rates, but other explanations must be considered.

The permeabilities of these clay filters range from 10^{-5} to 10^{-7} md with the lower permeabilities corresponding with the best filtration effects.

Geological interest in the salt filtration problem is justified by the evidence that the process can occur in shale-forming materials but specific application in geological problems requires a quantitative understanding of the effects of the many variables which must be considered in the subsurface. Continued efforts in this direction can lead to an understanding of fluid flow in fine-grained rocks.

REFERENCES

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