

1 BACKGROUND TO PROJECT

Filtration is widely employed in the water industry, for the clarification of suspensions, the concentration of suspensions and the dewatering of sludges. In most instances, the cakes formed are compressible, i.e. it undergoes changes to its structure and properties during the filtration process. This can significantly affect the performance of the filter, as well as introduce seemingly spurious system behaviours. Accordingly it is necessary for workers in the filtration field have a knowledge of the mechanisms that determine cake compression and the effects that compressible cakes have on systems.

The design and optimisation of filtration systems would be significantly improved if the performance of the filter under different operating conditions and configurations could be predicted. This would be possible if the compressibility characteristics of the cake could be quantified and employed in appropriate filtration equations. The prediction of filter performance from sludge characteristics would also greatly assist in determining the effectiveness of sludge conditioners and coagulant aids, prior to implementing them on an operating plant.

Various sludge characterisation tests have been reported in the literature. However, the only test that seemingly enjoys a degree of application is the Buchner Funnel test. Although this can be used to obtain an indication of the relative resistance of a cake, it is inadequate in reasonably predicting compressible cake properties and filter performance. Other tests, e.g. the compression-permeability test and the settling test, are not widely employed, possibly due to contradictory claims regarding their validity as well as a lack of knowledge of how to perform the tests. The basic filtration equations are also rarely employed in optimising filtration systems. This could be due to the perceived difficulty in obtaining basic CPV data.

The aim of this study is to acquaint workers in the water field with the effects associated with compressible cakes, and to identify and develop methodology that would enable workers to characterise compressible cakes and predict the performance of large scale filters from laboratory tests and the basic filtration equations.

2 OBJECTIVES

The objectives of this project are as follows :

- (i) to investigate the mechanisms responsible for compressible cake behaviour,
- (ii) to investigate the effects that compressible cakes have on filtration systems,
- (iii) to investigate methods to characterise cake compressibility,
- (iii) to identify and develop models and equations to predict filtration performance for compressible cake systems.

3 REALISATION OF OBJECTIVES

The mechanisms responsible for cake compression in filters have been investigated. The major cause of cake compression in filters is hydraulic compression, where fluid frictional forces cause particles to irreversibly infiltrate existing void spaces, leading to a more densely packed cake of reduced voidage and permeability. As a result of hydraulic compression, solids compressive pressure, permeability and voidage profiles are established through the cake. Further, the resistance of the cake layers to fracture by axial shear forces also varies along the thickness of the cake. A major feature of hydraulic compression is that it is irreversible, i.e. once a layer in a cake is exposed to a higher pressure it maintains the consolidation appropriate to that pressure even if the pressure is subsequently lowered.

This hydraulic compression of the cake has various effects on the cake properties and the filter performance. These include the *skin effect*, where most of the resistance of the cake becomes confined to a thin skin adjacent to the filtration medium, an insensitivity to operating variables, and a sensitivity to the operating path taken to reach the operating point. This last aspect is of special significance in the control of filtration systems, since the filter *remembers* the worst conditions that it was exposed to and performs accordingly irrespective of subsequent operational changes to improve it. This dependence of the filters performance on the operational path is due to the irreversibility of hydraulic compression. Irreversibilities due to hydraulic compression were not previously comprehensively studied in the literature.

Methods to characterise the compression-permeability-voidage (CPV) relationships for a cake have been investigated. The theory, apparatus and experimental procedure for three characterisation tests were presented, viz. the compression-permeability (C-P) cell, the settling test and the centrifuge test. The tests were then performed on a waterworks clarifier sludge to determine their applicability and ease of implementation. All tests yielded results with meaningful trends. The results for the centrifuge tests were somewhat inconsistent with those of the C-P cell and the settling tests, calling the validity of that method into question. The repeatability of the settling test was good, but there was some scatter in the results obtained in the C-P cell tests.

The basic equations for planar, internal cylindrical and external cylindrical filtration were presented together with a solution algorithm. The equations for the internal cylindrical filtration of compressible cakes were not previously reported in the literature and were developed during the course of this project. The use of the equations was illustrated. The CPV data for the waterworks clarifier sludge was utilised to predict the performance of a planar filter and an internal cylindrical filter. These predictions were compared to results experimentally obtained on a bomb filter and the tubular filter press. A very good correlation was found between predicted and experimental filtrate fluxes and average cake solids contents. The predicted values are closer to the experimental values when only the CPV data from the C-P cell and the

settling tests are used, excluding the data from the centrifuge tests. Overall, the study indicated that a good prediction of filter performance may be obtained from employing sludge characterisation data in the appropriate filtration equations.

4 RECOMMENDATIONS

The results of the study indicate that the performance of filters may be reasonably predicted from basic sludge characterisation data. Recommendations arising from the study mainly concern methods to make these techniques more accessible to workers in the filtration field :

- (i) For various reasons, workers may not be able to accurately perform the sludge characterisation tests. However, most plants monitor the performance of their filters. The feasibility of extracting compression-permeability-voidage data from operation plant data should be investigated. The data may then be used in the optimisation of the operation of the plant.
- (ii) Even if the sludge characterisation data is available, the solution of the filtration equation requires numerical solution techniques that may not be readily available to workers. It is recommended that the solution procedures be coded into the form of a *user friendly* computer package which, together with a detailed Guide on sludge characterisation, should make the methodology developed in this study available to a wider audience.