asbestos-cement manufacturing technology

Formation of the elementary asbestos-cement layer during the process of filtration

based on work by Dr. **I. I. Berney** — part IV

In many processes of manufacture, filtration is only a means of dewatering the suspension and the solids retained by the filter are usually removed by scrapping or some other method, forming a shapeless mass; the interest is limited to the moisture content of the obtained product.

Asbestos-cement manufacture differs in as much as the end product is formed from a number of individual layers and their compactness depends not only on the moisture content but also on the structure of the delivered layer and the distribution in it of cement and fibres.

The asbestos-fibre/cement ratio in the layer depends on the properties of the asbestos-cement suspension and on the method of filtration and this relation will be examined in detail later; in the meantime the results of experimental work referred in table 4 should be examined as they are indicative of the influence of the average rate of filtration on the weight of the layer.

These experiments were carried out on the special filter described in No. 7/8 - 1968 AC/M, using the same suspension but pressures of 30 and 240 g/cm². It can be noted that when the rate filtration of is higher than 1 cm/sec., the delivered layers, with angles of inclination of the filter of 90° and 135°, have the same weight and an almost equivalent mean specific resistance; as the rate of filtration decreases, however, the weight ratio between layers obtained with angles of 135° and 60° respectively, drops while mean specific resistance of the layer obtained with angle of inclination of the filter of 135° increases, in comparison to that of the layer obtained at an angle of 60°.

The results of these experiments are particularly significant as they reveal an important fact i.e. the increase of the rate of filtration reduces considerably the structural instability of the layer and makes possible a better collection of the particles of the solid phase, during the process of filtration of asbestos cement suspension.

Examination of the data referred in tables 2, 3 and on graph fig. 15 (see AC/M Nos. 7/8-1968) and table 4 enables to determine the causes for which the structure of the layer is influenced by the method of filtration.

The influence on the process of filtration of the relation: rate of filtration/rate of sedimentation of the solid particles of the suspension.

Let us imagine that fig. 16 is a non rotating sieve cylinder immersed in the suspension for 3/4 of its diameter and connected to a vacuum pump; that agitation of the suspension is intense enough to prevent sedimentation of the solid phase in the bottom of the vat and to maintain uniformity of the concentration in all parts but not intense enough to wash off the sediment deposited on the surface of the sieve cylinder; that filtration is taking place at constant pressure for a determined time.

An imaginary line passing through the centre of the transversal section of the sieve cylinder, will divide the suspension into two parts, upper and lower (zones 1 & 2).

In zone 2, the suspension is kept in agitation by means of special agitators. The suspension thus agitated, batters against the walls and bottom of the vat and against the surface of the sieve cylinder moving disorderly in different directions.

When considering the «washing off» of a solid body by a turbulent flow, the existence of a boundary layer having a laminar flow, is admitted. Fluid velocity through this layer decreases as it comes in proximity

TABLE 4.

The influence of filtration of asbestos-cement suspension, on the specific resistance and weight of the layer.

	Filtration at pressure of 240 g/cm²					Filtration at pressure of 30 g/cm²				
Time of filtration t/sec.	1,2	2,15	3,11	4,08	5,12	1,05	2,07	3,03	4,03	5,01
Average rate of filtration cm/sec.	1,02	0,78	0,62	0,50	0,43	0,58	0,40	0,32	0,26	0,24
Average specific resistance of layer cm/g. ($\psi = 60°$)	373	760	1110	1090		195	260	312	330	
Weight ratio of layer obtained at angles of 135° and 60°	1,01	0,92	0,86	0,82	0,79	0,73	0,67	0,65	0,63	0,62
Average specific resistance of layer cm/g. ($\psi = 135°$)	390	850	1320	1350		280	394	490	534	

N.B. Composition of the solid phase of the suspension: Chrysotile asbestos grades 5 & 6. 50 % each: cement type 400. fineness of grinding: residue on sieve 4900 - 7,5 %. Solid phase composed by 13,5 % asbestos and 86,5 % cement (by weight). Concentration: 0,08 g/cm³.

to the solid body until it is equal to zero on its surface. If the surface of the moving in the liquid, solid body is a filtrating surface (as is the surface of a sieve cylinder) then the velocity of the fluid through the boundary layer, will be the geometric sum of the two velocities: flow velocity washing off the surface of the sieve cylinder and rate of filtration. On the surface of the cylinder, when fluid velocity is equal to zero, the rate of movement of the liquid — velocity and direction — is equal to the rate of filtration. It can consequently be stated that the a/m concepts will be correct both with rotating and non-rotating sieve cylinders.

Let us now examine how the process of filtration is influenced by the movement of the particles of the solid phase of the suspension under the effect of gravity.

At the moment a particle reaches the filtrating surface, the speed of its movement will be equal to the rate of sedimentation (Uoc) under the effect of gravity plus rate of filtration ($U'\varphi$). Speed of sedimentation can be figured as a function of the diameter of the particle.

$$Uoc = f\,(dm) \tag{2-22}$$

Particles of irregular form are subject to the same rules provided the size of the irregular particle is equal to the size of an equivalent spherical particle.

It is only through the very thin first layer deposited on the surface of the sieve cylinder that flow of the liquid and filtration are equal regarding rate and direction. The motion of particles of the solid phase of the suspension will be in some way similar to the motion of particles in a vertical stream. Its course can be imagined in the following way:

As a consequence of the intense agitation of the suspension, particles of different sizes are pushed by the blades of the agitators towards the surface of the filter, but not all of these particles remain on this surface. The filter retains only those particle the rate of sedimentation of which is lower than the rate of filtration; the larger particles, sedimenting at a rate higher than that of filtration, will not be retained and will again pass in the suspension. A

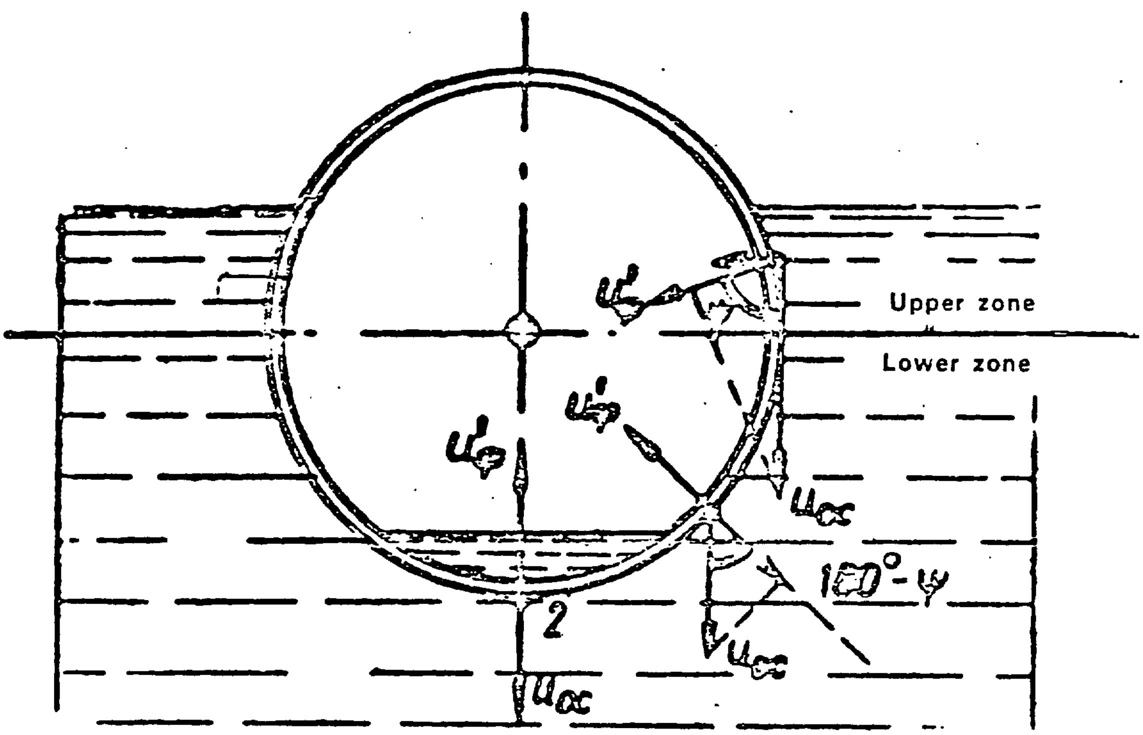

Fig. 16. - Diagram of a sieve cylinder, 3/4 of its diameter immersed in a suspension, showing direction and rate of filtration and direction and rate of sedimentation of the solid particles.

similar process can be observed when the sieve cylinder rotates.

Rates of sedimentation have been plotted against percent corresponding weights of particles contained in the suspension the rate of sedimentation of which is equal or less than Uoc, to construct graph figure 17.

Referring to zone 2, fig. 16 (lower zone) sedimentation and filtration are directed in inverse sense. When assuming that at a given movement the rate of filtration is equal to $U'\phi$, then on the surface of the layer will be retained only part of the particles of the solid phase, those for which

$$Uoc < U'\phi \qquad (2\text{-}23)$$

The quantity of such particles in the suspension (see fig. 17) constitutes $n_2\%$. Consequently when determining the volume unit of the filtrated material. « c » which expresses the weight of the layer delivered on the filter, this will be less than « a » (weight of concentration) and will be $n_2\%$ of « a » the reason being that the layer will not contain the particles whose rate of sedimentation is higher than the rate of filtration.

At the moment the rate of filtration will be equal to $U'\phi$ the largest particles delivered on the layer will have a speed of sedimentation $Uoc = U'\phi$.

As the process of filtration progresses at constant pressure its rate gradually decreases and consequently the quantity of maximum and minimum size particles, passing from the suspension to the layer. will also decrease.

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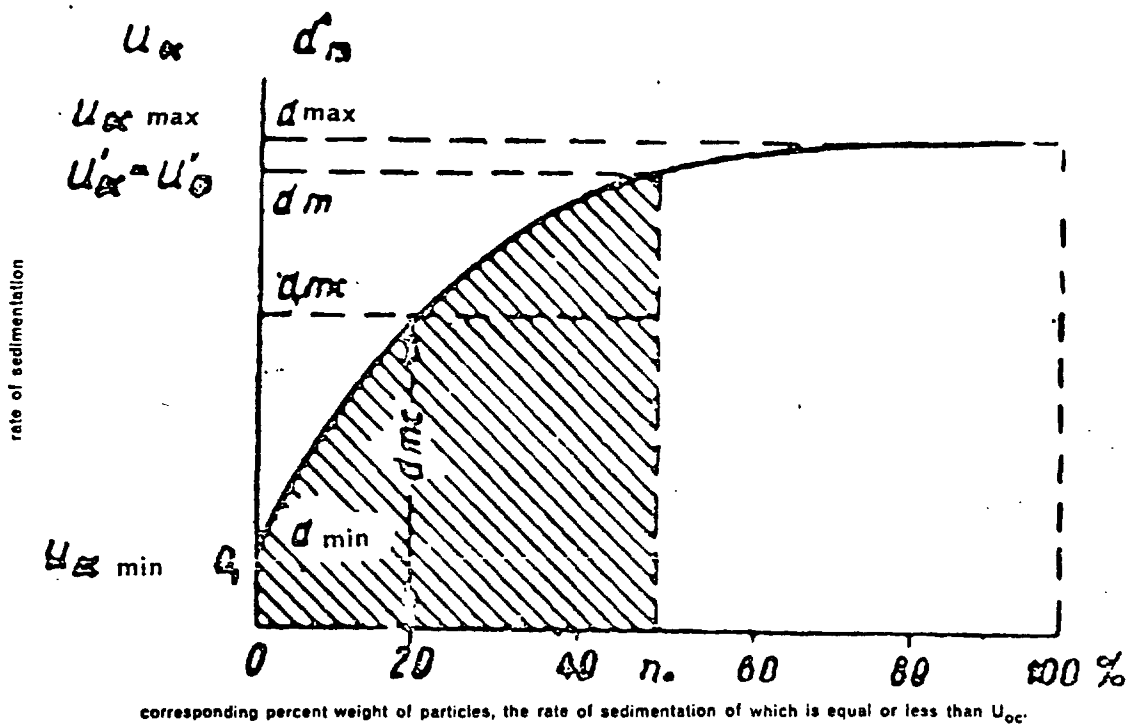

Fig. 17. - Graph of distribution of the solid phase of a suspension.

When U'φ will be less than Uoc max. the weight of the layer delivered per volume unit of filtrated material V and average diameter of particles, will have changing values. Movement of particles at point 2 (fig. 16) has been examined. For the points of the surface of the cylinder in the lower zone (where the directions of filtration and sedimentation constitute the angle ψ - see fig. 16), the inequality (2-23) must be expressed in the following form:

$$U_{oc} - \cos(180^\circ - \psi) < U'_\phi$$

or

$$U'_\phi - U_{oc} \cdot \cos \cdot (180^\circ - \psi) < 0 \qquad (2\text{-}24)$$

During the process of filtration, the following cases are possible in the lower zone. (fig. 16).

1. The rate of filtration on all points of the lower zone, is higher than the projection, at maximum speed against the filtration flow, of the sedimenting particles of the solid phase of the suspension.

This would mean that the rate of filtration is so high that inequality (2-24) would be correct for all the particles of the suspension, including the largest. In this case, the layer would be formed from particles with the same unchanged correlation, as this exists in the suspension. Particle size distribution, through the whole thickness of the layer, would be the same and every volume — unit of filtrated suspension would deliver on the filter in the course of the entire cycle, a sediment of equal weight in proportion to the concentration of the suspension. The value « c » would be constant during the whole cycle and the average specific resistance of the layer will also have a constant value.

Filtration with such characteristics delivers a homogeneous layer and equation (2-18) which is used for designing vacuum filters, applies to such filtration.

2. The rate of filtration on all points of the lower zone, is lower than the projection at maximum speed against the filtration flow, of the sedimenting particles of the solid phase of the suspension.
   In this case, particle size distribution would be different in the different sections of the layer. As we come nearer to point 2 — thus increasing cos. ($180^\circ - \psi$), the inequality (2-24) will be correct for the particles with smaller value of Uoc. This means that the size of the particles forming the layer, will continuously decrease. As filtration progresses, and the rate of filtration decreases, the average diameter of the particles delivered in the layer, with constant cos. ψ, will decrease (the change of the value of cos. $180^\circ - \psi$ is only one of the causes for the delivery of a homogeneous layer). Particle size distribution in the layer will not correspond to particle size distribution in the suspension and the quantity of small diameter particles, delivered in the layer, will be progressively increasing causing, as a consequence, the increase of the average specific resistance because the size of the pores in the layer will be smaller not only on account of pressure but mainly on account of the decrease of the average diameter of the particles which form the layer. Accordingly, the weight « c » of the layer delivered on the filter in the lower zone, will also be decreasing because as the rate of filtration progressively decreases, the filter will retain only those particles for which the inequality (2-24) is correct.
   Thus, diameter of particles, weight of layer, average specific resistance and other factors which characterize the process in the lower zone, depend not only on the rate of filtration but also on the point of the circumference of the cylinder on which the picking up takes place.
   Under these conditions the delivered layer will have unequal particle size distribution in its different sections and is a heterogeneous layer.
   In the course of experimental work carried out, the obtained data referred in tables 2 and 4 (increase of the average specific resistance during the process of filtration, the influence of the angle of inclination ψ and of the rate of filtration on the specific resistance and weight of the layer, the decrease of « c » during the process) indicate that filtration of asbestos-cement suspension is a process of filtration with formation of a heterogeneous layer.
3. The rate of filtration on all points of the lower zone is higher ($U'\phi$ max.) at the beginning and lower ($U'\phi$ min.) at the end of the cycle, than the projection at maximum speed against the filtration flow of the sedimenting particles of the solid phase of the suspension. At the beginning of the cycle, a homogeneous layer will be delivered (as in case 1) until the rate of filtration will be corresponding to the equation $U'\phi$ = Uoc max. cos. ($180^\circ - \psi$).
   After this moment and until the end of the cycle, the delivered layer will be heterogeneous (case 2).
4. The rate of filtration, is higher at the beginning and lower at the end of the cycle, than the projection, at minimum speed of the sedimenting particles of the solid phase of the suspension, against the filtration flow. Under these conditions, filtration takes place only up to the moment when the rate of filtration and speed of projection against the filtration flow of the seimenting smallest particles, become equal. At this moment the rate of filtration will be insufficient to retain even the smallest particles of the suspension, on the layer. The filtrated material will pass through the layer with a constant minimum speed ($U'\phi$ min.) but the particles will not remain in the layer.
5. The maximum rate of filtration, at the beginning of the cycle, is lower than the projection at minimum speed of the sedimenting particles of the solid phase of the suspension. Under these conditions, no particles will be retained by the surface of the filter.

In the light of the indicated principles, the processes of filtration can be classified as follows:

a) Processes with rate of filtration higher than the speed of sedimentation of the largest particles of the solid phase of the suspension; the delivered layer is homogeneous.

b) Processes with rate of filtration lower than the speed of sedimentation of the largest particles of the solid phase of the suspension; the delivered layer is heterogeneous.

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Sufficient data is available on classification «a». Equations (2-14 and 2-18) are specifically related to this classification. However, these equations cannot be applied for calculations referring to classification «b» to which the filtration of asbestos-cement suspension belongs.

The investigation of the influence on the process of filtration of the relation rate-of-filtration-flow/speed of sedimentation of the particles of the solid phase of the suspension, allows to figure more clearly the process of formation and structure of the elementary asbestos-cement layer.

The data referred in tables 2 and 4, obtained from experimental investigation, indicate that the increase of the average specific resistance of the layer, during the process of filtration, takes places in all cases and does not depend on the position of the filtrating screen or on the rate of filtration.

Considering the presence in the suspension of asbestos-cement particles and of free grains of cement, so widely differing in size, experiments have been carried out to explain the phenomenon:

It has been established that the asbestos-cement particles, delivered on the surface of the wire during the time period 0,9-1.2 seconds from the beginning of the process, have such large pores that the free cement grains pass through them together with the water. The quantity of solid particles carried away during the first 2 seconds, attains 14.6 % of the weight of the layer (see table 2).

After 0,9-1,2 seconds (time can differ with suspensions differing in composition), no solid particles are observed in the filtrated material although filtration and delivery of particles on the filter still goes on. During this period, the layer will retain all the particles, which until this moment were carried away by the filtrated material. Consequently after the end of the transition period, delivery of the smaller particles increases and because of this, specific resistance also increases.

It is also important to establish in which part of the layer and how evenly, free cement is deposited. The depth of penetration of free cement depends on the compactness of the layer.

The outer part of the layer being still not sufficiently compact and in the stage of formation, filtration will take place under conditions similar to those which are observed at the beginning of the process. The free cement particles are not retained in this part of the layer but penetrate more deeply and deposit near the surface of the most compact part of the layer which is in contact with the surface of the filter.

However, as the process of filtration progresses, deposition of cement gradually approaches the outer part of the layer. It results that the layer is not uniformly saturated with cement (see table 3).

Saturation of the layer with cement increases as the duration of the process increases but near the surface of the filter, an intermediate layer with insufficient cement content, will still be formed. The saturation with cement of this intermediate layer is impossible due to its great compactness.

The degree of compactness of this intermediate layer depends on hydrostatic pressure (compactness creases with the increase of hydrostatic pressure).

When filtration takes places with angle of inclination $\psi < 90°$ particle size distribution in the layer will be even less uniform.

When the rate of filtration increases the solid phase in the layer will have a composition almost identical to that of the suspension. Under these conditions, layers obtained at angles $\psi = 60°$ and $\psi = 135°$ will differ less both in weight and specific resistance.

The correctness of these conclusions has been confirmed by the experimental work the results of which are referred in table 4.

The rate of filtration can be increased in different ways. In the course of the above referred experiments, rate of filtration was increased by increasing the pressure but this method should not be recommended as it leads to excessive compactness of the layers in contact with the solid surface of the filter and prevents their saturation with cement. A recommended method to increase the rate of filtration is by making the cycle shorter. It results from the above that uniform distribution of cement in an asbestos-cement layer depends on the conditions of filtration. Best uniformity of distribution of cement can be obtained by filtrating asbestos-cement suspensions under the following conditions:

1) with high rates of filtration;
2) with short cycle.
3) with low hydrostatic pressure.

Uniformity of distribution of cement in the layer or otherwise degree of homogeneity appears to be a basic factor influencing the quality of asbestos-cement.

In order to establish the effects on quality, a series of experiments has been carried out and the results will be examined in another paper.