Superfilled paper with alumina hydrate and other conventional fillers

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ABSTRACT

Production of superfilled papers based on alumina hydrate and conventional fillers such as talc and titania has been examined. Four indigenous alumina hydrate samples have been evaluated of their filler properties and compared with the other fillers. The flocculating behaviour of each filler has been determined from dispersibility test. Physical properties of hand sheets made with all the fillers have been measured at filler additions of 10 to 60%. The high brightness, platelet structure and textural properties of alumina hydrate have been discussed in terms of its possibility to be used as common fillers in future and specially for production of superfilled papers. The results obtained from Pulmac trouble shooter have been interpreted to focus on the fibre strength and fibre bonding, the fundamental aspects in production of superfilled papers.

Introduction :

The term "superfilled paper" has been recently evoked (1) and considered to be of high economical importance in paper manufacturing (1,2) in view of the increasing cost of fibres. Production of such papers has been cenceived through various retention aids, pre-flocculating agents and lumen loading. The studies were, however, confined to the conventional fillers such as clay, titania and talc. The present work, intended initially to experimentally determine the flocculating behaviours of the fillers, led us to extend the work on alumina hydrate. It can be quite efficient in production of superfilled paper. However, use of alumina hydrate as common filler material appears worth receiving attention according to the present study.

Unlike in other countries, kaolinite clay of suitable quality is not available in plenty in India. The properties which have limited the use of clay as filler in India are : Black specks, low brightness, presence of impure minerals and oxides. It is reported that the brightness can be improved by removal of iron and quartz impurities in clay through floatation beneficiation process (3). Titania is too costly to be used as filler. Finally talc is extensively used at present in India as filler material. However, its deposit is very much limited (4).

With the commissoning of gigantic alumina refining industry (National Aluminium Company) in 1987, availability of alumina hydrate has increased enormously. It is apprehended that export possibility of alumina will go down in the coming years because of tough competition in the world market The alumina producers in the country are therefore bound to look for diversification products other than alumina metal. As the hydrate is a synthetic product, its qualit ycan be quite uniform compared to the naturally occuring minerals such as clay or talc. There is therefore interest in considering alumina hydrate as the common future filler in paper manufacturing (5,6). Use of alumina hydrate as filler can be considered quite cost-effective.

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Experimental :

The alumina hydrate samples used here are designated as AlH-1, AlH-2, AlH-3 and AlH-4. The talc sample is from Udaypur in Rajasthan and titanium dioxide is from Kerala. State Industry Product Trading Corporation, Kerala. The alumina hydrate used in results (Figs. 1-9) is AlH-1.

The furnish used is mill bleached kraft pulp (80% bamboo; 20% hardwood) which was beaten in laboratory Valley beater.

Stocks were prepared using rosin, alum and different fillers. Final pH was maintained at 4.5. Filler doses were varied from 10 to 60% on OD pulp basis.

Hand sheets have been made following to Tappi's method (T 205 Om-88; year 1991) where the surface wire specification is 0.067—0.071 mm diameter. We have used wire mesh of same dimension. It is therefore obvious that particles finer than 200 mesh (0.076 mm) will not be retained in the hand sheet. In the paper mill where recirculation of white water is carried out, there is possibility of retaining some portion of the particles finer than 200 mesh in the sheet. However, retention of extremely fine particles may not be appreciable even in the paper manufactured in the paper mill because such particles present themselves in colloidal form.

However, the method followed here is standard laboratory practice. The accuracy in filler retention is $\pm$ 0.15 g.

All the physical properties were also determined according to Tappi test methods.

Pulmac trouble shooter (made in USA, model TS 100) was used for testing the fibre strength and bonding properties.

The results obtained from Pulmac trouble shooter are shown in Figs. 7-9. Fibre strength in zero and 0.4 mm span have been measured from which, the bond factor has been calculated as follows :

$$\text{Bond factor (BF)} = \frac{\text{Dry short span strength}}{\text{Wet short span strength}}$$

Zero span breaking length is calculated by converting the zero span strength in psi to kg/15 mm.

$$\text{Zero span breaking length} = \frac{2/3 \times (\text{kg}/15\text{ mm}) \times 10^5}{\text{gsm}}$$

The flocculating behaviour of the fillers has been determined by dispersibility test, carried out in a graduated cylinder. The pigment slurry is allowed to settle and the suspension is drawn in a pipette at the middle of the cylinder. It is transferred to petri dishes and then dried. The weights are taken and percentage of solid in the suspension can be calculated.

Results and discussion :

Alumina hydrate is manufactured generally for metallurgical grade in the country, namely for Al-metal where the particle size is required to be high (—45 um>10-12%). Whiteness of the product is not important. On the other hand, requirement for paper filler is :—45 um<1%, and brightness >90% EI.

Co-precipitation and addition of hydrate gel as nuclei are methods for production of alumina hydrate suitable as paper filler.

The brightness of normally produced hydrate is 80% EI and thus quite unsuitable to be used as paper filler. On acid leaching and washing, its brightness is improved to 82-83% EI only. Therefore, the hydrate required for paper industry has to be processed separately.

The properties of different fillers are summerised in Table 1. It can be seen that alumina hydrate has same platelet structure as kaolinite clay and talc, with lower specific gravity and very high brightness value (Table 1A).

The results of dispersibility tests of the various fillers used are shown in Fig. 1. The dispersibility of alumina hydrate is quite superior to the other filler materials. There is practically no settling taking place on standing the suspension for 4-5 minutes as the time required for stock preparation in 5 minutes (for the filler), the studies were conducted upto 5 minutes only. The present method gives fairly good indication on the dispersion properties of the filler.

The percentage retention values of different fillers are shown in Fig. 2. The filler addition was made from 10 to 60%. The ash percentage in the hand sheets

TABLE-1

Properties of different fillers

		Alumina hydrate						
		AlH-1	AlH-2	AlH-3	AlH-4	Talc	TiO_2	Clay
Moisture	(%)	0.92	0.532	0.76	0.94	0.081	1.05	1.324
Brightness	(%EI)	94.0	93.7	94.3	94.9	80.2	92.3	76.3
Particle size (>45 μm)	(%)	Nil	Nil	Nil	Nil	0.2	Nil	Nil
Dispersibility after 5 min.	(%)	89.0	97.0	98.8	99.1	20.7	55.4	81.0

TABLE - 1A

Properties of different fillers*

Filler	Particle size (um)	Specific gravity	Particle shape	Brightness, (% EI)	Surface area (m^2/g)	Refractive Index
Kaolinite clay	0.5-2.0	2.5-7.8	Platelet	78-90	7-25	1.56
Talc	0.5-2.0	2.75	Platelet	70-90		1.57
Titanium dioxide	0.15-0.3	4.2	Spherical	99	6-10	2.76
Alumina hydrate	0.5-1.0	2.4	Platelet	99	6-14	1.57

*Literature values.

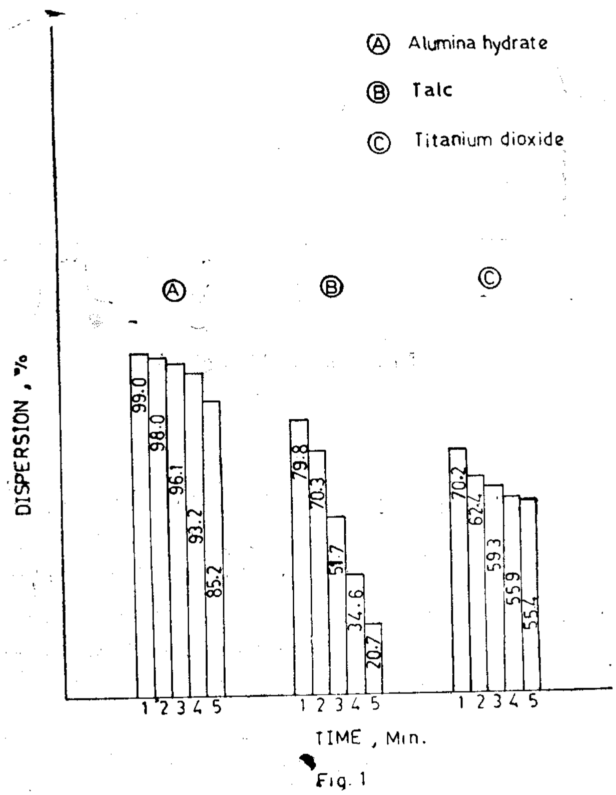


Fig. 1—Histograms showing dispersibility of fillers.

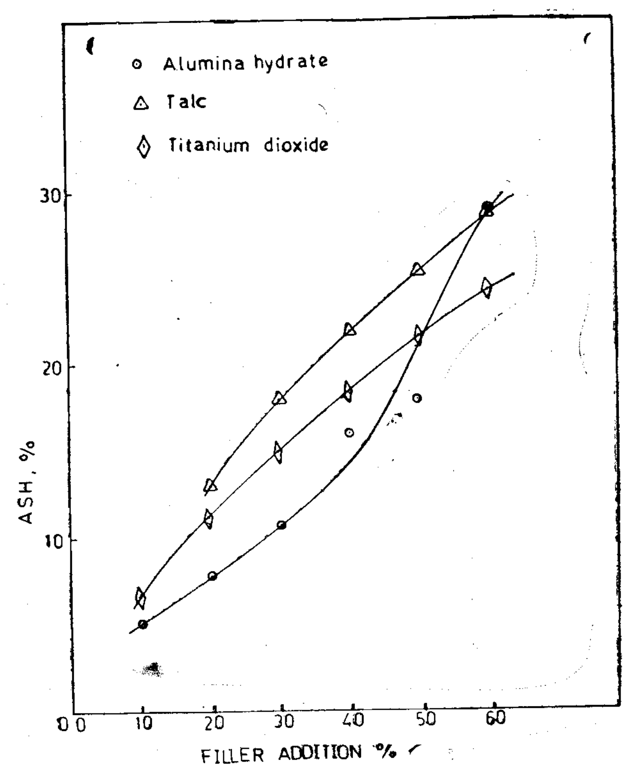


Fig. 2—Retention of different fillers.

was found to be highest in case of talc, followed by TiO_2 and then alumina hydrate. At about 40% of filler addition, the ash percentage in case of talc is 22%; 17% in TiO_2 and 14% in aluminah ydrate. The corresponding ash percentage at 60% filler addition is 28%, 22% and28% respectively for alumina hydrate, TiO_2 and talc. The ash content shooted upto 28% in case of alumina hydrate at 60% of filler addition which is quite remarkable. The % retention values are shown in Table 2.

TABLE - 2

Retention values

Addition, %	Retention, % Alumina hydrate	Titanium dioxide	Talc
10	51.4	66 4	
20	41.2	52.9	64.8
30	39.9	49.4	60.3
40	35.8	44.5	54.5
50	35.7	43.3	50.6
60	47.9	40.4	47.6

The bulk properties are found to remain unaffected on increasing the filler content in the paper (Table 3); for alumina hydrate it is 1.57; for TiO_2 1.78; for talc 1.42.

TABLE - 3

Bulk of papers filled with different fillers

Addition, %	Bulk Alumina hyrate	Titanium dioxide	Talc
10	1.58	1.52	
20	1.56	1.50	1.44
30	1.56	1.49	1.40
40	1.57	1.48	1.42
50	1.57	1.43	1.40
60	1.57	1.43	1.45

The burst index Vs. ash percentage for the fillers are drawn in Fig. 3. The burst index of alumina hydrate is found to be higher than all the other fillers at ash percentage of 4 to 32. At about 16% of ash, the burst index of alumina hydrate is about 19 which is 17 for talc, and 16 for TiO_2. Even at 28% of ash content, the burst index of alumina hydrate containing paper remains 16 kpa m^2/g.

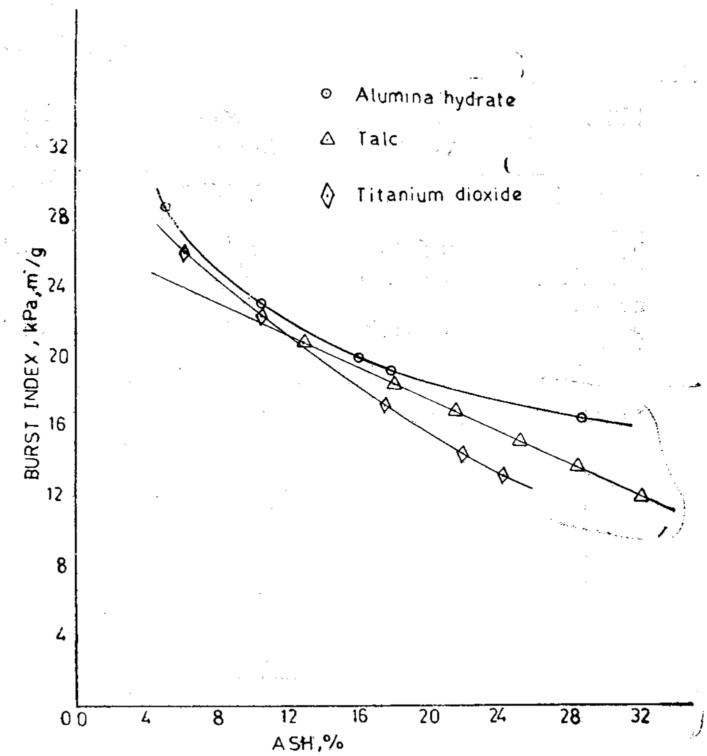
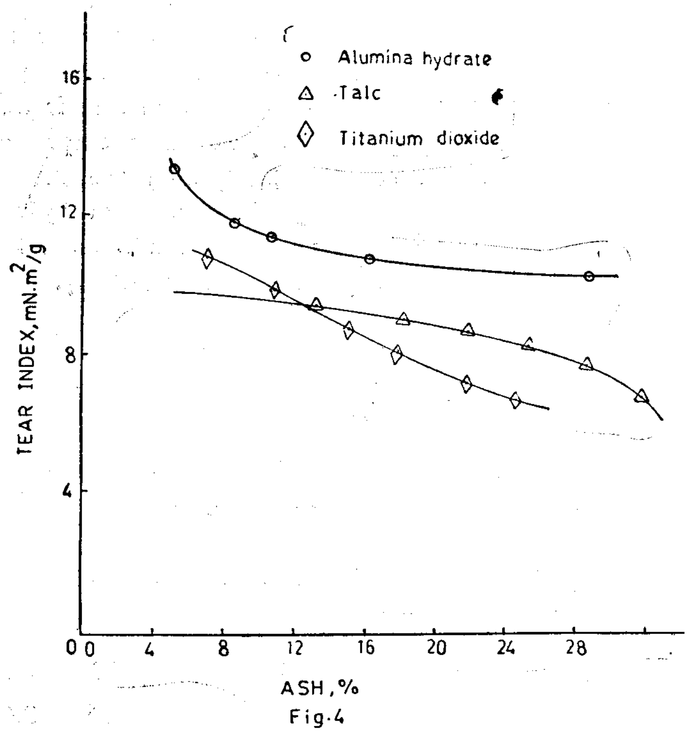


Fig. 3

Burst index Vs ash %

Fig. 4 represents tear index values at similar ash percentages for papers containing alumina hydrate and other fil er materials. The tear index values of alumina hydrate filled papers are superior to all others at ash percentages varying from 4 to 32% It is remarkable that at 28% of ash content, the tear index value of alumina hydrate-filled paper is higher than TiO_2 and talc-filled (8-12% ash) papers. The tear index at 28% content for alumina hydrate is 12 mN m^2/g while it is 9 mN m^2/g for talc and 7 mN m^2/g for TiO_2.



Tear index Vs ash %

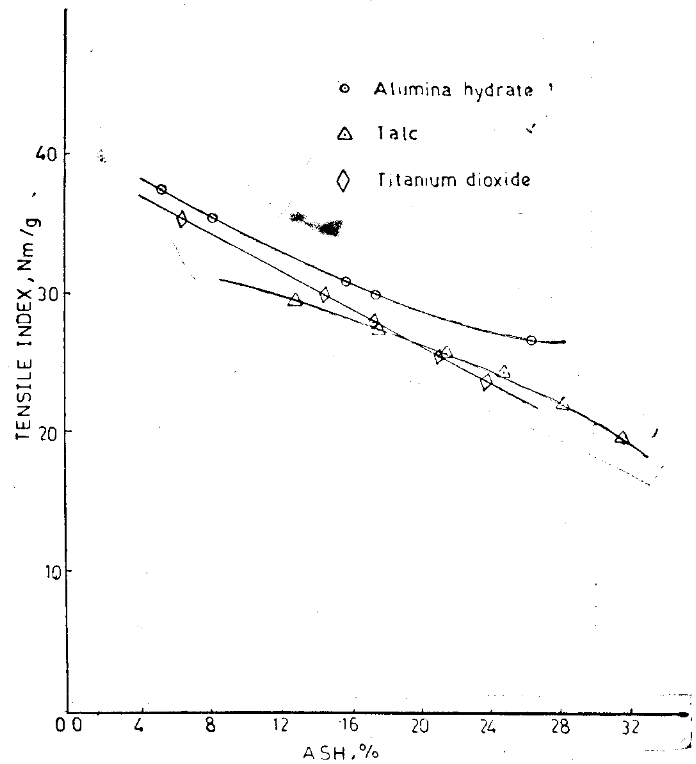
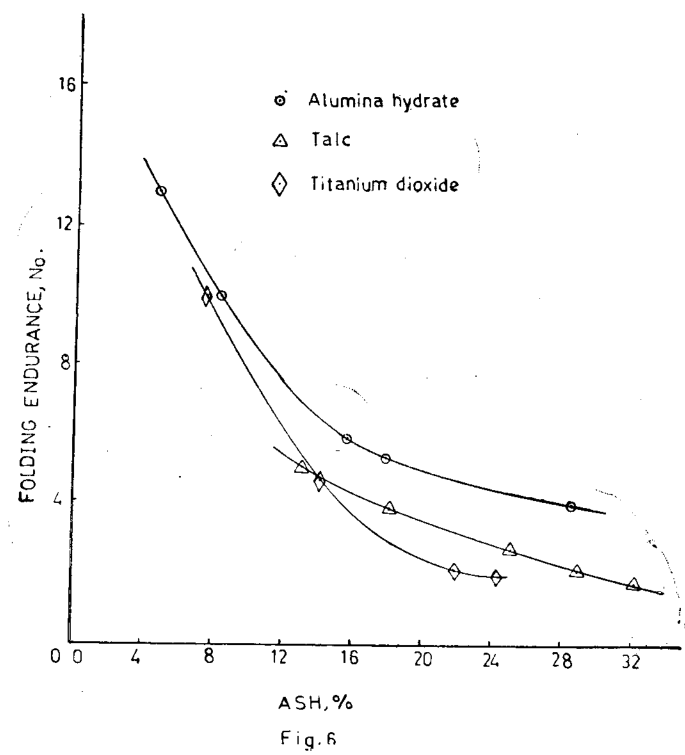


Fig. 5
Tensile index Vs ash %

Tensile index Vs. the ash percentage of the products are drawn in Fig. 5. Here also, the tensile index values of alumina hydrate-filled papers supersedes the other three products at ash percentage even upto 32. At ash % of 28, the tensile index of alumina hydrate filled paper is 31 Nm/g followed by 22 Nm/g for talc and 20 Nm/g for TiO_2.

The folding endurance curves for the fillers containing papers are shown in Fig. 6 against ash percentage values of 4 to 32. The following endurance number falls down abruptly on increasing the filler content. However, the superiority of alumina hydrate - filled paper over other fillers is exhibited here also.

The fibre strength of alumina hydrate is again dominant over other filler containing papers; the values being 18, 16, 15 for alumina hydrate, talc, and TiO_2 respectively at maximum ash level. The zero span breaking length (Fig. 8) for talc and TiO_2 are inferior to that of alumina hydrate containing papers at all levels of ash content. Similar trend is found for bond factor (Fig. 9) also.



Folding endurance Vs ash %

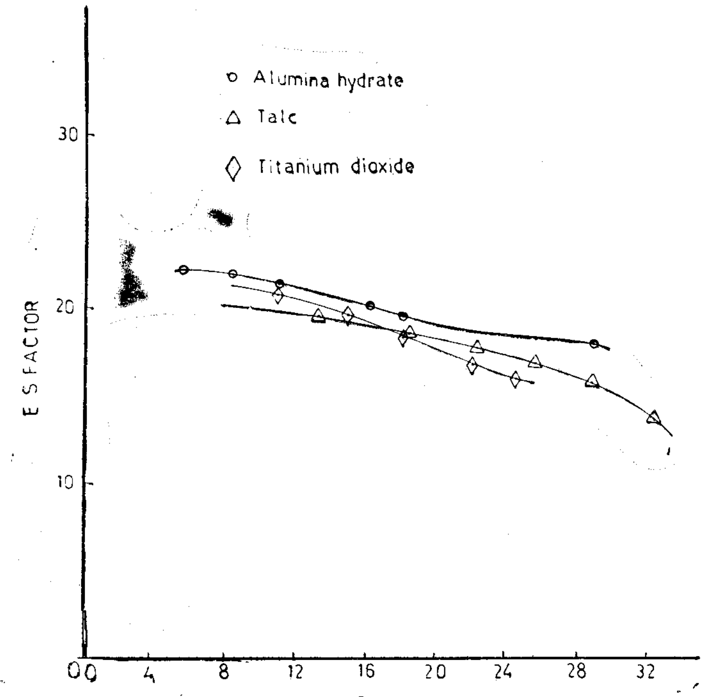


Fig. 7

Fibre strength factor Vs ash %

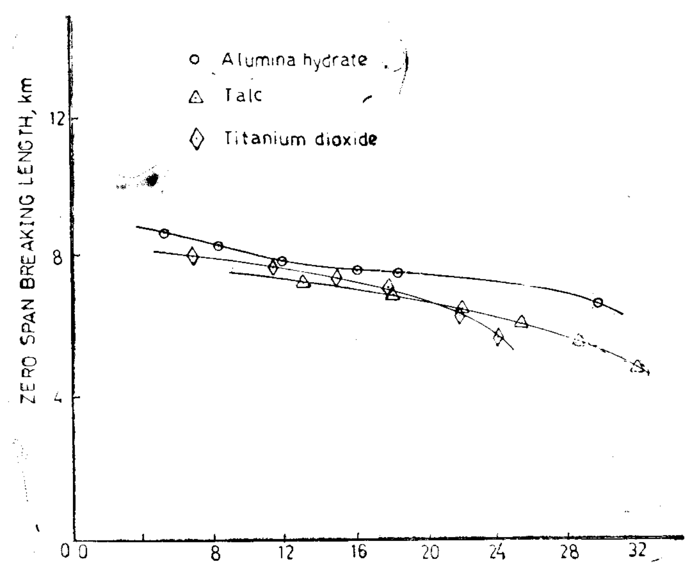


Fig 8

Zero span breaking length Vs ash %

Alumina hydrate, having same platelet structure as clay, it can orient in similar fashion as clay over the cellulosic fibre surface and thus imparts superior properties over other fillers (6). Its particle size is also fine and can remain preferentially in form of suspension with higher degree of dispersibility than the classical fillers. (The physical properties of alumina hydrate filler containing hand sheets are shown in Table 4. The properties are quite comparable with each other).

TABLE - 4

Physical properties of hand sheets made with different alumina hydrate samples

Properties	AlH-1	AlH-2	AlH-3	AlH-4
Bulk, (cc/g)	1.58	1.59	1.52	1.51
Burst index, (KPa m2/g)	2.16	1.83	2.15	2.64
Tear index (mNm²/g)	11.76	10.83	11.29	11.24
Tensile index (Nm/g)	30.9	30.5	32.4	30 3
Folding endurance (Nos)	8	7	8	7
Ash, (%)	10.75	11.0	10.6	10.9

This leads to better diffusion of the particulates over the fibre capillaries (7). The alumina hydrate has special property of being amphoteric (8-10) and therefore, it can compensate the negative charge density prevailing over the cellulosic fibre surface (11). Consequently, the strength properties obtained in case of alumina hydrate filled papers are significant.

The tear index values remain unaffected on higher loading of fillers which are in co-relation with the non-alteration of fibre strength values determined from Pulmac trouble shooter (Fig. 7). Though it is not easy to distinguish, it is implicit that the bonding properties are only affected at higher filler loading. It is presumed that part of the filler particulates (12) diffuse into the fibre lumens and bring in amilioration in mechanical strength of the fibres (7, 13). This will be the objective for another paper.

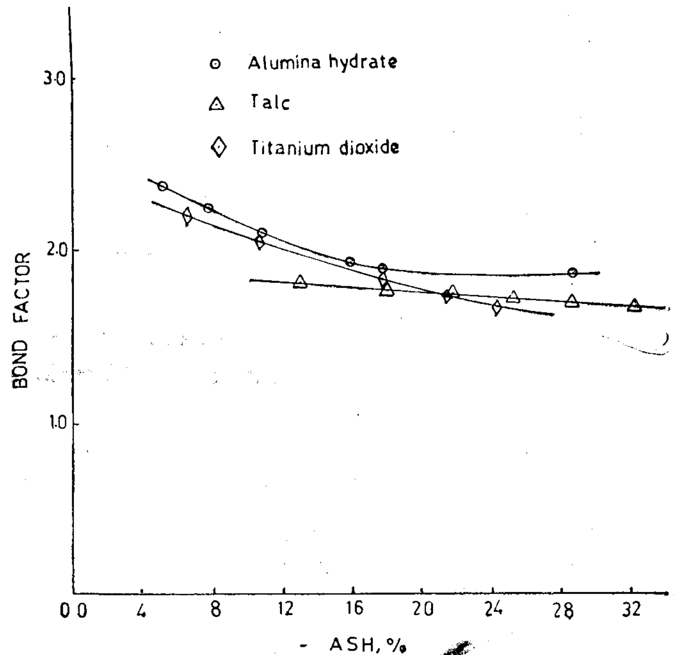


Fig. 9

Bond factor Vs ash %

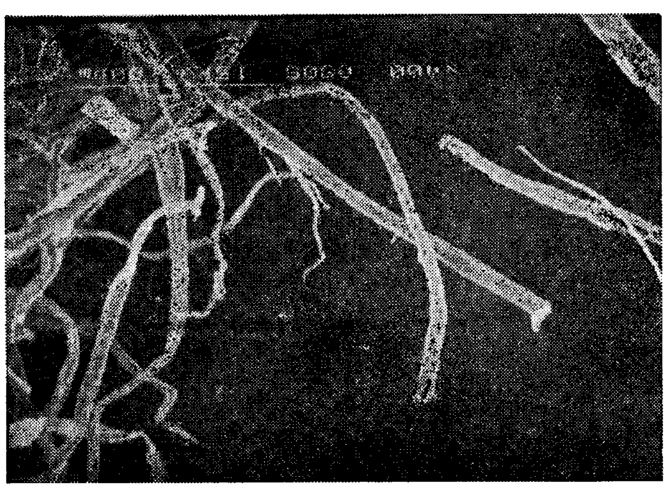


Fig. 10

SEM micrograph showing fibres and fillers of sheet having 28% alumina hydrate (X 400).

SEM micrograph of sheet produced with 28% of alumina hydrate is shown in Fig. 10. The lumens or rather the fibre capillaries (13) have been filled up with the hydrate particles as can be seen from the white colour over the surface. The surfaces of fibres appear to have a white deposit of the hydrate and thus adsorption on the surface has also taken place. The twisting of fibres has also been reduced. The fibres are varying dimensions (0.1-15μm) width according to the micrograph with length of 300μm. As the furnish is mixed having bamboo as well as eucalyptus, the initial fibre forms are different. The fibre cross sections show patches of solid hydrate particles (7,14). Possibi lity of lumen-loading with alumina hydrate has been explained previously (13).

Conclusion:

Alumina hydrate has been found to be quite effective as filler material. Barring aside the cost part which is certain to come down in the near future, alumina hydrate stands as the best future filler material. The tear index in particular of alumina hydrate filled paper is quite appreciable even at 32% of ash content in the paper. Other properties such as burst index, tensile index, folding endurance are also found to be higher for hydrate-filled papers than in papers having talc and TiO_2. Alumina hydrate can be used quite effectively for production of superfilled paper.

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