DE-WATERING OF IRON ORE FINE PARTICLES IN AQUEOUS MEDIUM

R. P. Bhagat

INTRODUCTION

Solid - liquid separations form an integral part of many mineral processing and hydro-metallurgical operations. During the wet processing of iron ores, a considerable amount of fine particles, known as slimes, are generated which need to be recovered effectively through solid -liquid separation. This assumes even more importance in case of iron ores in view of the large tonnage treated in India or elsewhere in the world. Proper de-watering is essential due to :

(a) Material recovery : Slimes to the tune of 10-15% of the processed ore is generated. Slimes produced at different iron ore washing plants in India vary in their chemical constituents depending on the source. However, they are largely rich in Fe value. Any additional recovery of Fe from the slimes leads to an enhanced economy of the mines, besides a sustainable development of the nation through the rational and judicious usage of the natural resources.

(b) Water conservation/ recycling : In case of iron ore processing the requirement of water is around 2-3 times the ore treated. Enhanced thickening is required to reduce the load on slime pond and to recover additional recycled water in the processing plant.

(c) Environmental consideration : About 85-90% of the iron ore slimes happens to be below 150 micron size which has difficult settling characteristics. Besides, the settling characteristics of the suspension in the slime pond gets adversely affected when iron ores rich in goethite/ limonite is fed. It is generally viewed that the total suspended solid (TSS) in the overflow water which report to Nala/ river and used for drinking and irrigation purpose far exceeds the norm of 100 ppm which would reduce the fertility of the land, besides enhances the water pollution.

(d) Economic consideration : Most of the hematite based iron ore processing plants in the Jharkhand, Chattisgargh and Orissa states were originally designed to handle a lower percentage of fines. However, as the excavation in mines is deeper the percentage of fines has increased causing load on the existing thickener. Besides with the opening of newer mines in these sector, the capacity of the existing thickener has to be enhanced considerably. This assumes more significance in view of the fact that the availability of land (for the slime ponds) would be strained coupled with more stringent environmental regulations.

GENERATION OF IRON ORE SLIMES

The generation of iron ore slimes from the washing plants is estimated to be 10 to 25% by weight of the total ore mined. The quality of slime produced at different iron ore washing plants in India vary widely. In most of hematite ores Fe percent varies from 55 to 62 whereas alumina percent from 2.8 to 6. In case of Kudremukh the slime has 27% Fe, 51 % Silica and 2% alumina. Irrespective of the quality of the iron ore slimes, it important to consider that a significant scope for its enrichment following advanced gravity, magnetic and flotation based separation techniques because of the fact that the material is already in '*Prepared Stage*' which require no size reduction operation.

THE PROCESS OF DE-WATERING

Process wise, the de-watering of suspension of the slimes is carried out in two stages: the first involves a thickener where most of the fine grains settle out of the water. The procedure is termed as clarification (rather than thickening) if the principal aim is to recover a clearer water (rather than a thick pulp of high solids content). The process of thickening depends on the principle of relative movements of solid particles into a fluid (water) medium thrust upon the external forces (gravity in this case). A thickened pulp of 20 to 35% volume percent solid can be produced through this process. The pulp can further de-watered in filters to a wet cake containing some 60 to 65 volume percent solid. The cake coming off the filters could be handled as a solid on a shovel or on a conveyor. The later process is more important in case of the processing of magnetite ore concentrates in India where the moisture content of the concentrate has been recognized as one of the most important properties in pellet making. Obviously, a real economic advantage accrues to the ability of control the moisture content of the filter cake within the range required for optimum pellet production.

The most widely used type of thickener is the Dorr tank, a cylindrical vessel of large diameter. The pulp settling out of the bottom from a feed introduced at top centre is crowded by a slowly rotating rake mechanism to a central outlet, where the clear liquor overflows the tank rim.

Filters are usually vacuum filters of continuous operation. In the course of the filter's rotation, part of the filter screen dips into the suspension to be filtered; clear liquor is sucked out from the pulp through a filter layer by depression created inside the drum using a vacuum pump ; the solids on the filter cloth form a cake which is removed before the filter dips into the pulp once again. Filter cloth on a drum filter covers the cylindrical shell of a perforated drum. In a disc filter, discs composed of several segments, each covered with filter cloth, are mounted on a hollow shaft. In a plate -and frame filter, the filter cloth is stretched between alternating plates and empty frames. The solids of a suspension, pressed into the cells at several bars pressure, are retained on the empty frames, whereas the clear liquor leaves at the bottoms of the plates through apertures that can be opened or closed by means of stopcocks.

CAPACITY ENHANCEMENT OF THICKENER

The capacity enhancement of the existing thickeners draws a considerable benefit to the iron ore processing plant in view of the fact that (a) life of the existing slime pond can be increased significantly, (b) more of water can be recycled to the process from the thickener itself. This can be achieved by :

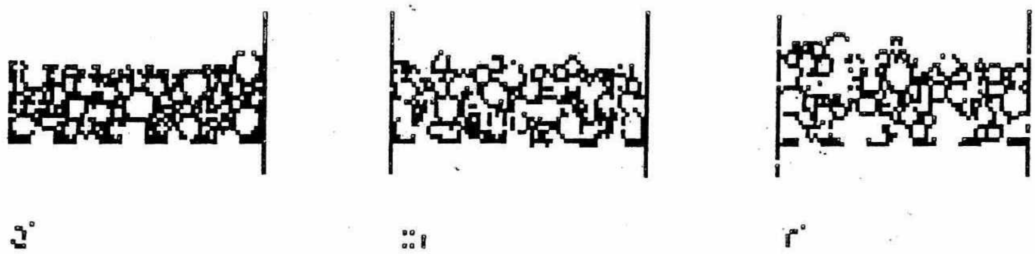
i) Mechanical Means : Trouble free operation by avoiding jamming etc. , and

(ii) Enhanced Settling : The sub-sieve particles can be subjected to the enhanced settling in the thickener by agglomerating them to bigger ones through the use of coagulants / flocculants.

EFFECT OF COAGULATION AND FLOCCULATION

In the case of sedimentation, one differs between the nature of applied force field, i.e. between the separation in the earth's gravitational field (in a thickener) and in a centrifugal field (centrifuge/ hydro-cyclone). The low mass (to the surface) of the solid particles in sub-sieve range or the hardly differentiable density difference which occasionally exists between the solid and liquid phase may make sedimentation within the earth's gravitational field almost impossible and that within a centrifugal field inadequate. This is due to the convection currents and Brownian motion, which cause particles in sub-sieve range to remain suspended over a period of time. During the filtration process, the suspension passes through a porous medium, whereby the solid particles are deposited either on or within the filter substance. The presence of both fine and deformable particles can induce the formation of dense cakes possessing extremely high permeation resistance. As a result, an acceptable solid- liquid separation efficiency frequently demands a pre-agglomeration of the fine particles within the suspension in order to obtain particles clusters which then either possess a sufficient mass for a rapid sedimentation (in a thickener) or can form coarse pore structures possessing an adequate permeability (in case of filtration).

The aim of agglomeration is to convert the suspended fines to mechanically separable flocs. The main criterion for the desired floc structure is the nature of the subsequently applied separation technique. (i) The filtration and sedimentation in a centrifugal field demand compact agglomerates with high mechanical stability, whereas (ii) The sedimentation by means of earth's gravity is facilitated by large, high density flocs. As such, the definition and determination of the characteristic properties of agglomerates is essential. Figure shows the influence of the agglomeration on the filter cake structure. (a) dispersed, (b) coagulated , and (c) flocculated.



1. Dispersed Stage : The finest -grain of a suspension exerts a strong resistance in the filtration since the lodging of the extremely fine particles within the pores between the coarser particles can create a densely packed bulk with small pore diameters (Fig. a)

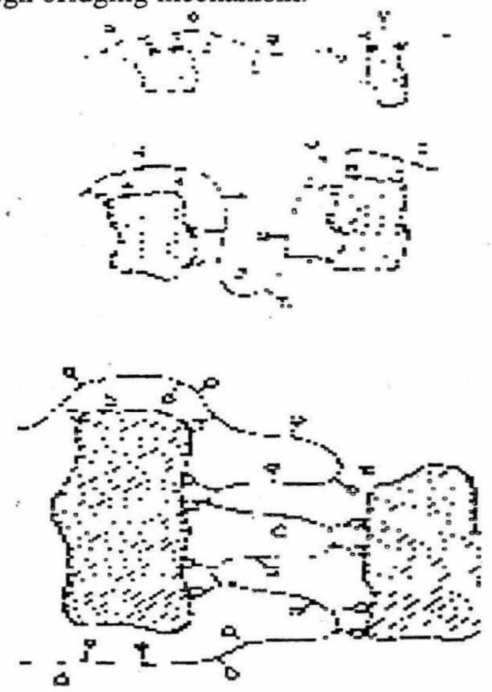
2. Coagulation Stage: A coagulation can bind the finest particles together to form particle collectives which are as large as the mean particles of the original fraction (Fig. b)

3. Flocculation Stage : The finest fractions can also be bound by the inter-linkage mechanisms of flocculation (Fig. c).

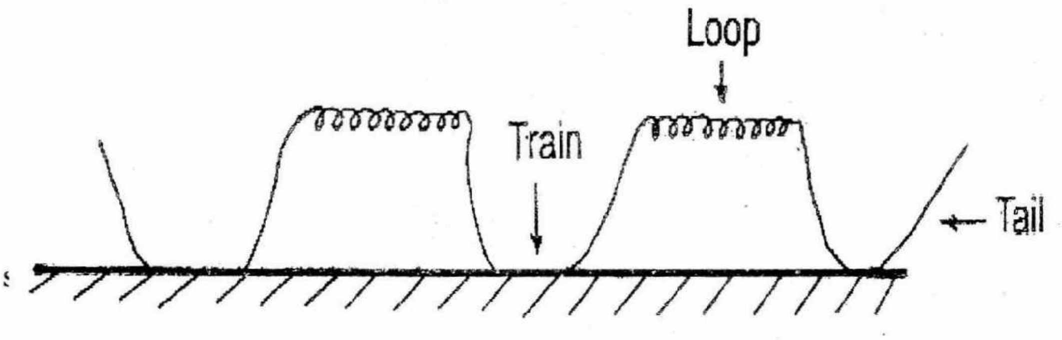
FLOCCULATION : MECHANISM AND STEPS

The purpose of a flocculant or a flocculation process is to aggregate fine solid particles into clumps of flocs. Large flocs promote settling and are desirable for clarification of thickening. Dense flocs, on the other hand, are most appropriate for consideration of the sediment and size is of lesser importance.

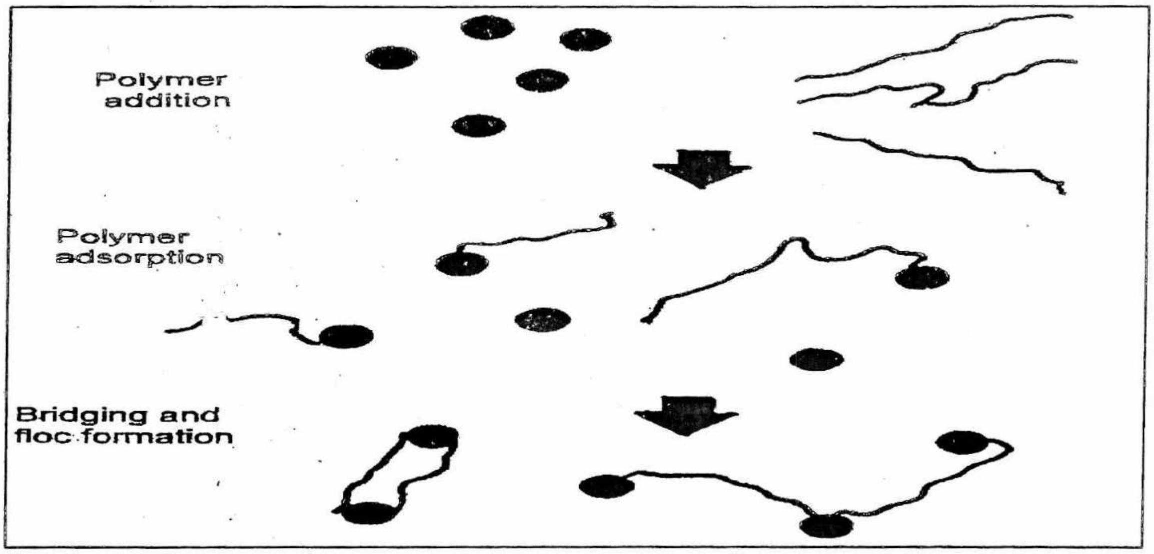
Charge neutralisation and the adsorption of the polymeric chain onto the solid surface followed by bridging of the particles have been proposed as the crucial mechanism behind the phenomenon of flocculation. The addition of polyacrylamide/ polysaccharides agglomerates fine particles into larger identities through the bridging mechanism even though the Zeta potential is not conducive for de-stabilisation. Figure shows the flocculation of particles through bridging mechanism.



The configuration of polymeric chain onto the solid surface is different from that in the bulk and is decided by type of reagents, suspension pH etc. The isotherms data in many cases including for the starch/ hematite system follow Langmuir type of adsorption –in spite of complexity in the polymeric configuration. **Figure** shows schematic of the adsorption of a Polymer on Particle Surface

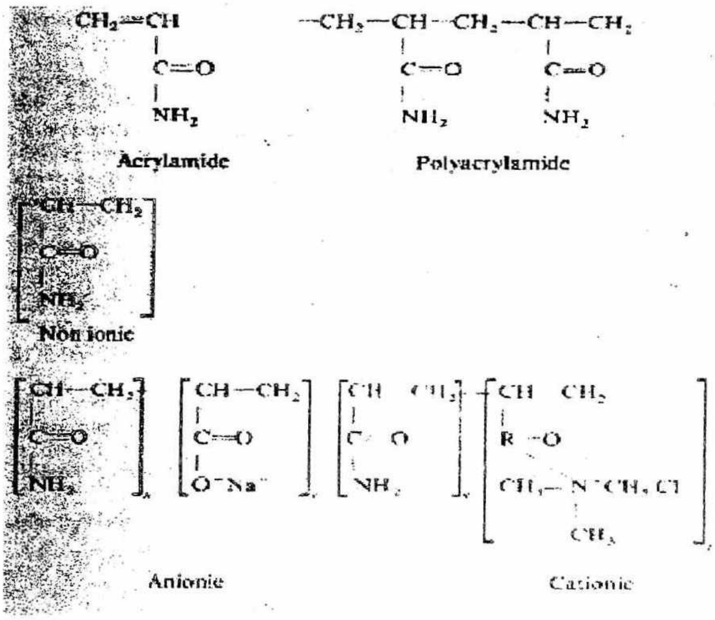


The flocculating polymer is added in a well dispersed suspension of fine particles. The polymeric chains are adsorbed onto the surface of the particles through their segment called, *'train'* while the remaining dangle into the aqueous medium (to be adsorbed onto another particles). Thus the bridging and floc formation takes place. **Figure** shows schematic of the essential steps in a flocculation process.



CHOICE OF FLOCCULANTS

Polysaccharides such as, starch are natural polymers used as flocculants. Besides, high molecular weight poly-acrylamides (non-ionic & anionic) are synthetic flocculants and commercially available. In case of iron ore medium anionic high M.W. are widely used. Typical structures of the poly-acrylamide based flocculants are shown below.



Polyacrylamide based mild anionic & non-anionic very high molecular weight flocculants are commercially available. For example. Manafloc series are well known brands and manufactured and supplied by *Allied Colloids Limited, PO. Box. 38, Low Moor, Bradford, Yorkshire BD12 0JZ.*

ı) Magnafloc 1011 : Very high molecular weight anionic polyacrylamide flocculant.
ɔ) Magnafloc 155 : High molecular weight anionic polyacrylamide flocculant
:) Magnafloc 1017 : Medium molecular weight anionic polyacrylamide flocculant

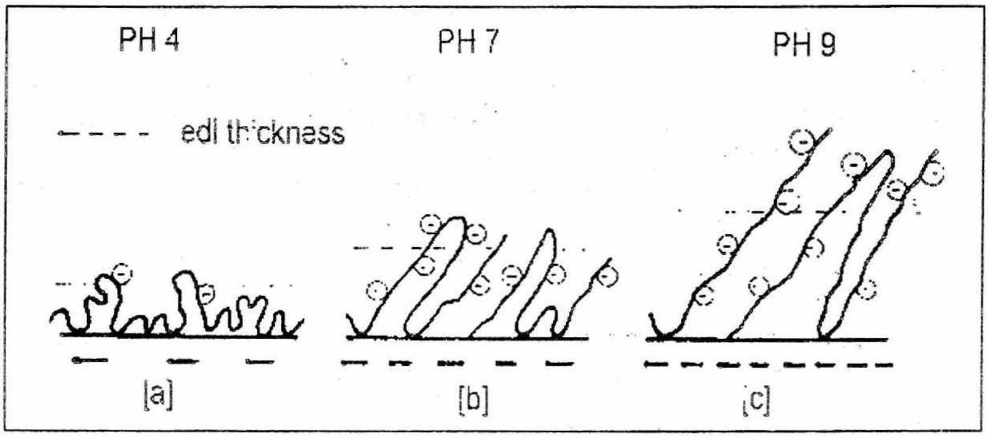
Table, mentioned below, shows the apparent viscosity (in cps) using Fann viscometer at the shear rate 5.11 sec^{-1}:

Flocculant Concentration, %	Apparent viscosity at 5.11 Sec^{-1} shear rate using Fann Viscometer		
	Magnafloc 1011	Magnafloc 155	Magnafloc 1017
1.0	1997	2047	1798
0.5	1248	999	800
0.25	606	599	449
0.10	300	200	200

PARAMETERS AFFECTING FLOCCULATION

The flocculation of solid particles depends largely on the manner the polymer is adsorbed on the surface. Several factors, such as pH of suspension, solid concentration, manner of flocculant addition (divided or at a time) influence the process. Besides the polymer chemical (surfactant) interaction plays an important role.

Effect of pH The suspension pH has considerable effect on the configuration of polymeric chain when adsorbed onto the mineral surface. **Figure** shows the configuration of the polymeric chain in the acidic, neutral and alkaline media. In acidic pH , the chains are too much coiled and hence does not extend to the particles for effective bridging to take place. In alkaline pH, the chains are loosely extended beyond the edl thickness and hence though particle- particle bridging can occur, the flocs are not stable. Only in case of neutral pH, the polymeric chains are extended to a reasonable thickness and are justifiable coiled and hence this is ideally suited for effective bridging.



SE OF GRAFTED FLOCCULANTS

olyacrylamide and polysaccharides based water soluble polymers have been extensively sed as flocculants. While the natural polymers are biodegradable, the synthetic ones are rone to degrade under shear. A new class of flocculants have been developed by grafting olyacrylamide on the polysaccharides backbone in order to overcome drawbacks ertaining to the degradability to some extent. These polymers have limited biodegradability and have higher resistance towards shear. A graft co-polymer consists of a polymer backbone with laterally covalently linked side chains of different polymers . Polysaccharides, such as guargum, xanthan gum, CMC and potato starch have been grafted by polyacrylamide using redox initiator adopting solution polymerisation techniques . By this technique, the possibility of homo-polymerisation is minimal and free radicals are formed basically on polysaccharide backbone. These grafted co-polymers are more bio-degradation resistant in comparison with polysaccharides.

A recent study has shown that the efficacy of flocculation in case of iron ore (slimes) particles using the synthesised starch- g- acrylamide polymer is better than that when commercial (and imported) polyacrylamide flocculant is used, particularly at high alkaline pH and high shear rates. **Table**, mentioned below, shows the initial settling rate using various flocculants at neutral pH in a batch settling process (500 ml cylinder). It is apparent that the settling rate is enhanced by using the synthesised flocculants.

No flocculant	0.31 mm/s	Starch	0.38 mm/s
Synthesized graft polymer	2.50 mm/s	Magnafloc	3.10 mm/s

The better flocculation efficiency of grafted polysaccharides is due to the basic molecular structure of graft co-polymers. The polyacrylamide chains are dangling on a long rigid polysaccharides rod like molecule. Thus their approachability to particles becomes high resulting in enhanced flocculation efficiency.

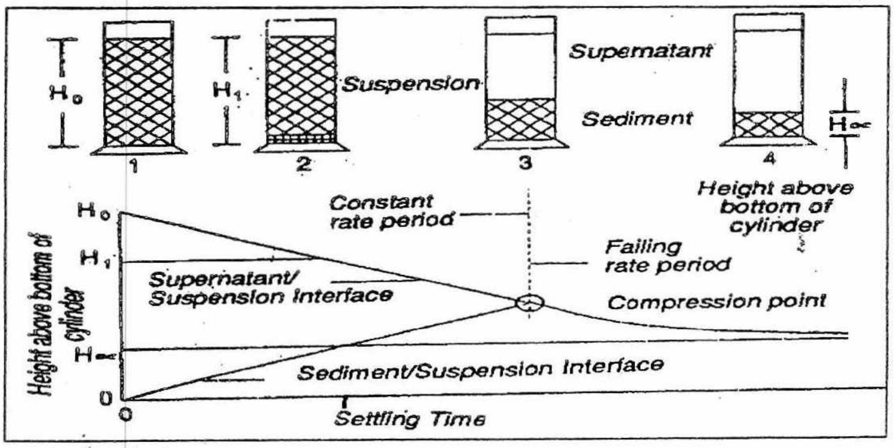
Effect of Hydrolysis The partially hydrolysed product with medium neutralisation equivalent shows better performance in flocculation than other partially hydrolysed/ un-hydrolysed products.

Divided Flocculant Addition

Flocculation improves considerably at lower flocculant dosage when the same amount is added in stages. There exists scope for flocculant economy by virtue of greater compactness of the flocs by divided addition

VARIOUS ZONE IN SETTLING

A settling curve for a suspension is characterised by a linear segment, corresponding to a constant suspension settling rate, and a non linear segment, corresponding to a decreasing settling rate. The onset of a period of decreasing rate coincides with the intersection of the mud line and the sludge line. The point on the settling curve where the constant rate period ends is called the "compression" point. **Figure** shows schematic of the settling zone



Sedimentation Kinetics and Models in Settling

Settling kinetics of particles in a thickener is crucial in determining solid-water separation and product recovery. Various models have been proposed by the researchers, such as Richardson and Zaki (1), Michaels and Bolger (2), Rober (3) and Kynch (4) etc. and well described in the literature which make important contribution to the understanding of the settling kinetics. Models in the settling have been developed according to various zones of the settling as mentioned below:

Zone of initial Rate of Settling :

It is characterised by

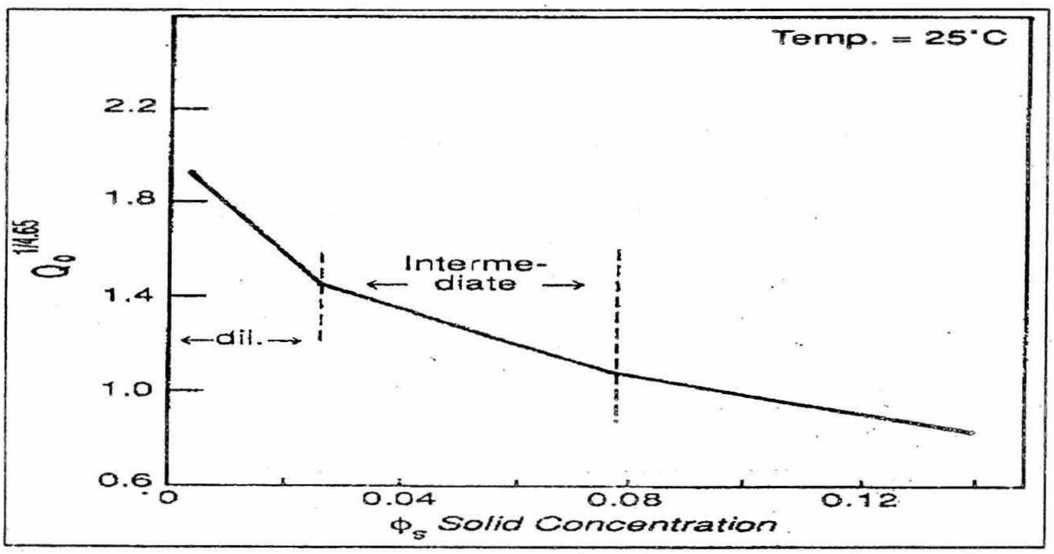
- Larger particles settle rel. to smaller ones
- Free settling condition and Increase in effective □ ,□ of suspension

Michaels & Bolger [2] has proposed the following model based on Richardson & Zaki *[1]*

The Initial settling velocity, $\mathbf{Q_0}$, is related to the Stoke's settling velocity, $\mathbf{V_{SA}}$, according to the following Equation:

$$\mathbf{Q_0\ (1/4.65) = V_{SA}\ (1/4.65)\ (1\text{-}CAS\ \Box S)}$$

where, CAS = □A/ □S (Vol. conc. of aggregate/ Vol. conc. of solid)
Figure shows that the parameter, Q_0 (1/4.65), is linear function of the initial solid concentration



Settling in compression zone

This is characterised by *consolidated zone and the suspension with very high initial concentration*

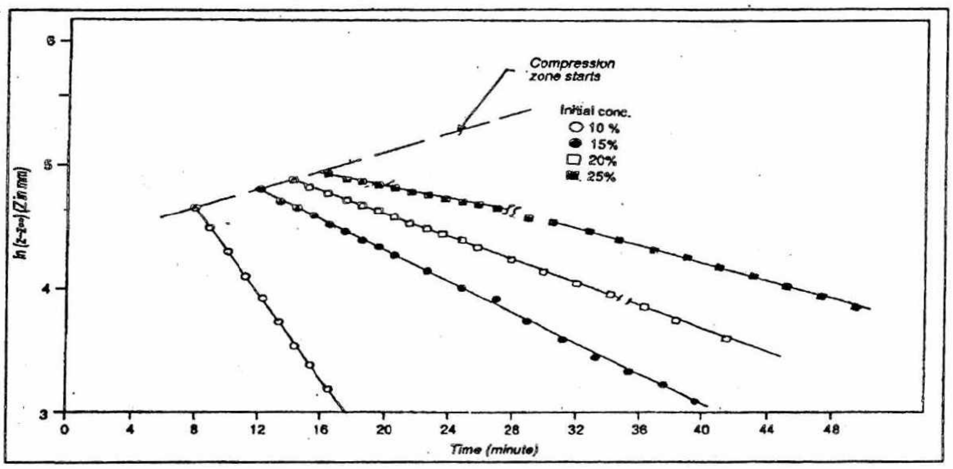
- Particles are very close

- Settling velocity and drag force markedly decreased

- Porosity of the sediment is smallest at the bottom
- Liquid is being squeezed out (condition of filtration)

E. J. Robers (1949) has proposed the first order kinetics in relation to settling of the particles in this zone:
$-dZ/dt = K(Z-Z_{oo})$, or, $-\ln (Z-Z_{oo}) = -k (t-t_c) + \ln (Z-Z_c)$
Z, Zc, Zoo = Interface height at time t, critical conc. and final sludge height

Figure shows that the parameter, $-\ln (Z-Z_{oo})$, is linear function of the time of settling once the compression zone starts



Parameters affecting Settling Rate

Dispersed Particles

Many of the previous studies have been confined to the suspensions of dispersed, non-attracting particles. Attempts have been made to extend Stoke's law to cover non-spherical particles. Several workers have presented effects of the various physical parameters on the settling rate. Notable factors amongst them are: solid concentration (1,4,), boyancy force (5) slurry viscosity (6) additives (7) including surfactants (8).

Flocculated Particles

The first general study of flocculated suspension was by Coe and Clevenger (9) who described the various concentration zones which exist within a settling suspension. They observed that the upward flow of displaced supernatant was a special case of pore flow. Kynch (4) analysed the solutions to the conservation of mass equations using the methods of characteristics.

Parameters affecting Filtration Rate

The filtration data could well fit to the Kozeney Equation in case of iron ore slimes

$t/v = (r\mu v) / (2\ (sq)A\ \square P) * V$, where ,

V = vol. of liquid flowing in time, t
□P = total pressure drop
r = specific resistance to filter cake
μ = viscosity of fluid
v = volume of cake deposited
A = filtration area

The addition of flocculant improves the filtration rate by agglomerating the particles land thus reducing the resistance of during filtration. However, it depends on pulp density (PD). Table, below, typically shows the result

PD (%)	Change in FQ (PPM)	Improvement
10	10 to 20	substantial
10	20 to 30	marginal
15	10 to 20	marginal
15	10 to 30	substantial
20	20 to 30	substantial
20	30 to 40	marginal

Besides the flocculant dose and pulp density, pH has considerable effect on the filtration rate. In case of iron ore concentrate, at acidic pH clear filtrate was obtained through the use of synthesised co-polymer or commercial polymer, but at alkaline pH, filtrate with high turbidity was obtained.

CASE STUDY

Settling of Hydro-Cyclone Products (Overflow and Underflow) from typical Mines

A case study on the settling characteristics of hydro-cyclone products (overflow and under-flow), which were generated through conducting the test work on the classifier slimes (<150 micron) and classifier fines (< 420 micron) samples pertaining to Noamundi & Joda mines is presented here. The objective was to generate adequate experimental data in relation to settling of these products samples so as to ascertain life of the existing thickener/ modify thereupon.

Samples The following samples were investigated :

- The products generated through the test work on hydro-cyclone (under-flow, **U/F** and overflow, **O/F**) of the materials consisting of classifier slimes (-150 □) and classifier fines (-420 □) at the Joda mines sites (referred hereafter as ***Joda Slime U/F & Joda Slime O/F***, respectively).

- The products generated through the test work on hydro-cyclone (under-flow, **U/F** and overflow, **O/F**) of the materials consisting of classifier slimes (-150 □) and classifier fines (-420 □) at Noamundi mines sites (referred hereafter as ***Noamundi Slime U/F & Noamundi Slime O/F***).

Flocculants : Polyacrylamide based mild anionic & non-anionic very high molecular weight flocculants were used for the flocculation and settling tests. These (water soluble) polymers are well known brands and commercially available. The selection of flocculants were done based on the past experience and the through scanning the literature including the available information brochures.

a) Magnafloc 1011 : Very high mol. wt. anionic polyacrylamide flocculant

b) Magnafloc E10 : Very high mol. wt. slightly anionic polyacrylamide flocculant

These two were manufactured and supplied by *Allied Colloids Limited, PO. Box. 38, Low Moor, Bradford, Yorkshire BD12 0JZ.* (Perhaps Ciba Chemiicals Specialists has been its Indian Agent)

c) RISH- 8100 : Non-ionic polyacrylamide

d) RF –8140 : Low anionic polyacrylamide

These two were manufactured /supplied by *Rishabh Metals & Chemicals Pvt. Ltd. , 4th Floor, Eros, Theatre Bldg. J. T. RD, Churchgate, Mumbai -20.* Further details on the products' characteristics are not available and can be had from the supplier.

Stock solution of 1000 ppm concentration was prepared by dissolving .250 g flocculant in 250 ml distilled water in a measuring flask. This was diluted to 250 ppm by transferring whole of the flocculant solution into a flat bottomed measuring flak of 1000 ml capacity and filling the flask with water up to the mark. *Tap water* was used to make suspension of the material of desired pulp density. Its pH value lie in between 7.4 and 7.6 and conductivity in between 0.56 and 0.60 m moh/ cm. We have taken it density as 1000 kg/ cu.m. for calculation purpose.

Settling Procedure :

Weight quantity of sample was transferred in a graduated measuring cylinder of 500 ml capacity which was filled with exactly 450 ml water. Thereafter, required ml of the flocculant from the stock solution (in case of the tests with flocculants) was added to it. Balance amount of water was transferred to the cylinder so as to reach its level up to 500 mark and its exact volume was measured and noted. The suspension was mixed thoroughly by inverting the cylinder 10 times ups and down while closing the open end of the cylinder with palm. Then it was placed on the table and the settling rate was noted with the movement of liquid/ suspension interface starting from the top (as reference point) as function of time till there was no appreciable movement of the interface as time progressed. The consolidated volume of the thickened slurry was noted exactly after 19 hour and the volume of water (supernatant) remained over the slurry was calculated by difference. pH and conductivity of water and liquid before and after the settling test respectively were also noted.

Parameters & their Calculation

The following parameters were calculated as per standard requirement to calculate the thickener area:

- Settling curve (Height of liquid/ suspension interface in mm vs. time in min.)
- Settling velocity (mm/min.)
- Ultimate pulp density (after 19 hr. of settling)
- Liquid to solid ratio in feed (g/g), and
- Liquid to solid ratio at ultimate pulp density (g/g)

esults:

he settling of Noamundi U/F was immediate while the settling of Joda slime U/F in the uspension at 45%, 55% and 75% PD happened to be an ideal case of plug flow where liquid/ uspension interface was distinctly observed since the beginning.
he results are as follows :

arameters	Pulp Density		
	45%	55%	75%
nitial Water (in suspension). ml	450	431	407
Vater with solid after 19h, ml	98	111	142
ulp density after 19h, kg/kg	2.296	2.477	2.641
iquid to solid ratio , Feed, kg/kg	2.000	1.567	1.085
iquid to solid ratio, Slurry at ultimate PD, kg/kg	0.436	0.404	0.379
ettling rate , m/ h	0.436	0.260	0.180

he study on settling of Joda slime under-flow was conducted in order to explore the pulp density alue at which the maximum of the solid settles per unit time. Besides, operating the hydro-cyclone : lower pulp density of the under-flow stream would provide ease in operation and possibly a harper separation. The rationale being the fact that the quantity of material which moves ownwards in the thickener increases with increasing the solid concentration, but the rate of settling ecreases. Whereas at lower solid concentration the settling rate is higher, but the quantity of aterial which is being settled is lower.

able shows the initial solid flux (Sc), kg/(sq. m* h) of the Joda slimes being settled against the ulp density. It is apparent that within the range considered (45% -75%), the quantity of solid being ettled is maximum when the pulp density was 45%.The initial solid flux (Sc) has been computed om the data on initial solid concentration (Co), Kg/cu.m, and initial settling rate (Qo), m/h as hown below :

Pulp density (PD)	Initial solid conc. (Co)	Initial settling rate (Qo	Initial solid flux (Sc)
wt. %	kg/cu.m.	m/h	kg/ (sq.m*h)
45	450	0.4358	196.12
55	550	0.2603	143.18
75	750	0.1797	134.77

oamundi Slime O/F (Without Flocculant)

able shows the results of the settling in case of Noamundi slime O/F at 8% and 10% PD when no occulant was added.

Table : Settling parameters in case of Noamundi slime O/F (without flocculant)

Parameter	PD 8%	PD 10%
Initial water in suspension (ml)	490	486
Water with solid after 19 h. (ml)	11	14
Pulp density after 19 h (g/g)	3.636	3.571
Liquid to solid ratio of feed (g/g)	12.25	9.72
Liquid to solid ratio of slurry at ultimate PD (g/g)	0.275	0.28
Settling rate (mm/min)	55.57	47.84

Joda Slime O/F (Without Flocculant)

Table shows the settling results of Joda slime U/F at 12%, 14% and 16% PD when no flocculant was added.
Table : Settling parameters in case of Joda slime O/F (without flocculant)

Parameter	PD 12%	PD 14%	PD 16%
Initial water in suspension (ml)	485	485	480
Water with solid after 19 h. (ml)	30	37	40
Pulp density after 19 h (g/g)	2	1.89	2
Liquid to solid ratio of feed (g/g)	8.08	6.93	6
Liquid to solid ratio of slurry at ultimate PD (g/g	0.5	0.53	0.5
Settling rate (mm/min)	28.04	27.73	24.07

Noamundi Slime O/F (10% PD) (Selection of flocculant type)

Table shows the settling results of Noamundi slime O/F at 10% PD when Magnafloc 1011 and Manafloc E10 were used at 0.015kg/T.

Table : Settling parameters in case of Noamundi slime O/F (at 10% PD & 0.015 kg/T FD)

Parameter	**Magnafloc E10**	**Magnafloc 1011**
Initial water in suspension (ml)	487	489
Water with solid after 19 h. (ml)	21	21.5
Pulp density after 19 h (g/g)	2.38	2.33
Liquid to solid ratio of feed (g/g)	9.74	9.78
Liquid to solid ratio of slurry at ultimate PD (g/g)	0.42	0.43
Settling rate (mm/min)	231 (up to 1 min.)	85

It is apparent that the performance of Magnafloc E10 and Magnafloc 1011 was comparable. The liquid to solid ratio was marginally lower and pulp density was marginally higher in case of Magnafoc E10 than those in case of Magnafloc 1011. The intermediate settling rate in case of Magnafloc E10 was higher..

Joda Slime O/F

Table compares the results in case of settling of Joda slime O/F at 12% PD when Magnafloc E10 was used and when RISH 8100 flocculant (the best of the two RISH brand) vis-à-vis without the addition of flocculant. From the Table it is apparent that the performance of RISH 8100 is inferior than that of Magnafloc E10.

Table: Settling parameters in case of Joda slime O/F at 12 % PD

Parameter	PD 12%		PD 12%	
	Without Flocculan	Magnafloc E10, 0.01kg/T	RISH 8100 0.01 kg/T	RF 8140 0.01 kg/T
Initial water in suspension (ml)	485	485.9	485.4	485.4
Water with solid after 19 h. (ml)	30	40.9	40.4	35.4
Pulp density after 19 h (g/g)	2	1.47	1.49	1.69
Liquid to solid ratio of feed (g/g)	8.08	8.1	8.09	8.09
Liquid to solid ratio of slurry at ultimate PD (g/g)	0.5	0.682	0.67	0.59
Settling rate (mm/min)	28.04	110	54.12	31.03

Noamundi Slime O/F at 10% PD (Minimizing the flocculant dosage)

Having established in the previous sections that the performance of Magnafloc E10 was superior than that of RISH brand, attempt was made to further ***reduce*** the flocculant (Magnafloc E10) dosage from 0.01 kg/T to 0.005 kg/T in case of Noamundi slime O/F keeping the fact that the settling rate was higher in this case (Noamundi slime O/F) when compared with Joda slime O/F at the same PD (10% in this case) . . Table shows the results

Table : Settling parameters in case of Noamundi slime O/F *(10% PD, Magnafloc E10)*

Parameter	0.01 kg/T	0.005 kg/T
Initial water in suspension (ml)	491	489
Water with solid after 19 h. (ml)	27	26
Pulp density after 19 h (g/g)	1.85	1.92
Liquid to solid ratio of feed (g/g)	9.78	9.76
Liquid to solid ratio of slurry at ultimate PD (g/g)	0.54	0.52
Settling rate (mm/min)	283 (up to 1 min)	293 (up to 1 min)

From the above Table it is apparent that the settling parameters are comparable when the Magnafloc E10 flocculant was used with dosages 0.01 kg/T and 0.005 kg/T. Hence, the flocculant dosage can be reduced to 0.005 kg/T level in case of Noamundi slime O/F (which is denser than Joda slime O/F).

Noamundi Slime O/F (8% and 10% PD) (Magnafloc E10:0.005kg/T)

Having inferred from the above that the dosage of Magnafloc E10 could be reduced from 0.01kg/T to 0.005 kg/T the effect of the pulp density on the settling parameters using Magnafloc E10 at 0.005 kg/T was studied. Table shows the results. It is apparent that the settling parameters were better at 8% PD using the flocculant Magnafloc E10 at 0.005 kg/T.

Table 13 : Settling parameters in case of Noamundi slime O/F (Magnafloc E10 : 0.005 kg/T)

Parameter	8% PD	10% PD
Initial water in suspension (ml)	488.8	489
Water with solid after 19 h. (ml)	18	26
Pulp density after 19 h (g/g)	2.22	1.92
Liquid to solid ratio of feed (g/g)	12.2	9.76
Liquid to solid ratio of slurry at ultimate PD (g/g)	0.45	0.52
Settling rate (mm/min)	451 (up to 45 s)	293 (up to 1 min)

Joda Slime O/F at possibly minimum of flocculant dosage (Magnafloc E10, 0.005 kg/T)

Having established in the just concluded previous section that the dosage off Magnafloc E10 could be reduced to 0.005 kg/T, the next study was to assess whether the same could be applied to Joda slime O/F, as its settling characteristics are inferior than those of Noamundi slime O/F. Table shows the result at 10% ,14% and 16% PD.

Table : Settling parameters in case of Joda slime O/F (*Magnafloc E10, 0.005 kg/T)*

Parameter	10% PD	14% PD	16% PD
Initial water in suspension (ml)	490	480.8	480.8
Water with solid after 19 h. (ml)	34	40.4	48.4
Pulp density after 19 h (g/g)	1.47	1.73	1.45
Liquid to solid ratio of feed (g/g)	9.78	6.85	6.85
Liquid to solid ratio of slurry at ultimate PD (g/g)	0.68	0.58	0.69
Settling rate (mm/min)	76.84	44.54	45.24

Table compares the settling parameters at 14 % PD for three cases namely,

- When no flocculant was used
- The flocculant dosage was 0.005 kg/T of Magnafloc E10, and
- The flocculant dosage was 0.01 kg/T of Magnafloc E10.

Table : Settling parameters in case of Joda slime O/F (14% PD)

Parameter	Without flocculant	Magnafloc E10, 0.005 kg/T	Magnafloc E10, 0.01 kg/T
Initial water in suspension (ml)	485	479.4	485
Water with solid after 19 h. (ml)	37	40.4	46
Pulp density after 19 h (g/g)	1.89	1.73	1.52
Liquid to solid ratio of feed (g/g)	6.93	6.84	6.93
Liquid to solid ratio of slurry at ultimate PD (g/g)	0.53	0.58	0.66
Settling rate (mm/min)	27.73	44.54	34

From Table it is apparent that a flocculant (Magnafloc E10) dosage of 0.005 kg/T is minimum and also, possibly, optimum as the settling parameters are better than that at 0.01 kg/T or when no flocculant was used.

COMPUTATION OF THICKENER AREA

Several relationships have been developed for the design of thickeners. Among these relationship is the Coe and Clevenger formula :

A = W (F-D) / R S, Where,
A : Thickener area ((sq. m)
W ; Rate of dry solid in feed (t/h),
F; Liquid to solid ratio in feed,
D; Liquid to solid ratio in discharge,
R; Settling rate, m/h
S : Density of solid, (kg/t)

Tables, below, show the settling characteristics (typical ones) of Noamundi slime overflow and Joda slime overflow under the blank condition and when flocculants were used.

Table: Settling Characteristics of Noamundi Slimes Over Flow

Parameter	Without Flocculant	MF E10, 0.005Kg/ T	Without Flocculant	MF E10, 0.005Kg/ T
Pulp density, %	8	8	10	10
Liquid/ Solid ratio of feed (F) (g/g)	12.25	12.20	9.72	9.76
Average settling rate, mm/min.	55.6	450	47.8	290
Average settling rate @, (R) ft./hr	10.95	88.58	9.41	57.1
Liquid/ Solid ratio at ultimate PD (D) (g/g)	0.28	0.45	0.28	0.52
Settling area required per T[1.35*(F-D)/R]	1.48	0.18	1.35	0.22
Settling area req. at 125% of above in Sqft./ T	1.85	0.22	1.69	0.27
Settling area required in Sq m/ T	0.17	0.02	0.16	0.03

Table: Settling Characteristics of Joda Slimes Over Flow at 12% PD

Parameter	Without Flocculant	Magnafloc E10	Rish 8100	RF 8140
Liquid/ Solid ratio of feed (F) (g/g)	8.08	8.10	8.09	8.09
Average settling rate, mm/min.	28	110	54	31
Average settling rate @, (R) ft./hr	5.52	21.65	10.63	6.10
Liquid/ Solid ratio at ultimate PD (D) (g/g)	0.50	0.68	0.67	0.59
Settling area required perT[1.35*(F-D)/R]	1.85	0.46	0.94	1.66
Settling area required at 125% of above in Sqft./ T	2.32	0.58	1.18	2.07
Settling area required in Sq m/ T	0.22	0.05	0.11	0.19

@ : The initial settling rate has been taken here for computation.

It is apparent from the above computation that the computed settling area of the thickener decreased quite significantly when the flocculant was used.

CONCLUDING REMARKS

- Optimum pulp density in case of Joda slime under-flow (so as to result in the maximum solid flux per unit time) has been worked out which is around or below 45%.
- The Noamundi slime O/F needs flocculant at the minimum possible dosage, say 0.005 kg/T of very high mol. wt. polyacrylamide (Magnafloc E10) for the faster settling as well as for better compact volume of the settled solids. The Joda slime O/F needs flocculant at the minimum possible dosage, say 0.005 kg/T of very high mol. wt. polyacrylamide (Magnafloc E10) for the faster settling as well as for better compact volume of the settled solids.
- In case of Joda slime O/F and using the Magnafloc E10 at 0.005 kg/T, 8% pulp density provides better settling parameter. Whereas in case of Noamundi slime O/F and using the Magnafloc E10 at 0.005 kg/T 14% PD is the optimum level (out of 10%,14% and 16% PD) with regards tc the settling parameters.

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