Rheological Properties of Tailings Materials

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Abstract: **Mining and mineral extraction is very important sector of economy but along with that it also leads to production of huge amount of wastes which is called tailings. The main issue is the storage or the disposal of the tailings because if it is not handled carefully it can lead to huge damages. Thus, this report mainly focuses on the flow properties of the tailings what remedial measures can be taken to reduce the failures if it is stored in reservoirs. Various literatures, reports or technical journal has been referred and it is been concluded that flow mainly influenced by the yield stress and the viscosity of the tailing fluid. So, the main focus is to increase viscosity and yield stress so that on failure of any structure flow can be delayed and damages could be avoided. Thus, it is inferred the best solution can be thickening of fluid or making it as non-Newtonian. Also, small size particles can be added and concentration of particles can be increase.**

Keywords— Rheology, Newtonian, tailings, viscosity

I.INTRODUCTION

With the rapid growth of the global economy, demand for mineral deposits has escalated, resulting in a significant increase in yearly mine tailings discharge. The large proportion of the tailings which have been heaped on the land results in the formation of tailings reservoirs, and as tailing dam safety is bad, it leads to devastation as a result of a tailings dam collapsing and causing a catastrophic tragedy beyond estimate. Furthermore, the breach of a tailings dam has all of the hallmarks of a catastrophic event. As a result, in past few years, this has become one of the most hotly debated topics in catastrophe prevention and mitigation.

In mine, tailings are one of the most dangerous hazards. Tailings are the leftovers from the refining of an ore's profitable fraction.

The link between the strain and the stress in the flowing of the tailings, which displays them

kinematic and physical features, is referred to as the rheological characteristics of tailings, and it is a significant aspect of research to analyse the rheological behaviour of tailings. The choice of rheological parameters is critical since they are impacted by specific weight, solid concentrations, slump, tailing/cement ratio, and chemical/physical characteristics of the mill tailings. In this context, assessing the homogeneity and the simplicity with which cemented tailing backfill can be mixed, carried, laid, and compacted while preventing blockage or malfunction of pipelines delivering cemented tailing backfill is critical. Many researches have looked at the rheological behaviour of cemented tailing backfill in terms of consistency, flowability, and workability. The Bingham model, is the model which requires two separate properties to describe the rheological behaviour of cemented tailing backfill, is widely accepted. These properties include yield stress that matches to the shear stress that is required to begin flow of the tailing backfill (cemented) and the plastic viscosity, which characterises the paste/slurry resistance to the deformation of the tailing backfill (cemented) under the influence of certain external stresses.

II.NEED OF STUDY

The tailings obtained from the piled dam are generally in a saturated condition during the functioning of a tailing’s reservoir. When there is a collapse of the tailings dam, the dam and the water in the tailing’s reservoir are released simultaneously. Earthen flow forms, which will have an influence on the reservoir's riparian zone. As a result, studying the rheological features of the tailings was critical in terms of understanding the safety of a tailings dam and the effects of the sludge discharge under the circumstances of a collapsed dam.

Because of the large levels of non-ideal (unclean) suspensions used in the industries like mining, innovative, inexpensive, and transportable rheological methods and techniques were required to test and understand the fundamental flow parameters in both shear and compression rheological behaviour. Furthermore, some previous empirical methodologies have to be adjusted and understood in a more basic way in order for the data to be employed in design. The disposal technique has improved dramatically as a result of greater understanding and use of this rheology.

As there are many parallels between the soil minerals and the tailings, because they're both pore media made up of the particles, there are also significant distinctions. The particles in the two substances differed in size, geometry, and physicochemical qualities. As a result, the rheological features of the tailings have to be thoroughly investigated. The computation of the fluid velocity, rate of flow, and the impact force of the mud-sand flow, as well as the management and prevention of the tailings dam rupture, required the measurement of the rheological parameters.

An accurate assessment of the consistency, workability, and flowability of cemented tailing backfill is essential for assessing the convenience and uniformity by which it can be combined, transferred, deposited, and compacted while preventing blockage or failing of cemented tailing backfill conduits.

The mining sectors are the world's major garbage generators. Most of these wastes are generated as a fine particulate mix that is piped to a storing facility, in which it behaves like a

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Newtonian fluid, usually at a lower concentration. Just extracting, recycling, and reusing water from the slurry is a way to making this enterprise more ecological. The particles show non-Newtonian behaviour, which itself is characterised by shear thinning, yield stress, and, in certain cases, thixotropic behaviour, when the percentage of such slurry increases as a consequence of dehydrating. In the mineral sectors, such incredibly high, nonideal (bad) suspensions necessitated the development of novel rheological methodologies and procedures for measuring and interpreting primary flow parameters.

III.MINING INDUSTRY

Introduction

Most of the things we use are either farmed or extracted. Mining is a vital process for mankind. For the purposes of this report, the mining business includes different minerals, ores and earth materials.

Materials management encompasses both the goods and the packaging the discharge flow as a result Energy consumption and demand of metals rises in the developing world as the population rises and the level of lifestyle rises.

With falling mineral grades across the world, the amount of trash created by the mining sector will grow rapidly, as well as concerns related to its dispersal and administration becoming even more crucial

Extraction Process

Reduction in size, isolation operations, and quality control are the three essential phases in the removal of a required raw component. The output and disposal stream are both part of the minerals management process. It can be shown in fig1.

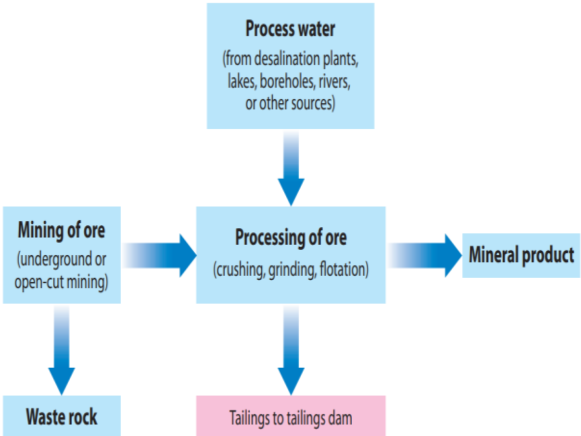

Figure 1: Process of extraction (Boger 2013)

Environmental Effects

The effluent from the procedure of extraction, fine particle tailings, departs the procedure as a small concentration fine-particle solution (slurry). The tailings are piped to lakes, with a few significant outliers where the allowed practise is to dump straight into rivers and oceans. Large, designed structures, such as the one illustrated in (Figure 2a), are created in the trough or with sidewalls. This little red mud dumps reservoir in Hungary collapsed on October 6, 2010. (Figure 2b). The crimson sludge swelled to a height of 2 metres, killing 9 people and injuring 122 others, according to reports. The fine-particle leftover after the separation of alumina from bauxite is known as red mud. At a pH of around 13, this is released. On a massive basis alumina refineries produce about 15,000 tonnes of fine-particle trash each day. This is little in compared to the world's largest copper mine.

Environmentally, the sector has a terrible reputation. Tailings dumps, dam collapses, leakages, unrehabilitated areas, and discharges into waterways are all part of the evidence. There have been 21 reported tailings dam disasters in the last decade at least, compared to 22 in the decade before that. Minimum 268 individuals have died as a direct result of tailings dam accidents in the last five years, yet these tragedies have gone unnoticed by the general public.

Figure 2: (a) red mud tailing in Hungary and (b) 2010 dam failure (Boger 2013)

IV.CASE STUDIES

Tailings Slurries Rheology

Slurries can be classed as Newtonian or non-Newtonian fluids based on their flow characteristics. Under many situations, existing tailings-disposal technique involves pumping low-concentration Newtonian mixtures to a dumping pond in turbulent flow. Usually, slurry and thickening tailings act in a non-Newtonian manner.

The generated shear stress and the shear rate in inelastic Newtonian fluids have a direct proportionality. As shear stress is imposed, flow begins.

A uniform viscosity is indicated by the proportional connection between shear stress and shear rate. In the presence of a yield stress, concentrating mining tailings exhibit non-Newtonian behaviour. The yield stress, is the crucial shear stress that should be surpassed in order for permanent deformation and flowing to occur.

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Figure 3 depicts the differences amongst slurry, paste, and filter cake. The concentrations (weight) and strength (i.e., actual rheological yield stress) are displayed below. For filler product, paste effluent might have yield stress variations ranging from 10-1000 Pa. The alumina production is subjected to a yield stress of 40 Pa. Because yield stress distribution curves can vary greatly even within the similar industry, it is concluded that concentration is not a distinct parameter, but yield stress is.

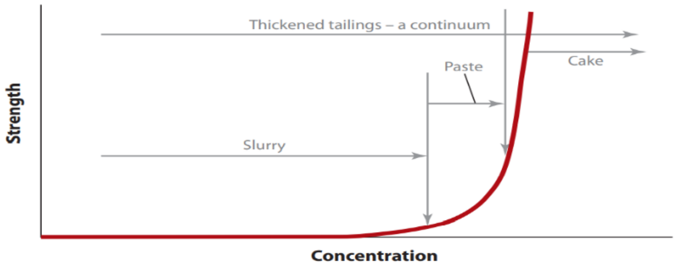

Figure 3: Strength vs concentration curve for slurry (Boger 2013)

For similar yield stress of 20 Pa, the concentration is found to change from roughly 36 per cent weight. to 53 per cent weight. Figure 4. Figure 5 displays yield stress as the factor of concentration for eleven distinct minerals. This variance happens within the similar industry and it differs widely from one industry to the other industry. The concentration ranges from roughly 0.24 (mass fraction) for coal mine tailings to almost 0.68 for copper tailings to 0.8 for mine slope fill material at a yield stress of 200 Pa. Therefore, for same yield stress different tailing have different concentration.

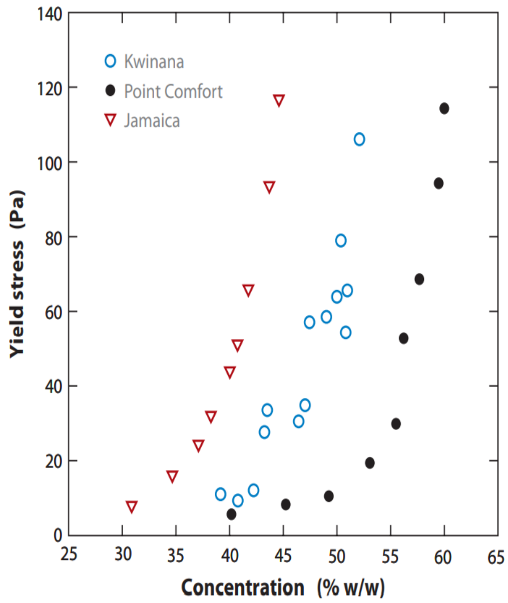

Figure 4: yield stress vs concentration for red mud for different alumina samples. (Boger 2013

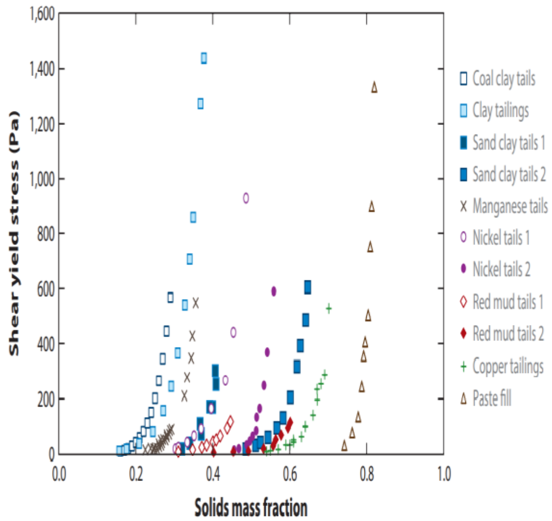

Figure 5: shear yield stress vs solid mass fraction for different minerals. (Boger 2013)

Mineral Tailings Rheology

The study conducted (Wang et. al) considered samples of gold, copper and iron tailings. Tailings are classified as tail silty soil, tail finer sand and tail silty sand as per the standards of particle size distribution. The influence of type of ore, size of particle, plasma concentration and rate of shear on rheological properties is studied.

Type of ore

It can be seen in fig 6 that as the time increasing viscosity decreases rapidly to a certain limit and then becomes constant. The reason is as the rotor started plasma was at rest thus there is some initial viscosity. In fig 7 it can be shown that yield stress increases up to certain limit and then becomes constant. It has initial value almost zero because as rotor started tailing also rotated with it. It was seen that iron ore has maximum impact and copper ore minimum because of difference in internal composition.

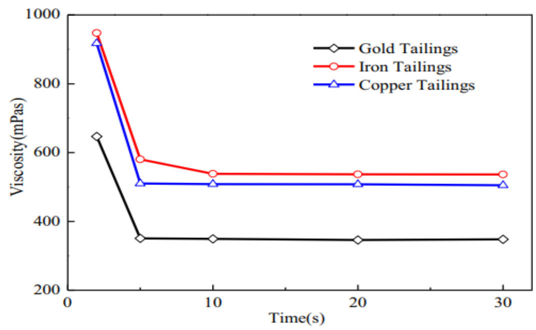

Figure 6: viscosity vs time Wang et.al

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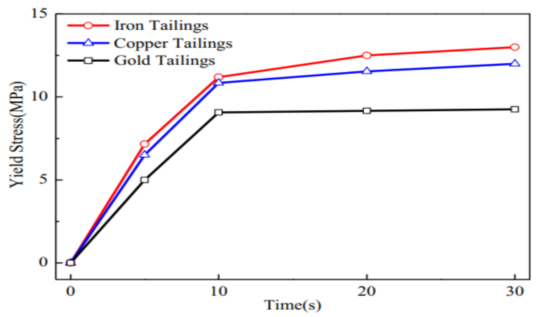


Figure 7: yield stress vs time (WANG et. al)

Particle size

It was seen as the particle size increasing both viscosity and yield stress in fig. 8 and fig. 9 is decreasing because for small particle surface area is more at same water content there will be less flowability and relative slip will be less and hence more viscosity.

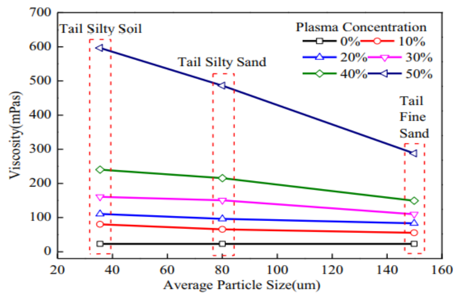


Figure 8: viscosity vs particle size (Wang et.al)

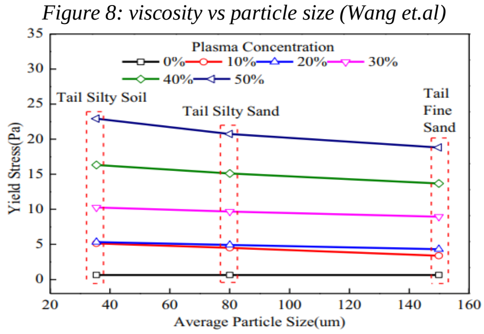


Figure 9: yield stress vs particle size (Wang et. al)

Concentration of plasma

In fig. 10 and fig. 11 it can be seen that as the concentration is increasing both viscosity and yield stress is increasing his could be because with concentration increase distance between particles will decrease thus intermolecular force will increase and hence resistance to flow will increase.

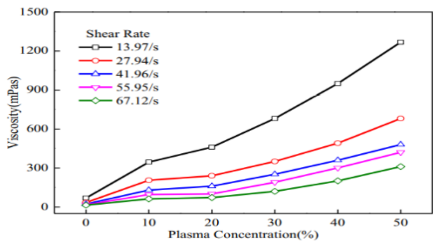


Figure 10: viscosity vs plasma concentration (Wang et.al)

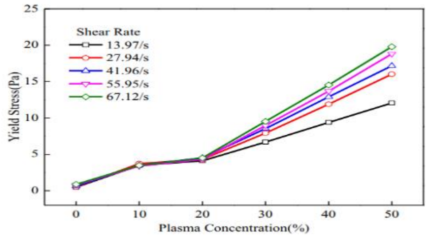


Figure 11: yield stress vs plasma concentration (Wang et. al)

Shear rate

In fig. 12 and fig. 13 it is shown that viscosity decreases while yield stress increases with the increase in shear rate.

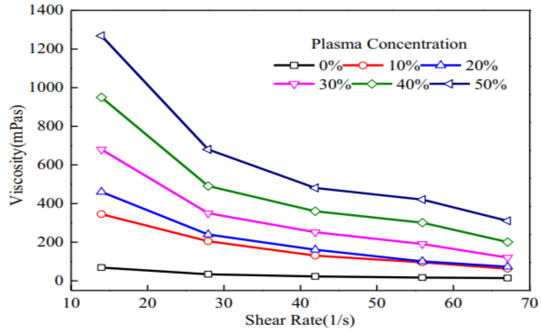


Figure 12: viscosity vs shear rate (Wang et.al)

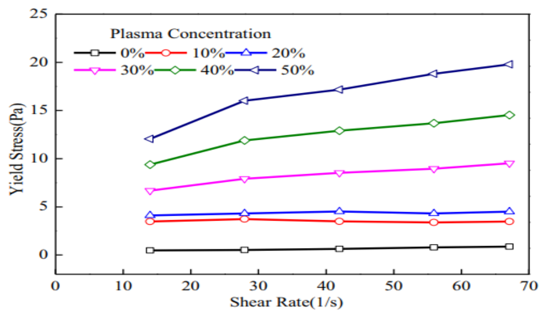


Figure 13: yield stress vs shear rate (Wang et. al)

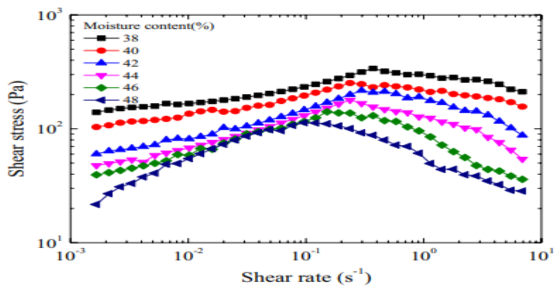
Bauxite Tailings Rheology

Variation of yield stress and viscosity is studied with-

Moisture content

It can be concluded from fig. 14 (a) that shear stress increases up to certain value of shear rate and then starts decreasing the reason could be that tailing could have detached from the plate when high shear rate is applied. It can also be inferred that M.C has effect on tailings behaviour as peak attained is not same at all M.C.

In fig. 14 (b) it is observed that viscosity has continuous decrease with shear rate this is indicated by shear thinning nature of tailings. Also, as M.C increases viscosity is decreasing due to increase in interparticle distance.



(a)

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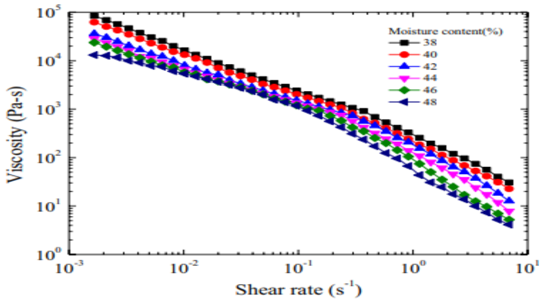
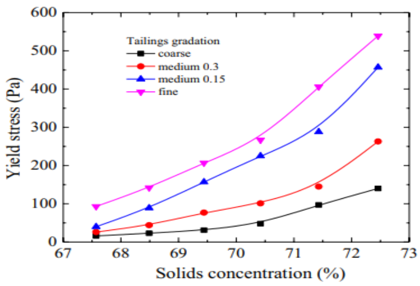


(b)

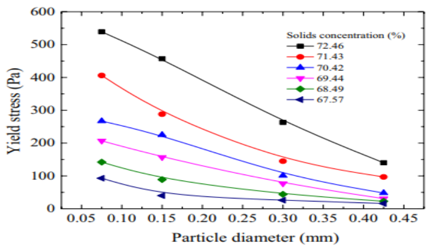
Figure 14: (a) shear stress vs shear rate (b) viscosity vs shear rate (Kumar et al, 2022)

Solid concentration and particle diameter

In fig. 15(a) and fig. 15(b) it is seen that as particle size is decreasing there is increase in yield stress of about 4-5 times at all solid concentration also as solid concentration increased, yield stress increased from 62.5% to 72.5%. Therefore, it is beneficial to add fine particles to red mud slurry as it can increase yield stress and decrease flow.



(a)

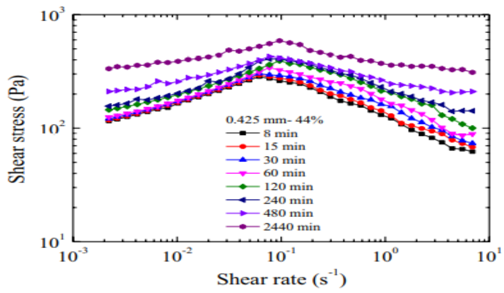


(b)

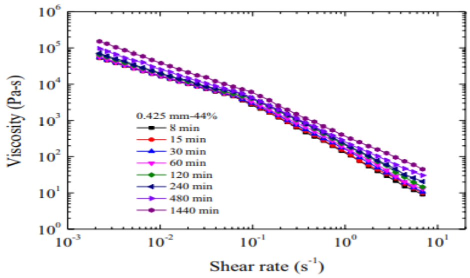
Figure 15: (a)Yield stress vs solid concentration (b) tailing gradation (Kumar et al, 2022)

Times

Study of time dependent nature of rheology of tailing is done because it is necessary to understand and get an idea about time up to which flow will take place after the failure of dam. Dependence on time of yield stress and viscosity is shown in fig 16(a) and fig 16(b). It is also observed that viscosity is more at longer time in comparison to initial time. Therefore, at more time flow will reduce.



(a)



(b)

Figure 16: (a) shear stress vs shear rate (b) shear stress vs viscosity

V.POSSIBLE SOLUTION

Tailings thickening might be a feasible remedy. The idea is to get rid of the water. The idea is simple: at the completion of the operation, water is removed from the trash before it is sent to a dumping place. The characteristics of the suspension shift from Newtonian to non-Newtonian when the moisture is withdrawn. As more water is withdrawn from the system, the material changes from a thick effluent to a paste. The difference between thickened tailings and paste is substantial in terms of rheology.

Figure 17: Paste tailing of iron ore (Boger, 2013)

VI.ADVANTAGES

At plant it increases the water recovery and achievement of high storage density.

It increases stability as it settles rapidly and once it settles it does not segregate.

There is very less requirement of large dams and problem of seepage of water from tailings in groundwater has reduced drastically and thus minimises the contamination of groundwater.

Fig 18. Dry and wet disposal comparison (Boger, 2013)

VII. SUMMARY

- Paste technology is proved to be beneficial for disposal of tailings.
- As the plasma concentration increases, viscosity and yield stress both increases.
- Viscosity decreases while yield stress increases with increase in shear rate especially at high plasma concentration.
- For less particle size yield stress and viscosity both increases. At high concentration curve becomes steeper.
- Rheological properties increase with solid concentration, no response shown ratio of tailing/cement but slump is affected by the ratio.
- Large initial shear stress and strong internal structure is observed for Bingham type rheological model.

VIII. CONCLUSIONS

It can be concluded that it is beneficial to have high concentration with small particle size with low moisture content because it will have high yield stress and viscosity. Also, appropriate shear stress to cohesion ratio is decided to avoid clogging of pipeline.

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