J. S. Afr. Inst. Min. Metall., vol. 93, no. 6.
Jun. 1993. pp. 143–146.

Technical note—The influence of binder addition on the hydraulic transportation of backfill containing full gold-plant tailings

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SYNOPSIS

The addition of binder to full plant tailings significantly affects the rheology of a backfill mixture and, consequently, the pressure gradients in the pipeline. The binder increases the yield stress and apparent viscosity of the mixture, and the transition velocity between the laminar and turbulent flow regimes. In a test conducted at a slurry relative density of 1,72 with binder addition, the mixture also exhibited time-dependent behaviour owing to the hydration of the binder.

SAMEVATTING

Die byvoeging van 'n bindmiddel tot die hele aanleguitskot het 'n beduidende invloed op die reologie van 'n terugvulmengsel en gevolglik op die drukgradient in die pyplyn. Die bindmiddel verhoog die sleurspanning en skynbare viskositeit van die mengsel en die oorgangsnelheid tussen die laminêre- en turbulentevloeiregime. In 'n die toets wat op 'n flodder met 'n relatiewe digtheid van 1,72 met die byvoeging van 'n bindmiddel uitgevoer is, het die mengsel ook tydafhanklike gedrag as gevolg van die hidratering van die bindmiddel getoon.

INTRODUCTION

Cooke *et al.*[1] investigated the influence of binder addition on the hydraulic transportation of backfill slurry containing classified gold tailings. The tests indicated that the influence of the binder on slurry with a relative density of less than 1,75 is negligible for cyclone-classified tailings. However, in a test conducted at a slurry relative density of 1,80, the pipeline pressure gradient increased continuously with time after the binder had been added.

This paper describes an investigation on the effect of the binder on the hydraulic transportation of a backfill slurry containing full plant tailings. The particle-size distributions of full plant tailings and cyclone-classified tailings are markedly different, as illustrated in Figure 1.

EXPERIMENTAL

The test facility and the experimental procedure have been described by Cooke *et al.*[1].

The standard rate of binder dosage in the industry for a slurry of 1,70 relative density is 5,0 per cent dry powder by mass of the wet slurry. This dosage rate has been found to provide an adequate early stiffness for most underground applications. Table I shows the binder dosages for the slurries tested to maintain a constant value of 0,14 kg of binder per litre of total water in the mixture. The required quantity of binder is mixed with water to form a mixture with the same relative density as that of the backfill slurry being tested.

PIPELINE-TEST RESULTS AND DISCUSSION

The test results presented are for a typical backfill slurry containing full plant tailings in a pipeline of 50 mm nominal bore.

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 SA ISSN 0038-223X/3.00 + 0.00. Note received January 1993; revised note received March 1993.

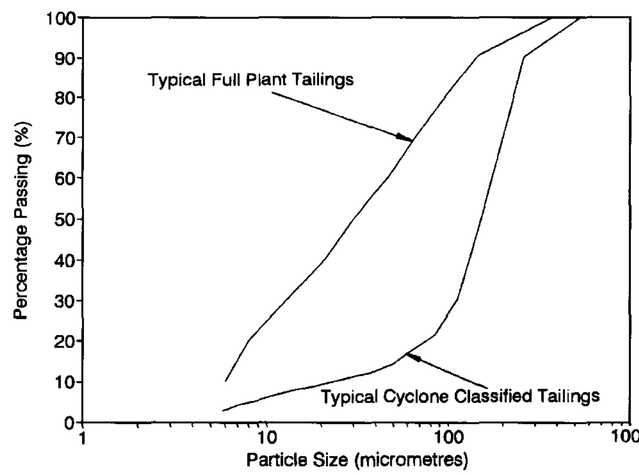

Figure 1—Particle-size distribution in two tailings slurries

Table I
Binder dosages

Relative density of slurry	Binder addition (% dry powder by mass of wet slurry)
1,65	5,4
1,69	5,1
1,72	4,8

Pressure Gradient Versus Pumping Duration

Figures 2 to 4 show how the pressure gradient in the pipeline and the mean velocity of the mixture varied with time at a nominal set mean mixture velocity with binder addition. The variation of the ratio of each individual value to the mean value is plotted against the pumping duration.

Figures 2 and 3 show that there was little variation in the pipeline pressure gradient with time for the tests conducted at slurry relative densities of 1,65 and 1,69 with binder addition.

Figure 4 indicates that there is an increase in pressure gradient of about 10 per cent over a 20-minute period for

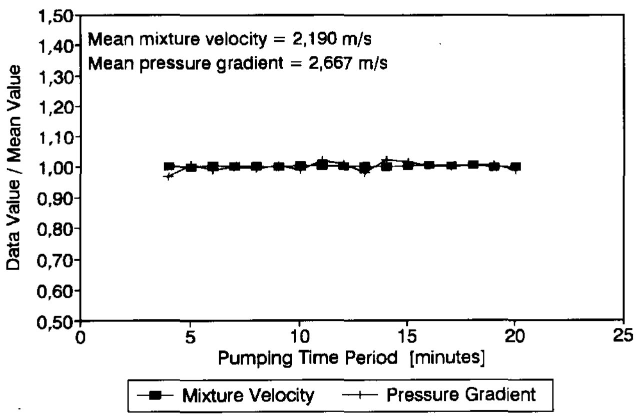

Figure 2—Variation of mixture velocity and pressure gradient with time for a slurry containing 5,4 per cent binder and having a relative density of 1,65

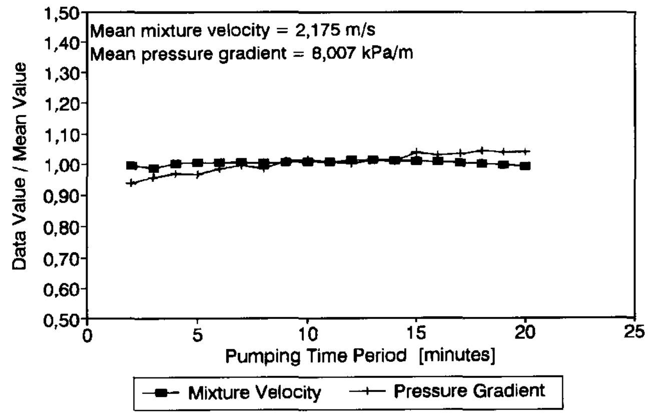

Figure 4—Variation of mixture velocity and pressure gradient with time for a slurry containing 4,8 per cent binder and having a relative density of 1,72

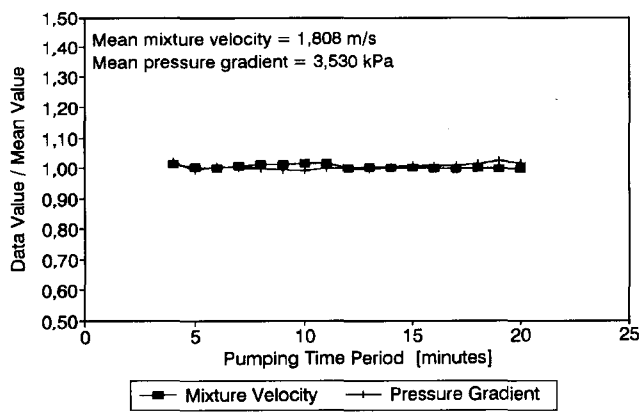

Figure 3—Variation of mixture velocity and pressure gradient with time for a slurry containing 5,1 per cent binder and having a relative density of 1,69

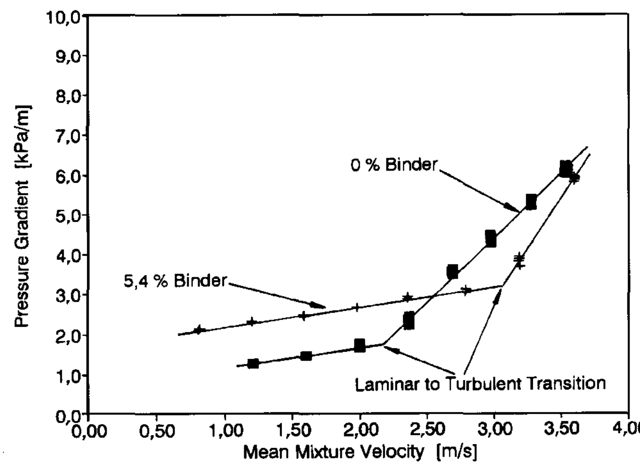

Figure 5—Variation of mixture velocity and pressure gradient for slurries with and without binder at a relative density of 1,65

the test conducted with binder addition at a slurry relative density of 1,72. Thus, 1,72 probably represents the slurry relative density at which the addition of binder, at a dosage of 0,14 kg of binder per litre of total water in the mixture, produces a rheopectic type of mixture (i.e. shear-thickening time-dependent behaviour). It should be noted that this is not a true time-dependent fluid since the changes in rheology are due to the chemical reaction between the binder and the solid particles, and are irreversible.

Pressure Gradient Versus Mean Velocity

Figure 5 compares the variation in pressure gradient with mean mixture velocity for the slurry of 1,65 relative density with and without binder. The addition of the binder modified the rheology of the mixture as follows.

(1) The mean velocity of the mixture at which the flow changed from laminar to turbulent flow was increased, i.e. the onset of turbulent flow was suppressed.
(2) The extrapolated pressure gradient at zero flow was increased, i.e. the yield stress of the mixture increased.
(3) In the turbulent-flow regime, the pressure gradient for the slurry with binder added increased at a faster rate than that of the slurry without binder.

Figures 6 and 7 show the variation in pressure gradient with mean mixture velocity for the tests conducted at slurry relative densities of 1,69 and 1,72 with and without binder. It should be noted that, for the test at 1,72 relative density with binder addition (Figure 7), the pressure gradient increased with time, and thus the curve for pressure gradient versus mean mixture velocity must be regarded as a 'snapshot' at a particular moment during the test. The effect of the binder was to modify the rheology of the mixture as discussed earlier.

Yield Stress Versus Relative Density

Figure 8 shows the variation in the yield stress of the mixture with relative density for the tests with and without binder. The binder caused the yield stress of the mixture to increase more rapidly with increased relative density, compared with the yield stress of the mixture without binder.

Pressure Gradient Versus Relative Density

Figure 9 shows the variation in the pressure gradient with relative density at a mean mixture velocity of 2 m/s (i.e. all the data points in the laminar flow regime) for the tests with and without binder. Table II shows that the pressure gradients in the pipeline increased significantly for the slurry containing binder.

CONCLUSIONS AND RECOMMENDATIONS

The addition of binder to non-Newtonian slurries containing full plant tailings affects the rheology of the mixture by increasing its yield stress, its apparent viscosity, and the

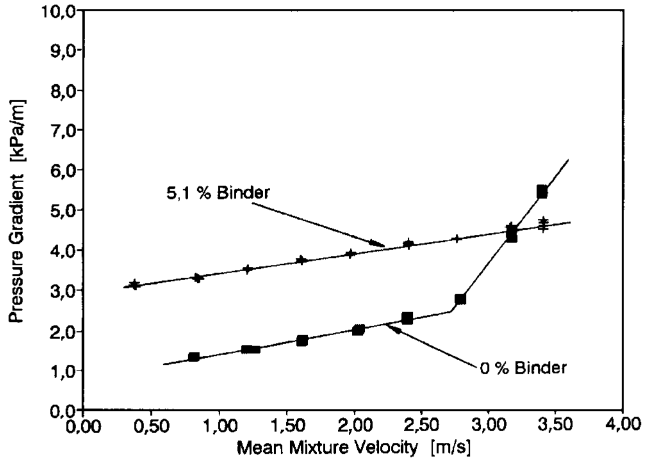

Figure 6—Variation of mixture velocity and pressure gradient for slurries with and without binder at a relative density of 1,69

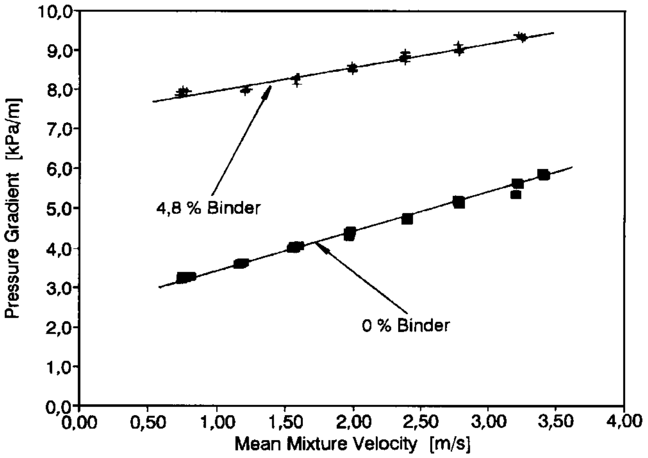

Figure 7—Variation of mixture velocity and pressure gradient for slurries with and without binder at a relative density of 1,72

Table II

Increase in pressure gradient with binder addition (laminar flow regime, mean mixture velocity = 2,0 m/s)

Relative density of slurry	Pressure gradient of slurry without binder kPa/m	Pressure gradient of slurry with binder kPa/m	Increase %
1,65	1,645	2,645	60,8
1,69	1,968	3,839	95,1
1,72	4,387	8,452	92,7

transition velocity between laminar and turbulent flow. Backfill containing full plant tailings and a binder is a homogeneous, simple slurry for transportation by pipeline, although the changes in rheology due to the presence of binders must be taken into account in the design of backfill-distribution systems.

For the slurry containing full plant tailings at relative densities greater than 1,72, the addition of binder at a dosage of 0,14 kg of binder per litre of water produced a rheopectic type of mixture exhibiting time-dependent behaviour.

The amount by which the pressure gradients in a pipeline are increased by the binder depends on the relative density

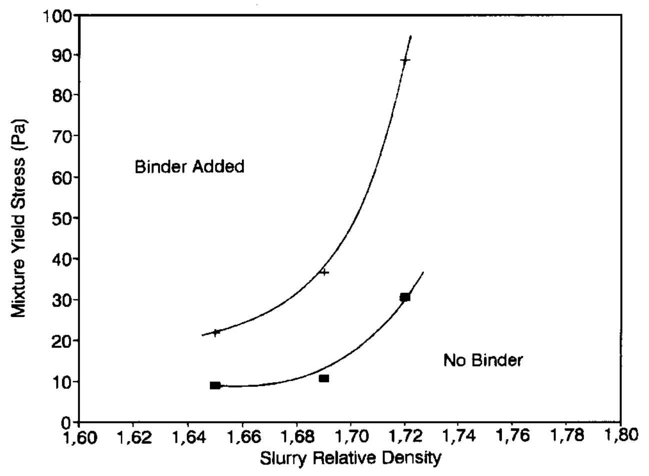

Figure 8—Variation in yield stress and relative density for slurries with and without binder

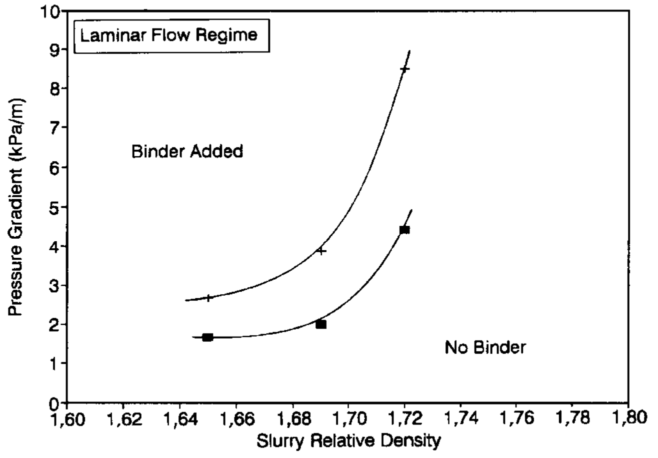

Figure 9—Variation in pressure gradient with relative density for slurries with and without binder at a mean velocity of 2,0 m/s

and mean velocity of the slurry. In certain cases, the flowrate through a gravity backfill-distribution system may actually increase for slurry containing binder because the onset of turbulence is suppressed. Generally, however, in a gravity-flow distribution system, the effect of the binder is to reduce the flowrate of the backfill.

Any backfill system that is to be upgraded to a cemented system should be audited to ensure that the supply of backfill to the paddocks will still be adequate. This would require the rheological characterization of the backfill slurry, at the relative density at which it is to be transported with the binder addition, in a tube viscometer for at least three pipe diameters. A conventional rotary viscometer is not suitable since it will not demonstrate any dependency on pipe diameter that is characteristic of highly concentrated full plant tailings.

For backfills containing full plant tailings at relative densities of more than 1,70, the required dosage of binder should be investigated to establish whether it is possible to use lower rates and thus avoid time-dependent behaviour.

It is probable that the rheology of backfill mixtures is sensitive to the rate of binder addition. It is recommended that tests be conducted on the sensitivity of pipeline pressure gradients to binder dosage rates. The tests would enable tolerances to be established for binder-mixing facilities on mines to ensure that the properties of the backfill slurry remain within reasonable limits.

ACKNOWLEDGEMENTS

This work forms part of the programme on the design of backfill-distribution systems being conducted by the Anglo American Corporation's Technical Development Services. The authors thank the senior management of the Gold and Uranium Division for permission to publish this note.

REFERENCE

1. COOKE, R., SPEARING, A.J.S., and GERICKE, D. The influence of binder addition on the hydraulic transport of classified-tailings backfill. *J. S. Afr. Inst. Min. Metall.*, vol. 92, no. 11/12. 1992. pp. 325–329.

*Steel guide**

Industry can now benefit from a publication compiled by Mintek for Columbus Stainless called 'A guide to the use of 3CR12 in water'. From this work, which is available from Columbus Steel, important aspects such as the localized corrosion behaviour of 3CR12 can be predicted, thereby assisting end-users who wish to know whether 3CR12 will be capable of satisfying their needs in specific aqueous applications.

3CR12 is a chromium-containing corrosion-resisting steel that has been proved to have superior properties to those of carbon steel, and even galvanized steel, in certain corrosion-resisting environments. Since its introduction in 1979, 3CR12 has been used extensively in aqueous environments. Its resistance to general corrosion is often good, because it relies on the formation of a passive film. Its resistance to localized corrosion depends upon a number of interacting factors.

The early recommendations on aqueous applications for 3CR12 were based upon intuition and case-by-case studies. This guide draws together all the research work undertaken by various academic and R&D organizations, particularly Mintek.

The water parameters considered in the guide include aeration and flowrates, suspended solids, scaling, fouling, temperature, pH value, alkalinity, and chloride, sulphate, and nitrate contents. A model predicts the maximum concentration of chloride permitted in water containing sulphate and nitrate before localized corrosion takes place.

* Issued by Mintek, Private Bag X3015, Randburg 2125.

*Mining expo in China**

The first-ever exhibition of South African mining equipment to be held in mainland China has sparked huge interest and support from both the South African and the Chinese mining industries.

SA Minetech '93 is a mining, processing, mineral, and metallurgy exposition and conference, which will be held in Shanghai from 31st August to 4th September, 1993. The exhibitors hope to obtain a share of the 10 million US dollars that the People's Republic of China spends annually to import mining equipment and technology into that country.

According to Mr Robert Moodie, the South African Department of Trade and Industry's representative in Beijing, the exhibition has created strong interest among local governing agencies. 'In particular, the Ministry of Geology and Mineral Resources is supporting the show, and is keen to establish a mining-industry business exchange through this and other avenues', he says.

Official support has also been forthcoming from China's key mining areas—coal, gold, and non-ferrous metals. The China Mining Association (CMA) has thrown its weight behind the show by organizing a national meeting during the exhibition, at which delegates from more than 300 mines will be in attendance. In a lengthy marketing-research document forwarded recently to the organizers of the exhibition, Exhibition Management Services (EMS) of Sandton, the CMA lists a wide range of technology and equipment required by the industry in order to increase its production potential. Foreign investment opportunities are also identified.

A one-day conference is planned to coincide with the exhibition, and the CMA will present two lectures aimed specifically at South African delegates entitled: 'The state of the Chinese mining industry' and 'How to do business with Chinese mining organizations'.

Mintek's director of marketing, Dr P.D. Scott, will assist with the identification of topics and speakers for the conference. He will also sit on an advisory committee, which will ensure that SA Minetech '93 fulfils the needs of the South African mining industry in China. A group tour to the exhibition is being organized by EMS.

According to Mr John Thomson, managing director of EMS, China produces 1,1 billion tonnes of coal a year, and also mines such key minerals as aluminium, copper, gold, iron, lead, silver, tin, tungsten, and zinc. 'Mining machinery and equipment are currently imported from the USA, Russia, and Germany into mainland China', says Thomson. 'However, the Chinese are keen to buy South African equipment because of its quality and competitive pricing'.

Further information about the exhibition and conference can be obtained from John Thomson at Exhibition Management Services on telephone (011) 783 7256.

* Issued by Elspeth Graham & Associates, telephone (011) 442 5603.