Proceedings of the First International Potash Technology Conference, Saskatoon, Saskatchewan. pp. 781-786. October 3-5. 1983

METHODS AND IMPLICATIONS OF A STATE OF THE ART GEOTECHNICAL FIELD INVESTIGATION OF POTASH TAILINGS NEAR LANIGAN, SASKATCHEWAN

D.C. Goodall*, D.G. Fredlund**, and K.N. Lamb***

*Golder Associates, Calgary, Alberta, Canada
**The University of Saskatchewan, Saskatoon, Saskatchewan, Canada
***The Potash Corporation of Saskatchewan Mining Limited, Saskatoon, Saskatchewan, Canada

ABSTRACT

A detailed geotechnical field investigation of the potash tailings which have been spigotted in a pile to a maximum height of 22 m above ground surface near Lanigan, Saskatchewan was conducted in October 1982 in conjunction with research studies at the University of Saskatchewan. Innovative application of new and proven techniques was directed to the *in situ* investigation of the potash tailings and underlying foundation, to the recovery of relatively intact tailings samples, and to the assessment of the hydrogeologic environment of the tailings and foundation soils beneath the tailings.

Observations and results of the field investigation indicate that the tailings are dense and cemented throughout their depth and that the degree of cementation increases with depth, particularly beneath the brine/water table. The thermal regime in the tailings appears to exert a significant influence on the degree of cementation.

The tailings are largely unsaturated with only a minor amount of hydrogeologic mounding occurring towards the centre of the tailings pile. Electrical logging indicates that brine contamination of the foundation may have occurred to depths of 13 m. There is some evidence of strength enhancement of the soil foundation by the brine.

KEY WORDS

Geotechnical; potash tailings; sampling; downhole geophysical logging; cementation; brine migration; foundation strength enhancement.

INTRODUCTION

Accumulation of sodium chloride tailings on ground surface adjacent to Saskatchewan potash plantsites is an environmental concern. All waters in contact with such tailings form brines which, if not adequately isolated, can contaminate local and regional surface and subsurface waters.

A paucity of data concerning tailings properties, the influence of brine on the properties of natural geologic strata, and the migration of brine to regional aquifers is currently precluding comprehensive tailings facility design. Obvious questions which should be answered pertain to the stability of the tailings pile and adjacent brine containment facilities, to the short and long term impacts of the

brine on Saskatchewan's water resources, and to the potential use of tailings underground as backfill. To this end comprehensive laboratory and mathematical modelling is currently underway at the University of Saskatchewan on behalf of the Potash Corporation of Saskatchewan. The experimental and innovative field investigation which was conducted at a typical site to initiate this research, as well as the implications of its findings, is the subject of this paper.

SITE DESCRIPTION

The tailings facility selected for study is located east of the Potash Corporation of Saskatchewan Mining Limited Lanigan plantsite which is situated about 100 km east-southeast of Saskatoon. General layout of the site is shown on Fig. 1.

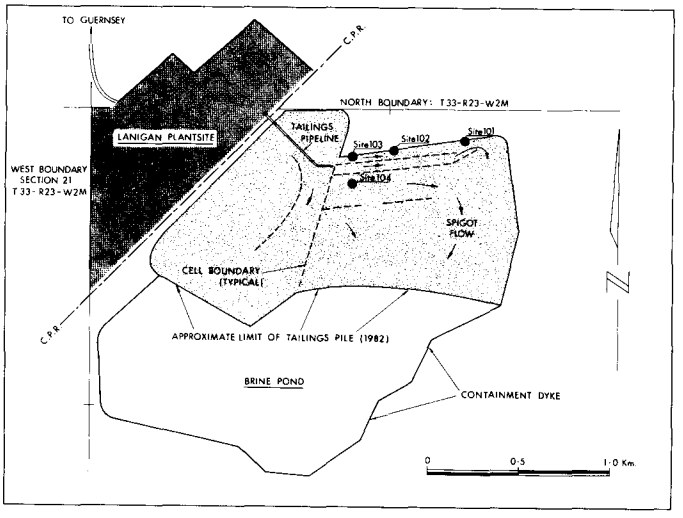

Fig. 1 Site location plan.

About 20 million tonnes of tailings have been deposited in the 270 hectare tailings containment facility since operations began in 1967. Current annual tailings production is about 2.5 million tonnes. The tailings pile has been constructed by progressive raising of the hydraulic spigot discharge which has been generally located in the north central area of the pile where tailings have been deposited to current elevations as much as 22 m above the original ground surface (see Fig. 1). The tailings are deposited in east-west strip cells which are bounded on the north and south by dozer-placed low dykes constructed of tailings.

The Lanigan tailings facility is located on a flat to gently undulating plain which dips locally to the south at about 2.5 m per kilometre. The site is founded on 1 to 7 m of glacio-fluvial soils which are underlain by up to 180 m of dominantly till glacial drift.

FIELD INVESTIGATION PROGRAM

Four principal sites were investigated in October, 1983 as shown on Fig. 1. Three of these (101, 102, 103) were located along the north edge of the tailings pile (tailings depths varying from 4.5 to 21.5 m). The fourth site (104) was located near the middle of the pile where the tailings were about 15 m thick. A summary of the investigation program is provided on Table 1.

TABLE 1 Investigation Program

Item	Tailings Thickness (metres)	Depth of Investigation (metres)	Monitoring Installation	+ Remarks
BH 101A	4.6	14.0	piezometer	A,E,N cased to 6 m
BH 101B	4.6	4.9	standpipe	A,C
BH 102A	15.1	16.9	piezometer	A,C,S, dry cement seal
BH 102B	15.2	21.4	piezometer	C,S,Z
BH 102C	>7.9	7.9	standpipe	A
BH 102D	15.2	27.5	piezometer	E,G,S,Z
BH 103A	>21.3	21.3	piezometer	A, sonic in diesel
BH 103B	21.6	32.4	inclinometer	G,S,Z
BH 103C	21.2	21.3	piezometer	dry zeogel seal, C,D,Z
BH 103D	>9.1	9.1	standpipe	pressuremeter, A
BH 104A	14.8	15.0	piezometer	A,S
BH 104B	>7.6	7.6	standpipe	A
BH 104C	14.9	21.8	piezometer	C,E,S,Z
BH 104D	14.9	27.9	piezometer	E,G,S,Z
BH 104E	15.1	29.0	piezometer thermistors	C,E,Z
AH 104F	15.1	15.2	--	B, 1.07 m shaft
TP 104-1	>4.4	4.4	--	B

\+

A denotes air drilling
B denotes block sampling
C denotes coring
D denotes oil based mud drilling
E denotes E-logging
G denotes comprehensive geophysical
N denotes water and bentonite drilling
S denotes Standard Penetration tests
Z denotes attapulgite and brine drilling

All items designated BH were drilled with a rotary rig. To avoid tailings dissolution and borehole enlargement, air, brine and attapulgite, or oil base drilling fluids were employed.

AH 104F was a 1.07 m diameter augered shaft which was excavated using a piling rig. TP 104-1 was a test pit which was excavated using a dozer equipped with ripper.

Coring

Two 1.5 metre run length HQ core barrels were used for coring the tailings and foundation soils. Both coarse tooth carbide insert and face discharge side slotted diamond bits were used, the latter being the most successful. Although expensive, coring with diesel based drilling fluids appeared to give the best quality and quantity core recovery in the tailings. Brine and attapulgite were only slightly less successful. Coring with air circulation was generally unsuccessful due to inadequate return of cuttings to surface.

Standard Penetration Tests

The Standard Penetration Test is commonly used in geotechnical soils investigations including those for tailings. This test is not well suited for potash tailings investigations due to the cementation of the tailings. Typically more than 50 blows of the standard hammer were required to advance the sampler a distance of 76 mm beyond the bottom of the borehole and in many instances no sample was recovered.

Abnormally high blow counts were also observed in the tailings pile foundation soils; these may reflect strength enhancement of the foundation by brine migration.

Piezometer Installations

Standpipe piezometers were installed in several boreholes (see Table 1). 50 mm nominal diameter schedule 80 PVC pipe was used for all installations. Typically the bottom 1.2 m of the standpipe was 0.25 mm machine slotted and wrapped in filter cloth to form the screened interval. This interval was backfilled with 20 to 40 sieve size silica sand and was isolated from the remainder of the borehole by displacing the borehole fluid with brine based, sulphate resistant cement and attapulgite grout. In general considerable care is required for the installation of grout seals to ensure that brine from the tailings deposits does not leak down the borehole and contaminate natural soil deposits at depth.

Inclinometer Casing

63.5 mm diameter ABS plastic inclinometer casing was installed in borehole BH 103B where the maximum slope height of free standing tailings (21.6 m) occurs at the Lanigan site. The inclinometer casing was installed to a total depth of 32 m and was grouted in place using a cement rich grout similar to that used for the piezometer seals. This casing remains intact some 8 months after installation.

Thermistors

Ten thermistors were vertically distributed in borehole BH 104E to a maximum depth of about 29 m. These thermistors were grouted in place and are intended to monitor the thermal regime of the tailings and underlying foundation.

Test Pit TP 104-1

A test pit was excavated to a depth of about 4.6 m at site 104 using a dozer and ripper. Block samples were carved from the wall of the test pit using a chain saw as is used for cutting wood. Excellent quality samples were obtained using this method.

Shaft AH 104F

The shaft was excavated through the 15 m thickness of tailings at site 104. Initially it had been hoped that a 1 m diameter core barrel, which is commonly used for developing pile sockets in bedrock, could be used for coring the tailings. This method was abandoned after several unsuccessful attempts. Instead block samples were recovered at 1.5 m depth intervals from the unlined shaft wall using the proven chain saw (electric) technique of block sampling. Samples could not be taken below a depth of about 11.3 m due to brine in the shaft. Again excellent quality samples were obtained.

Pressuremeter Tests

A Menard pressuremeter test was conducted in borehole BH 103D at a depth of about 4.5 m in the tailings. The borehole was advanced using a 114 mm diameter tricone bit with air circulation. The strength of the tailings was not exceeded when the 380 mm length probe was inflated to its 25 bar limit and therefore the results only provide an indication of the tailings modulus of elasticity.

The use of the pressuremeter at greater depths in fluid filled holes is considered feasible in view of consistent borehole gauge. A higher inflation capacity is necessary to monitor response beyond the pseudo-elastic range.

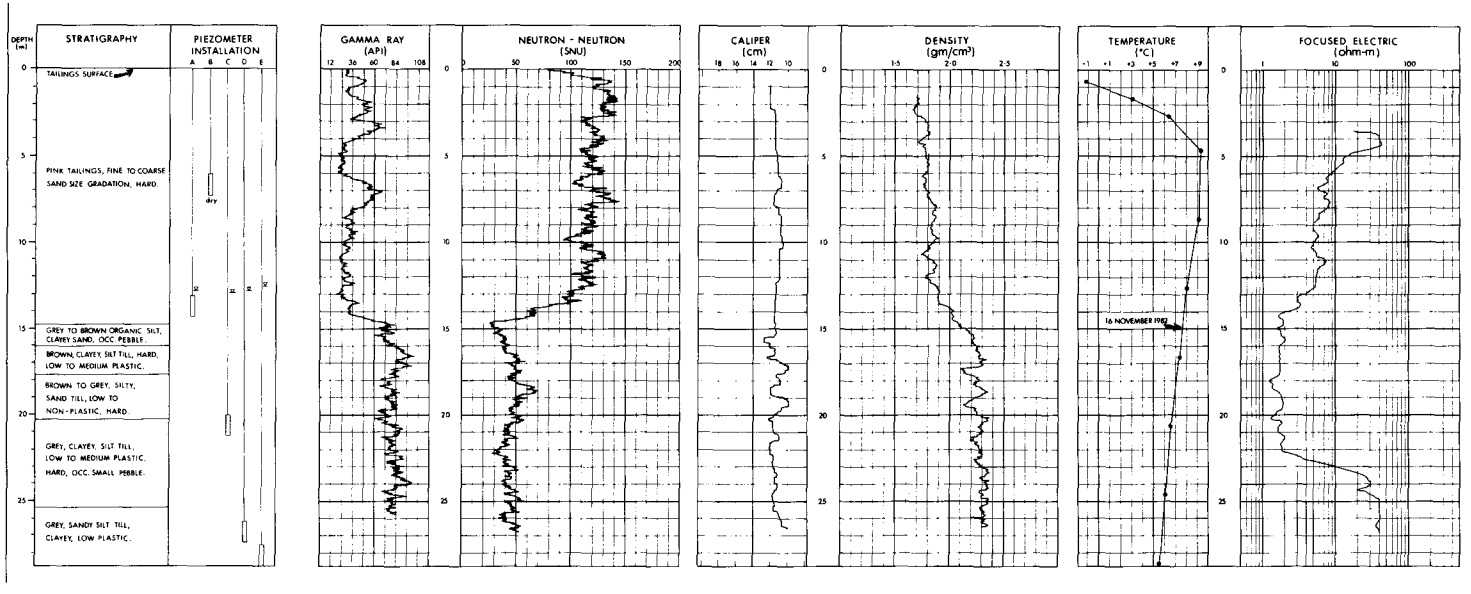

Fig.2 Tailings Pile and Foundation Geotechnical Profile (Site 104)

Downhole Geophysical Logging

Neutron, gamma, focused electric, caliper and density geophysical logs were run in boreholes BH 104D, BH 102D and BH 103B. The logging was performed in boreholes filled with brine based drilling fluids which have a density of about 1.4 g/cm^3 and is unusually high in terms of conventional downhole logging techniques. Correction of the density tool response for borehole fluid and size was automatically made by the logging unit software.

A sonic log was unsuccessfully attempted in the same boreholes where the other logs were obtained. A short tailings interval of borehole BH 103A appeared to be successfully logged when the hole was filled with diesel fuel. Indications are therefore that the tailings can be logged using a sonic tool provided that low density borehole fluids are used. Nevertheless the low velocity nature of the tailings is such that the sonic tool must function at the limit of its capability and its successful application to tailings has yet to be proven.

RESULTS SUMMARY

A summary of the observed stratigraphy, piezometric conditions, downhole geophysical logs and themistor data for site 104 which is located near the centre of the tailings pile (see Fig. 1) is provided on Fig. 2. Note that tailings had not been spigotted at this location for at least two years prior to the investigation.

IMPLICATIONS

1) The tailings can be cored using a rotary rig and diamond coring bit with brine or oil based drilling fluids.

2) Boreholes to depths of about 15 m can be advanced in the tailings using a rotary rig with air circulation although coring with air circulation proved unsuccessful.

3) The tailings are dense and cemented. Standard penetration tests can provide an indication of *in situ* tailings condition but downhole geophysical logging and pressuremeter testing are of more value. Observations of increased cementation with depth, particularly below the brine/water table, correlate with a decreasing temperature profile.

4) The tailings are well drained with only minor mounding of brine. Perched brine tables occur near the spigot streams.

5) Excellent samples of the tailings can be obtained using a chain saw to carve blocks from the walls of shafts and test pits.

6) Vertical brine migration through glacial drift of as much as 13 m has been indicated by geophysical logging at the Lanigan site in spite of negligible hydraulic gradients.

7) Strength enhancement of the tailings pile foundation soils appears to have occurred and correlates with the interpreted brine migration profiles.

ACKNOWLEDGEMENTS

The support of Mr. D.K.J. Noonan and other Golder Associates colleagues is gratefully acknowledged. Financial support for the field investigation and permission for publication was granted by the Potash Corporation of Saskatchewan. Appreciation is extended to BPB Instruments Ltd., of Calgary, Alberta and Hayter Drilling Ltd. of Watrous, Saskatchewan for their contributions to the field programme.