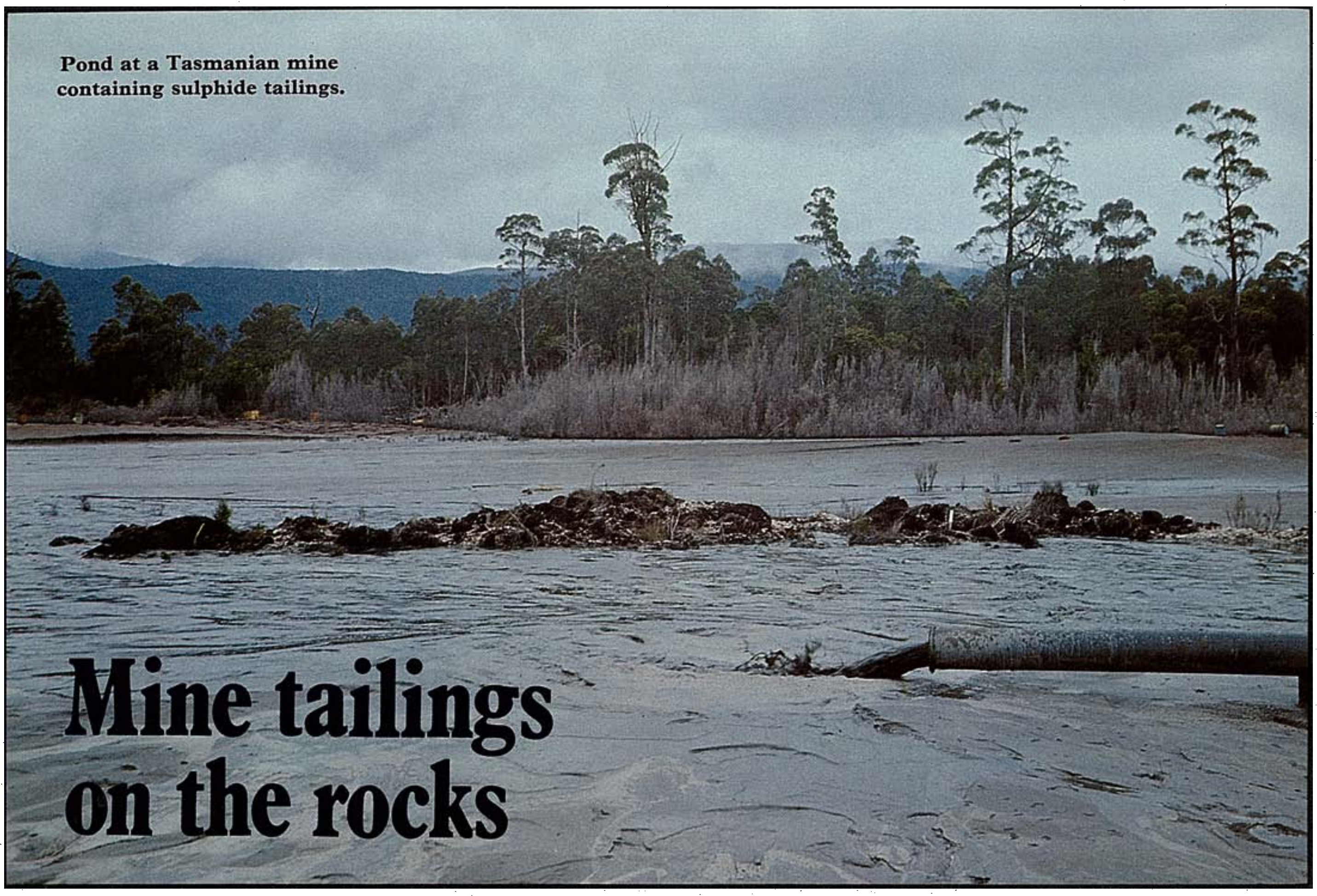


Pond at a Tasmanian mine containing sulphide tailings.

Mine tailings on the rocks

Unsightly heaps of rock waste and ponds of tailings are common sights at many of our metal mines. Years ago the public accepted them as part of the price of full employment and prosperity in the region, but now there is increasing pressure on the mining companies to do something about them.

The rock waste can often be used underground as mine fill, but disposing of the tailings is not quite so simple. These wet sandy residues are produced at a flotation mill where the broken ore is ground and the metal extracted. They may contain large quantities of sulphides, which often oxidize on contact with the air and form hard cement-like crusts. For a number of reasons, the slimy tailings must often be dumped in large ponds, which increase in number and size each year.

Six years ago, a group of researchers in the CSIRO Division of Mineral Chemistry at Port Melbourne began tackling the waste-disposal probem in a mine in western Tasmania.

The company concerned extracts the valuable metal from the sulphide ore, producing large quantities of tailings containing 40–70% iron sulphide in the form of pyrrhotite.

The researchers have come up with a solution that may solve this disposal problem and at the same time increase ore recovery from the mine. Recovering the maximum amount of ore at the minimum cost is a challenge facing the designers of all mining systems. Inevitably, some ore has had to be left underground as a safety measure to control ground movements.

The system used in the Tasmanian mine—and at others—involves excavating inclined drives to get down to the ore bodies and then cutting further drives into the ore bodies themselves to win the metal.

Pillars of rich ore are left between each mining level and the next.

As they take out the ore, the miners create open stopes (see the diagram). They use the rock waste from the mining operation as a working platform, which rises up as mining progresses.

Although it provides a firm base for further upward mining, the waste is not strong enough to completely support the surrounding rock. Pillars of valuable ore are left between each mining level and the next to improve stability.

Waste not, want not

The first task facing the scientists from the Division was how to get rid of the tailings waste. The team, led by Dr George Lukaszewski, had for several years worked on the oxidation of sulphides and observed their ability to set solid once they came into contact with air.

They proposed using the tailings as a natural cement, either alone or mixed with the existing rock waste. This would produce a stiff, durable, and cheap fill, while at the same time reducing the size of the tailings ponds. If the fill was sufficiently strong, it would allow the ore-rich vertical pillars to be mined without any threat of subsidence.

Cementing by oxidation was not a new idea. It had been used in the 1930s

As it turned out, the samples tested had very high compression strengths, very similar to those of concrete.

at a number of Canadian mines, but at the time it had met with several problems. These included the reduction of oxygen in the stopes, self-heating produced by the oxidation process, noxious sulphur dioxide fumes, and acid drainage water.

However, the group, through their earlier work, felt they could minimize these problems by correctly formulating and placing the fill in the mine under controlled conditions.

The self-cementing properties and strength of a fill made from sulphide tailings are due to the natural oxidation of the sulphides, which consume the oxygen in the air spaces between the rock fill.

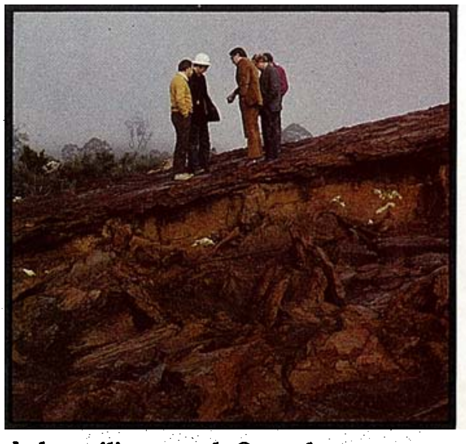
Rapid oxidation causes rapid production of heat. But the group believed that, by controlling the porosity of the rock fill and thus the availability of air, they could control the oxidation process and the rate of heat production. They felt that the heat produced could be slowly dissipated by evaporation of moisture from the rock fill and by absorption into the surrounding rock wall.

Starting small

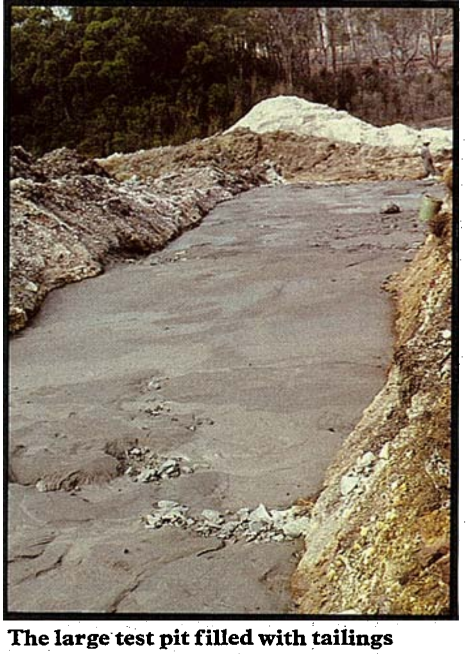
Initial laboratory work set out to find the optimum conditions for self-cementing of the tailings, and also their ability to cement other locally produced wastes. Dr Lukaszewski and his colleagues, Mr David Jenkins and Mr Bob Flann, also wanted to establish a formula for the combination ratios of rock waste and tailings to produce a strong and stable fill.

At first they worked on a very small scale. They tested more than 250 mixes (composed mainly of typical sulphide tailings), casting and curing each in containers in the laboratory. The smallest samples were 3–4 cm in diameter and 6–8 cm high, which made it difficult to evaluate the suitability of the mixes for filling a space some billion times greater in the mine.

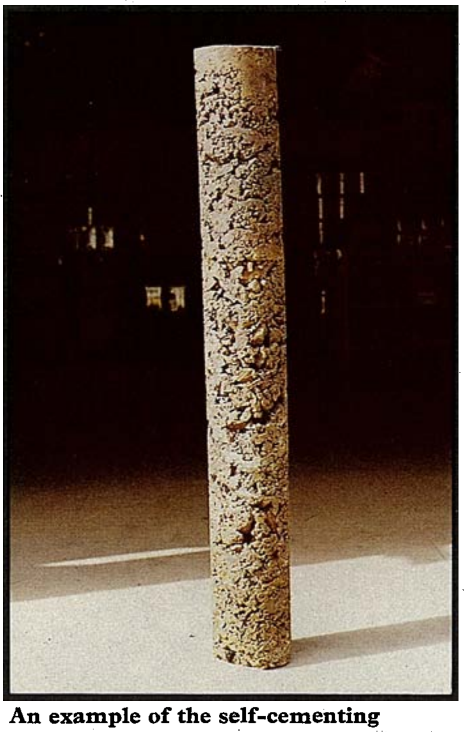
As it turned out, the samples tested had very high compression strengths, ranging from 7000 to 41 000 kilopascals —very similar to those of concrete, and



A dry tailings pond. Once the water has gone, the slime sets like concrete.



The large test pit filled with tailings and rock waste. No heating has occurred so far and it appears to be curing alright.



An example of the self-cementing mine fill produced by mixing rock waste and tailings.

Some of the rock waste.

much greater than those found in the mixture of tailings and Portland cement used as fill in some mining operations. They ranged well above the accepted mine-fill strengths of between 700 and 1700 kPa.

In fact, the laboratory equipment was unable to cope with some of them, and so the team also used the test facilities of the Aeronautical Research Laboratories in Melbourne.

Moving up the scale

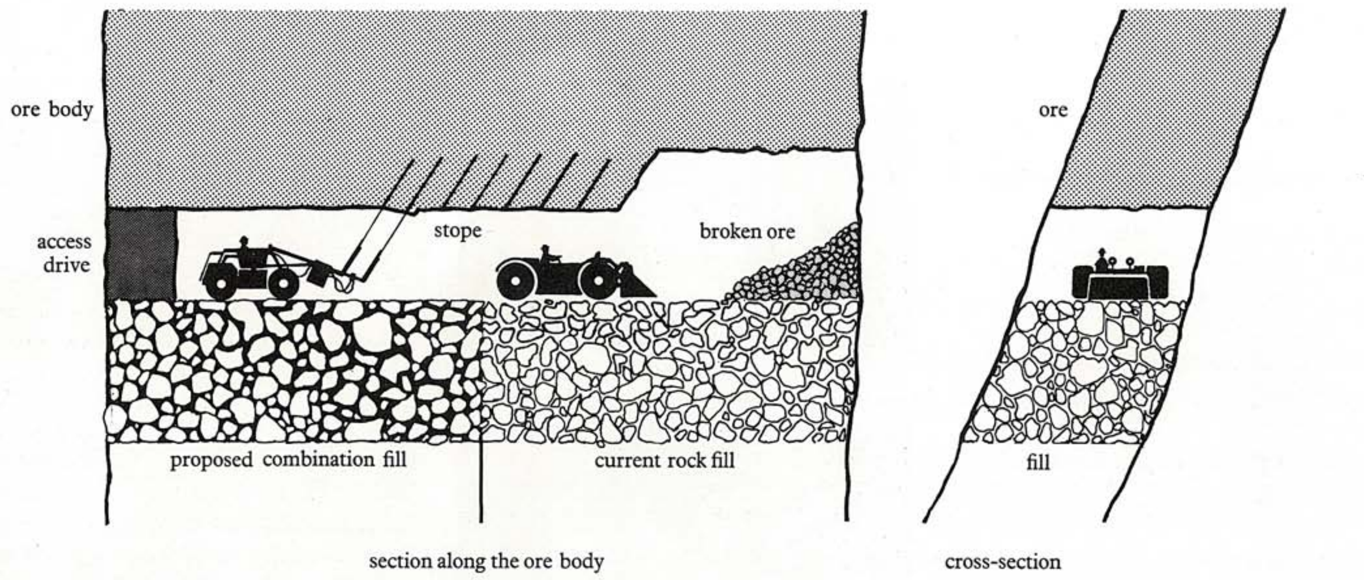
The favourable results prompted the group to begin tests on a much larger scale. They prepared six samples in 44-gallon drums, and found the strength varied with the percentage of tailings in the mix and the size of the air spaces in the fill. The higher the percentage of tailings and the smaller the air spaces between the rock fill, the stronger the mix became.

They carried out humidity tests, which showed that it was possible to cure the mix at relative humidities higher than those experienced in most mines. However, curing at lower humidities reduced the curing time and gave an increase in strength. Further tests showed that a rise in curing temperature also reduced the curing time and increased strength.

It appeared that under most underground conditions the fill would set in a satisfactory manner. No overheating occurred, and no sulphur dioxide was given off in any of the laboratory studies.

They next looked at the method of mixing the rock waste and the tailings. They had been batch-mixing the two before filling the moulds, but this method would be too labour- and equipment-intensive on a large scale. So Mr Jenkins began experimenting with percolating the tailings directly into the rock waste. At this stage, the team decided they needed to actually carry out experiments on site at the mine. They wanted to make

How the mining fill could be used



The research group proposes replacing the rock fill currently used with the much stronger self-cementing mix.

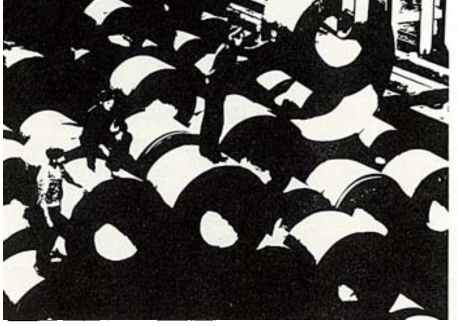
sure that self-cementing still took place at the high humidities and low temperatures that might be experienced in the Tasmanian mine.

Initially they prepared 20 samples, 50 cm in diameter, and placed them to cure in 44-gallon drums. They put moisture gauges in four of the samples to measure evaporation, and thermocouples in four of them to monitor any self-heating. They found that temperatures did not rise above normal (and after a year the moisture levels had dropped from 20 to 2%, while humidity varied from 79 to 96%).

The team then decided to go ahead with tests on a still larger scale. Last November, a pit was dug near the mine and, to simulate operations carried out underground, they filled it with rock waste in two stages. First they added a layer of rock waste 2 metres deep and percolated tailings from the flotation plant directly into this. Then they repeated the operation, adding another layer of rock and tailings.

They used inspection wells to make sure the tailings reached the bottom of the pit, while thermocouples and soil moisture gauges were placed in the fill. Since then, staff at the mine have read these regularly.

The readings have shown that no self-heating has occurred, and curing is taking place. Sulphur dioxide has been detected at only one spot and then only at a concentration of 5 p.p.m. Further tests on the material in the pit will begin later this year, with help from the Division of Applied Geomechanics in Melbourne.



The ore left in supporting pillars represents a lot of tinplate like this.

Samples of mine fill being placed to cure underground in 44-gallon drums.

They percolated tailings from the flotation plant directly into the rock waste.

From their preliminary investigations, Dr Lukaszewski and his group believe that self-cementing fills could be used at a number of places in Australia. Many mining operations produce mineral sulphides that tend to oxidize naturally and self-cement, but tailings containing pyrrhotite are the most effective for bonding together rock wastes.

Apart from the one in Tasmania, mining companies at Tennant Creek and Kalgoorlie, for example, produce pyrrhotite tailings. The group believes that it is technically feasible to percolate such tailings into mines already filled with rock wastes. Thus companies may be able to extract large quantities of hitherto-unavailable ore economically and safely, and at the same time dispose of the troublesome tailings.

More about the topic

Sulphides in underground mine filling operations. G. M. Lukaszewski. *Proceedings of the Australian Institute of Mining and Metallurgy Jubilee Symposium on Mine Filling, Mount Isa,* 1973, 87–96.