CORROSION OF AN ASBESTOS CEMENT SEWER RISING MAIN DUE TO HYDROGEN SULPHIDE

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ABSTRACT

In 1994 a new sewage pump station used a redundant 24 year old asbestos cement water main as its rising main. In the reverse direction, this main now had a crest along its length after which it acted as a drain. In 2011 the pumping system was altered, subjecting this pipeline to minor pressure increases and within a few hours, the rising main suffered two bursts just downstream of the pipeline's crest. This pipeline had no recorded bursts over its life.

Samples of the repaired sections were inspected and corrosion of the top of the pipe from the inside, was evident. The cause was attributed to sulphide attack in the gas head space above the sewage in the section of main where only part full flow was ocurring. The difference in pipe condition between the invert and obvert was due to the regular rinsing of accumulating acids from the invert only. Other samples of the rising main prior to the crest, revealed an AC pipe in perfect condition.

Westernport Water has another similar rising main that is planned for inspection in 2012. It is believed that other water corporations may also have asbestos cement or cement lined rising mains that are subject to this mechanism of corrosion.

1.0 INTRODUCTION

In 2011, Westernport Water commenced a project to repair corroded concrete within the wet well of the Rhyll Corner Sewage Pump Station (SPS). In order to undertake these works, this SPS was required to be taken offline and bypassed. The Rhyll Corner SPS has no gravity catchment, instead it receives from three sewage rising mains, one of which is the 150mm Asbestos Cement (AC) from Hastings St SPS in Rhyll. Once the bypass was in place, the static pressure for all rising mains was increased. Within a few hours a burst was reported on the Hastings St SPS rising main approximately 4.5 km along its 5km length. Why did this happen?

2.0 DISCUSSION

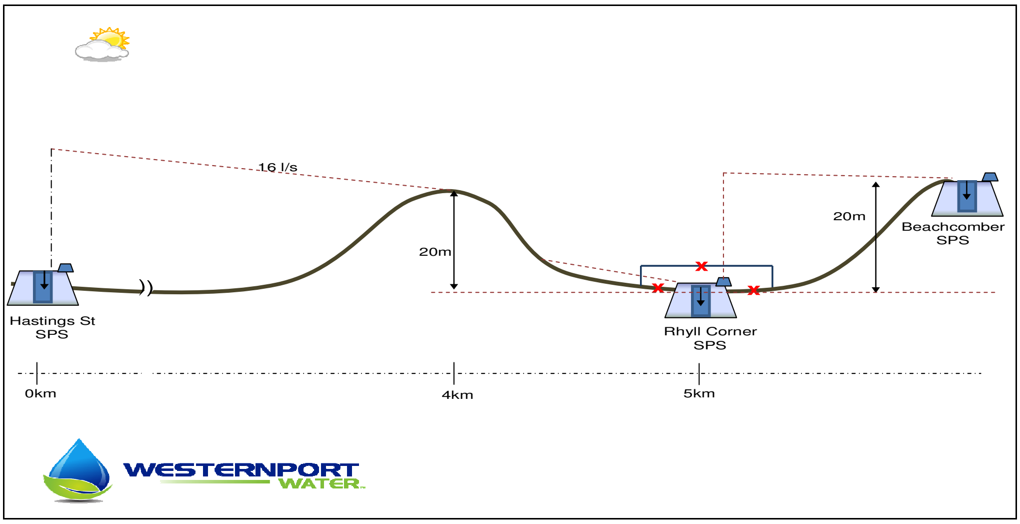
2.1 Pipeline History

The township of Rhyll on Phillip Island, Victoria, received town water in 1970 via a 150mm AC water supply main, operating at 110 metres head. In 1994, Rhyll was sewered and a new 225 mm water supply main was constructed to the town. The original 150mm AC water supply main was then used as a rising main, carrying sewage from the new Hastings St SPS, to the Rhyll Corner SPS 5 km away. By 2011, this AC main had no recorded bursts for 24 years as a water main and none for the next 17 years as a rising main.

2.2 Pipeline Hydraulics

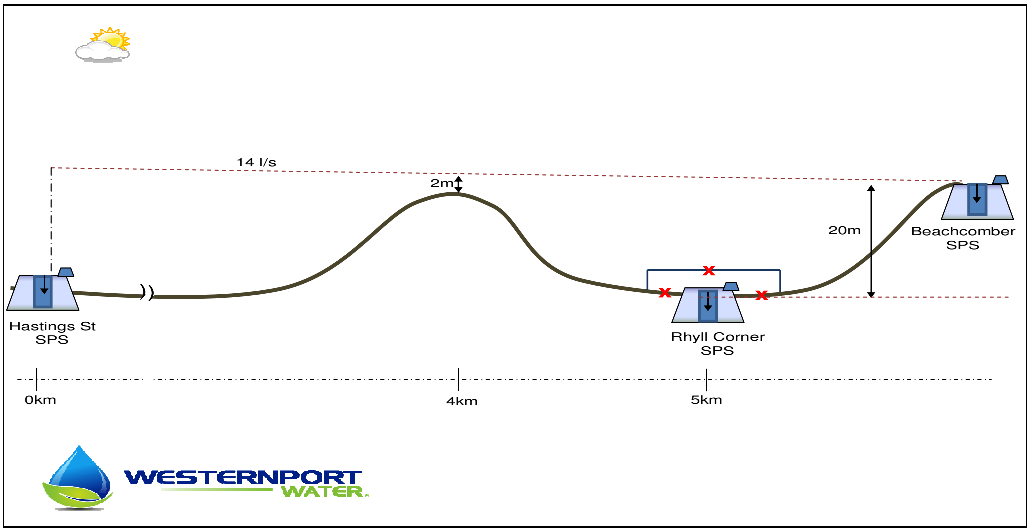
The geometry of the 150mm AC pipeline, now acting as a sewage rising main, is shown in Figure 1.

In summary it is a 5 km long main, rising to a crest at the 4 km mark then falling to the Rhyll Corner SPS. At the design pumping rate of 16 l/s, the pipe runs only part full at the crest with the sewage free draining over the last 1km of its length.



<u>Figure 1</u>: ***Longitudinal Section with HGL at 16l/s***

It is possible to bypass the Rhyll Corner SPS and when bypassed, the static head at the Rhyll Corner SPS increases by 20 metres, with only minor impact on the Hastings St SPS rising main. The pumped flow decreases to 14 l/s, reducing pressures along the first 4km of its length, and the crest experiences full pipe conditions. The final 1 km of the pipeline is subject to minor pressures of up to 20 metres, as shown in Figure 2.



<u>Figure 2</u>: ***ByPass Mode with HGL at 14l/s***

The first burst on the rising main was reported within a few hours of operating in bypass mode, at chainage 4400 m, approximately 600 metres from the end. The burst occurred in a section of main that had not operated full and under pressure for the past 17 years.

A burst on the Hastings St SPS rising main was only briefly considered during the risk assessment for the concrete repair project because it was a Class D AC pipe rated at 153 metres head.

Further to this, the pipeline had not incurred a single break in its entire life as both a water main operating at 110 meters head and as a sewer rising main.

2.3 Investigation

This was more than a burst main. It was a burst sewage rising main resulting in a sewer spill. This incident required thorough investigation to understand the failure mechanism in order to ensure that it did not burst again. A debrief was immediately arranged involving civil engineers, a mechanical engineer, technical officers and maintenance staff. These initial discussions brainstormed possible reasons for the burst.

Did a trapped air pocket compress and burst the pipeline?
The last 1 km of this main has not operated under pressure for 17 years, so was the air valve at the crest working? Was it seized in the closed position? Was it a sewage air valve or the original water style air valve? Our maintenance team confirmed that it was a sewage air valve and a site visit confirmed that it was functioning correctly.

Was there already a fracture in the main at the burst location?
Given that this section of main does not run full, there could have been a break in the top of the main, from an excavator bucket or post hole auger for example. Our maintenance team reported that the burst was fairly messy with the top blown out of the pipe, so a pre existing hole was hard to prove.

Have soil conditions softened the AC main?
There are areas of coastal acid sulphate soils on Phillip Island which may have attacked and weakened the pipeline. Our maintenance team who repaired the burst confirmed that it was difficult to cut the AC with chain cutters because areas of the pipe were soft.

2.4 Findings

The broken AC pipe was inspected more closely. Once the top and bottom of the pipe were identified, it became clear that the bottom of the main was very hard and dark, and the top of the main was a softer white material as shown in Figure 3.

Figure 3: ***Section of removed AC Pipe, clearly showing a corroded pipe wall***

Our mechanical engineer who was investigating odour and concrete corrosion in sewage pump stations at this time, suggested that the problem could be due to hydrogen sulphide corrosion.

This was an interesting theory, which begged the question - *Does asbestos cement pipe corrode in a sewer environment?*

According to James Hardie and Co 1981, asbestos cement pipes are a blend of water, asbestos silicates, portland cement and pulverised silica (very fine sand) resulting in a new range of hydrated calcium silicates that are chemically inert. This text also mentions that damage has occurred to sewerage systems designed without regard for the harmful effects of hydrogen sulphide, but did not elaborate any further. A brief internet search found various articles pertaining to corrosion of concrete structures in the sewer environment, but nothing directly related to corrosion of asbestos cement in sewers.

The more it was debated at the debrief, the more it made sense. If sulphides can corrode the cement from concrete, leaving the sand and aggregate to crumble away, then it is feasible that sulphides could also corrode the cement from the asbestos cement pipe, leaving behind an asbestos containing material with reduced bond strength. It was concluded that the top of the pipe in the final 1000 metres of this rising main was likely to be corroded and that the main would burst again. A short while later, a report was received of a second burst about 100 metres from the first. The bypass works were postponed and the rising main was returned to its normal operation.

Broken pipe from the second burst was better preserved and it was neatly cut then immersed in clear epoxy paint, and is shown in Figures 4 and 5. This section shows the lower half of the pipe being unaffected, then gradually corroding more and more from the half pipe until the 19 mm wall thickness is reduced to 3 mm at the top of the pipe. The corrosion is clearly occurring from inside the pipe.

Figure 4: ***Section of AC Pipe, showing gradual corrosion of pipe wall***

Figure 5: ***Section of AC Pipe, showing a crack along the top of the pipe***

The mechanism of sulphide corrosion in sewers is complex however in simple terms, bacteria in the sewage converts sulphite to sulphide which creates hydrogen sulphide gas in the presence of air. The hydrogen sulphide then reacts with moisture to form sulphuric acid on the concrete surface/pipe wall which breaks down the bonding capability of the cement by leaching its calcium, causing softening and loss of mechanical strength. This causes the collapse of whatever aggregates the cement is binding together.

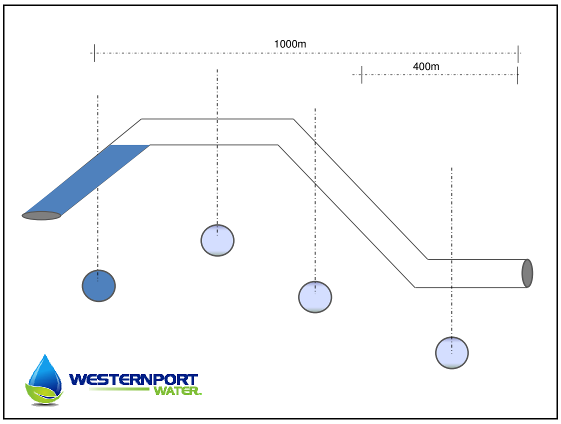
Figure 4 shows the lower half of the pipe in perfect condition because it was flushed every time the pump operated and the pipe ran half full. The top half of the pipe however, never ran full and the obvert was always damp due to the moist nature of part full sewers with insufficient ventilation.

Taking the Rhyll Corner SPS offline for an extended period was dependent on this rising main withstanding the minor pressure increase resulting from the bypass. This did not eventuate as shown in Figure 5. This gap in asset knowledge resulted in two sewage spills and the delay of essential repair works on the Rhyll Corner SPS.

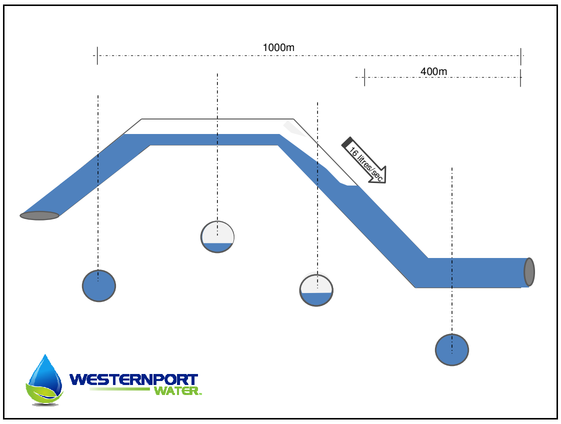
2.5 Further Pipeline Testing

The investigation at this point suggested that only the section of pipe between chainage 4000 m to 4600 m would be corroded. In order to confirm the condition of the entire rising main, several additional sections of pipe were excavated, removed and inspected, with the following results:

- ⇒ Chainage 2000 m (2km before the crest), the pipe was in perfect condition.
- ⇒ Chainage 3600 m (400 m before the crest), the pipe was in perfect condition.
- ⇒ Chainage 4200 m (200m past the crest) the pipeline was in poor condition with severe corrosion of the obvert only.
- ⇒ Chainage 4700 m (300 metres from the end), the pipe was in good condition although the top of the pipe was found to be softening on the inside.



<u>Figure 6</u>: ***NO FLOW in the final 1 km of the rising main***



<u>Figure 7</u>: ***PART FULL FLOW in the final 1 km of the rising main***

Figure 6 shows the final 1 km of the rising main, a few minutes after pumping has stopped. The pipe is full up to the crest and is therefore rarely exposed to hydrogen sulphide. The section from the crest to the end is empty and always subject to hydrogen sulphide.

Figure 7 explains why the sample taken at 300 metres from the end of the rising main showed a pipe in good condition. When the pump is operating, the pipe only runs part full to a point approximately 400 metres from the end, washing recently formed acids from the invert of the pipe only. After this point, the main runs full due to the small amount of head required to drive 16 l/s along the remainder of the pipeline, regularly washing both the bottom and the top of the pipe in the final 400 metres of main.

The corrosion inside this particular AC rising main can be compared to that in the wet well of a sewage pump station, where the concrete walls generally only corrode above the pump START level. Above this level, the concrete walls can be exposed to hydrogen sulphide but are generally not washed, similar to the top of the AC pipe at the crest.

Below the pump START level, concrete corrosion is generally minor because it is only exposed to hydrogen sulphide for short periods then the walls are regularly washed by the water level rising due to inflow, similar to the AC pipe at the end of the main.

Below the pump STOP level however, the concrete is never exposed to hydrogen sulphide because it is normally under water, similar to the AC pipe prior to the crest.

2.6 Solution

The final 1 km of the Hastings St SPS rising main was replaced by pipe cracking the 150mm AC main with a new 180 mm HDPE pipe. The testing of the various sections gave us confidence that the first 4 km was in excellent condition and not in need of replacement at this time. Even though the final 400 metres was in relatively good condition, it was decided to replace the entire section of the main from 100 metres before the crest to the very end. This was considered to be a better solution than only replacing to the point where the main actually stopped corroding by conducting further pipe sampling which involved the cutting of more AC pipe. Simply exposing the top of the main and observing the outside of the pipe would not have detected this type of corrosion because it occurs from the inside.

3.0 CONCLUSION

Westernport Water has another AC sewage rising main with a critical crest that creates part full conditions at normal pump flows. This pipeline is scheduled for cutting and inspection of the inside in 2012. This corrosion could also occur with concrete or cement lined rising mains that run part full, or that have closed air valves that eventually cause an air pocket to be formed at a high point that would otherwise run full.

During our investigations, limited information about sulphide corrosion of AC pipelines was found, therefore this investigation is documented here so that other water corporations may be more aware of the issues associated with asbestos cement sewage rising mains. This investigation is significant because it highlights a set of circumstances where a critical crest on a rising main, maintained a perfect pipe on one side and within 17 years, created imminent failure on the other.

4.0 ACKNOWLEDGEMENTS

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