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Feedback

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Rastatt TBM drive collapse and failure of its segmental lining

Aug 2017

Article references

Ground freezing TBM drive collapse in Germany - TunnelTalk August 2017
Discussion Forum: Rastatt collapse raises a list of queries and concerns - TunnelTalk August 2017

Feedback from: Rupert Sternath

One can see out of the available publications that the segments of the lining have dislocated some 40m behind the TBM. This is an indication that the ring gap has not been filled properly. As this happened to an experienced contractor it may be the case that the grouting operation together with the TBM drive through a frozen soil includes some particular problems.

Mining through an ice body has the characteristic of a hard rock drive, which requires some over excavation to enable shield steering.

Most shielded TBMs use grout lines through the shield tail to fill the annual gap immediately behind the tail seal. Under hard rock conditions the mortar tends - due to the over excavation - to flow around the body of the TBM and to the front and into the working chamber and so leaving voids outside the segmental lining. These voids have to be filled by a secondary grouting operation through the segments as soon as possible from the top of one of the trailing gantries.

In case of a frozen soil outside the gap however, it may happen that the voids are being filled by groundwater ,which would also freeze, and as heat is present inside the tunnel during the mining process, the ice in the gap may melt leaving the segments unsupported. In this case filling of the gap by blowing pea gravel through the segments combined with a cement grouting operation may be a better option in my view.

Anyway, the tunneling world is keen to see the outcome of the following investigations and very interested on further reports in TunnelTalk about them!

Regards,
Rupert Sternath
Stern Consult
Holzhamer Bogen 15 83624 Otterfing

Feedback from: David Caiden

In the discussion about the Rastatt collapse incident, mention has been made to some classic tunnel collapses and refers to precast concrete (PCC) segmental lining failures. But is it truly a "failure" in the usual sense of the word if the lining collapses under a load for which it was never designed nor intended?

Consider this: A car gets flattened by a meteorite - would we say the body shell had "failed"? I doubt it. We would say it was "flattened by a meteorite".

What I am talking about here is running or flowing ground and I am reminded of the collapse in Hennessy Road during the Hong Kong Island Line construction on 1st January 1983. The hole in the rock face through which the CDG flowed under water pressure was no bigger than a fist when the flow started. But the flowing ground opened it up so much with abrading material that we ended up with a full size street lamp within the debris in the tunnel.

My point is that flowing ground is an immensely destructive force similar to rushing floodwater. PCC linings are designed for static ground forces in the permanent cases and handling and building forces for the construction stages. They are not designed to withstand immense dynamic and changeable flowing ground forces with a battering of cobbles and other debris. The approach we take to overcome this disregarded loading case is to take measures to prevent ground flows. Naturally when these measures are unsuccessful the PCC ring will not hold up.

Regards,
David Caiden
Arup

Feedback from: Nick Shirlaw

Thank you for the write-up on a major failure, which appears so far to have had limited press coverage, despite the severe impact on train operation.

As far as I am aware, this is the fourth incidence of catastrophic segmental lining failure behind a pressurised TBM in the last eighteen years; these being:

- Hull wastewater transfer tunnel, UK [1999]
- Cairo, Egypt [2009]
- Okayama, Japan [2012]
- Rastatt, Germany [2017]

I know of two other cases of severe, local, distortion of gasketted, concrete segmental tunnel linings, in Singapore and the USA, where total failure was avoided by providing additional support in the tunnel.

Given the huge number of segmentally lined tunnels built over the last 18 years, the proportion that has failed is tiny; and in each case the failure has been local, without similar problems on the rest of the drive. However, the consequences of each of the failures have been catastrophic.

To date, the best documented of the failures is that at Hull, which was the subject of an investigation that was summarised in Grose and Benton (2005)[(1)]. Even in this case the investigation was limited and the conclusions tentative.

The paper was the subject of a number of discussions, to which I contributed, and which elicited detailed responses that contained much additional information to that in the original paper[(2)]. In my opinion, the conclusions were inconsistent with some of the observations made in the tunnel; I stated this in a further discussion, which was submitted, but rejected by the journal on the basis that they did not accept a second round of discussions.

The failures at Cairo and Okayama have been the subject of a number of articles in TunnelTalk, but I have not seen any definitive explanation of causation.

This limited response to these failures can be compared with that to the failure of the cut-and-cover tunnel at Nicoll Highway in 2004 in Singapore. This was the subject of a public inquiry, which published clear, extensive and detailed findings that have had a major effect on practice in Singapore.

Because the failure of segmental linings is so rare, those listed above have each occurred in different countries. As far as I am aware each has been assessed in isolation. I hope that the detailed results of the investigation into the failure at Rastatt are made public, but this will take months or years, based on previous experience. Given that there have been several failures there does appear to be a case for reviewing them together, to see if there are any common features, and lessons to be learned.

Even though these events are very rare, the consequences are so severe that we, as an industry, need to make sure that the relevant lessons are learned and the likelihood of another incident reduced.

1. Hull wastewater flow transfer tunnel: tunnel collapse and causation investigation, Grose and Benton, 158, October 2005, Issue GE4, Proceedings of the Institution of Civil Engineers, Geotechnical Engineering

2. Hull wastewater flow transfer tunnel: tunnel collapse and causation investigation, discussion report, Ground Engineering, Volume 159 Issue 2, April 2006, pp. 125-128.

Sincerely,
Nick Shirlaw,
Golder Associates,
Singapore

References

Germany: Ground freezing TBM drive collapse in Germany - TunnelTalk August 2017
Japan: Five feared dead in Japanese tunnel collapse - TunnelTalk February 2012
Japan: Possible causes of Japan's fatal tunnel failure - TunnelTalk March 2012
Japan: Salvage team recovers Japan disaster TBM - TunnelTalk Sepember 2013
Egypt: Cairo Metro tunnel collapse - TunnelTalk September 2009

Feedback from: Lok Home, President, The Robbins Company, from the company website blog

"I was inspired to write for the company blog following announcement that Elon Musk is entering our business—the tunnel boring business. It is great to see people with a vision of an improved world enter our industry. I agree with Musk that the advance rate of tunnels can be significantly improved if development money comes into the industry. Development money in tunneling, however, is at best minimal and is more often essentially non-existent. Nearly all tunnels are heavily specified to avoid risk taking by owners (therefore discouraging new development). Nearly all tunnels go to the lowest bidder and low bidders try to buy the TBMs at the lowest price; a further discouragement of development. The industry has therefore been slow to improve advance rates, but with Musk bringing the issue into the spotlight, perhaps things will change."

Lok Home
President
The Robbins Company

Design and performance of cast-in gasket discussion continues

Feb 2017

Article reference: New technology to avoid segment cracking - TunnelTalk February 2017

In response from Steve Casey, B.Sc MIMMM C.Eng, Sales & Technical Director, VIP to the Feedback contribution below from Peter Tiedemann of Dätwyler:

VIP recognises Dätwyler as a longstanding manufacturer of high quality tunnel segment gaskets. Both our organisations have made significant contributions in the development of high performance tunnel segment gasket design and manufacture. In response to Peter's comments, we would like to clarify the following.

VIP cast-in tunnel segment gaskets, created using the technology outlined in the original TunnelTECH Modern seals for segment lining integrity article on TunnelTalk in May 2016, do not have 'soft corners'. The advantage of the VIP approach is that the corner performance in terms of compressibility is consistent with the rest of the gasket, with proven sealing performance as demonstrated in recent contracts secured by VIP.

Using solid corners, by definition, exhibit a different compression behavior, compared to the rest of the gasket, and may lead to performance issues. The ability to create a gasket corner angle equal to that of the segment, as opposed to 'forcing' a solid right angle corner to work on acute or obtuse segment corners, is self-evidently a better option. The inventive steps in the VIP gasket fabrication process, relates to how the extruded lengths of gasket are joined to form the gasket corners. This unique process is the result of the development work VIP has undertaken, which requires bespoke manufacturing equipment exclusive to VIP.

Steve Casey, B.Sc MIMMM C.Eng,
Sales & Technical Director, VIP Polymers

The debate concerning the design and performance of cast-in sealing gaskets for tunnel lining segments continues with feedback on a VIP Polymer News Release article published on TunnelTalk from Peter Tiedemann of competitive gasket supplier Dätwyler.

Tiedemann contends that producing "soft corner is easy, but [the design] has no water tightness performance. The importance is to find the balance of a strong corner with high water tightness performance and in consideration with concrete strength and other parameters."

He adds that: "The cutting [technique] mentioned is done already for years" and that "if doing it now, then they are years behind".

The track record for the design, manufacture, production and application of cast-in segmental lining gaskets is relatively limited but growing steadily. The topics were discussed in the Modern seals for segment lining integrity TunnelTECH article on TunnelTalk in May 2016.

Share your comments and experiences of researching or working with the technique via our Feedback facility.

References

Modern seals for segment lining integrity - TunnelTalk May 2016

Considering the real costs of driving TBMs into predictably difficult situations

Article reference: TBM rescue for Tapovan hydro challenge - TunnelTalk December 2016

Feedback from: Dr Nick Barton

Dear TunnelTalk,
Maybe those contemplating long TBM drives into predictably difficult conditions should consider the time delays likely to be incurred for dealing with fault zones, and the deceleration of TBM progress as the drive advances. These two realities are, and have been, largely ignored by the industry these last 15 years.

My lecture for the ISRM (International Society for Rock Mechanics), entitled TBM Performance: From Best to Not So Good and Why, addresses these issues squarely and may be of interest to your readers.

With regards,
Dr Nick Barton

ISRM lecture by Dr Nick Barton - ISRM, September 2015
(Note: Lecture begins at 04.50 after the introduction)
Freeing stricken TBMs in tough Asian conditions - TunnelTalk, March 2012
Subsea tunnels for oilfield development - TunnelTalk, November 2013

Personal thoughts on the application of mega-TBMs

Apr 2015

Article references: Discussion Forum: Reflections on the Alaskan Way mega-drive - TunnelTalk Apr 2015

Yes for decades TBMs and a few digger shields have had similar problems as those being experienced currently on the SR99 TBM project in Seattle. That is why it is so SAD to see what highway engineers are doing for tunnels in Seattle and Los Angeles, thinking: "I can run a dozer. TBMs are not much different."

In 1985, I was assisting the first underground railway in Guangzhou, China for the heavy rail subway. French engineers wanted to give them a 25ft diameter enclosed face shield. I told them as long as it is free and to ask for 10 spares for anything made of rubber, plastic, and flexible piping.

Bertha probably had an equipment and operator error. It is called torque for a 60/30ft lever arm. Probably no pressure gauges in the TBM to measure torque or the 1% change in face alignment or the operator wasn't watching and no on-board CAO system was in place, operating, or being read. With torque, seals, gaskets, and bearing crash. This isn't rocket science. TBMs have been operating since 1982 or before.

I prefer open face mining like the 2014 completion of Caldecott fourth bore highway tunnel and the Devil's

Slide highway tunnel in the San Francisco Bay Area in California. No TBM problems.

Bertha's problems are applicable for comments in California where the Los Angeles SR-710 DEIR [draft environmental impact report] is proposing four (4) 60ft diameter TBMs to meet at 2 miles in. No inventory of abandoned water wells has been conducted. Many homes in the 1900-1930 period may have had their own water wells for irrigation. Sometimes they used steel pipes for casing the wells and most drillers of the period would use standard oil field technology – up to about 300ft deep – and including 8in steel pipes. If abandoned they would normally dump cement and sand down the hole. If Big Hilda TBM ran into such a pipe without proper pressure monitoring – poor Hilda stuck again – we told you so!

Dr Tom Williams
USA

Exploring the development of embedded liners on tunnel lining segments

Nov 2014

Article references: First use of embedded line in tunnel segments - TunnelCast video, Oct 2009

Dear TunnelTalk,

I was interested in the video article on your latest TunnelTalk Alert entitled First use of embedded liner in segment.

It describes the first use of a plastic liner fixed to the precast concrete segments during their fabrication which was developed for the Sacramento Upper Northwest sewer project in Northern California and managed during installation by Project Manager on site, Pat Doig, for Construction Management team Hatch Mott MacDonald for the owner, Sacramento Regional County Sanitation District.

Although it is the first use of an embedded plastic liner on precast concrete segments, as a matter of historical interest, it is not the first use of an embedded liner on concrete segments.

An earlier use was for the second Dartford road tunnel under the Thames in the UK that was built by Balfour Beatty in the 1970s and with Mott MacDonald as the project engineer and designer.

In that case it was a steel liner attached to the precast concrete segments by steel fishtails. Steel strips were then welded over the joints to make the lining watertight. Unfortunately the water pressure got behind the liner and in some places pushed it off the concrete segments, with the result that the tunnel started to leak in some places. As far as I know it was never used again.

Best regards,
Alastair Biggart,
UK Tunnelling Consultant

From the Editor: For those who have access to a print magazine archive, construction of the second Darford road tunnel was the topic of an article by Piers G Harding in the Jan/Feb 1997 issue of Tunnel&Tunnelling, the official magazine of the BTS-British Tunnelling Society

Detroit water tunnel projects crippled

April 2009

Anonymous

Shouldn't the alert headline this week read; "Detroit is incompetent in more areas than just the motor industry"? They seem to be able to destroy any decent contract from any position. I cannot imagine the ground conditions are so overwhelmingly bad that it is impossible to mine. Amazing!

Detroit outfall contract terminated – TunnelTalk, April 2009