

Using AI Agents for research - a case study the Lane Cove Tunnel Collapse

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ABSTRACT: The Lane Cove Tunnel (LCT) Sydney collapse in 2005 was a significant failure in urban tunnelling, highlighting critical deficiencies in geotechnical risk assessment, construction methodologies, surveillance and site communication. The tunnel collapse led to costly delays, legal disputes, financial losses, personal injuries, surface building damage and community disruption, underscoring the need for more management oversight and preventative measures the tunnels construction. In addition to this author's interpretation of the available published information and using NotebookLM agent to summarise the data efficiently, this paper identifies management issues and proposes an initial check list of mitigations for future projects. Reference to the ground conditions and the use of cement grouted rock bolts as opposed to fully encapsulated resin ones, and the breakdown in communication between the contractor and the projects consultants re: related to inconsistent quality of the cement grouted rock bolt installation reporting and basic design flaws. It is vital to learn from past mistakes.

1 INTRODUCTION

The LCT collapse (on the Pacific Highway exit ramp) in 2005 was a significant failure in urban tunnelling (Figure 1). Post collapse several publicly available documents, legal proceedings and published papers were accessed and reviewed. While it was a relatively small set of documents, an example of an efficient way to research and review this information, is by using a Large Language Model (LLM). In this case study we have used NotebookLM as the AI agent reviewing documents. NotebookLM can only access and review the documents that you have uploaded to the NotebookLM website. This document summariser and research assistant is powered by a 'thinking' AI model Gemini 2.5 Pro (from Google). We have also used the agent ChatGPT, Table 1 as one means of risk mitigation brainstorming and for providing a comparison between cement and fully encapsulated resin anchored rock bolts, Table 2.

- Using the NotebookLM agent it is possible to upload 50 documents in one project session, so its capabilities have certainly have not been fully challenged here (5 documents only).
- The NotebookLM agent does not save the responses for each chat. They have to be saved manually. If you leave a session and restart, all previous chats are lost.
- To get the best out of a LLM, like the NotebookLM agent, the requests must be precise. Initially before starting a chat session, the agent must be told by you what role it is taking so that it has some context for its role.
- It is important to tell the NotebookLM agent in what format you want the response to be given in. e.g. text, table, number of words etc.
- Note that the key engineering lesson given in the conclusions section is the author's opinion and was not generated or influenced by the AI agents. It is based on the author's knowledge and experience.

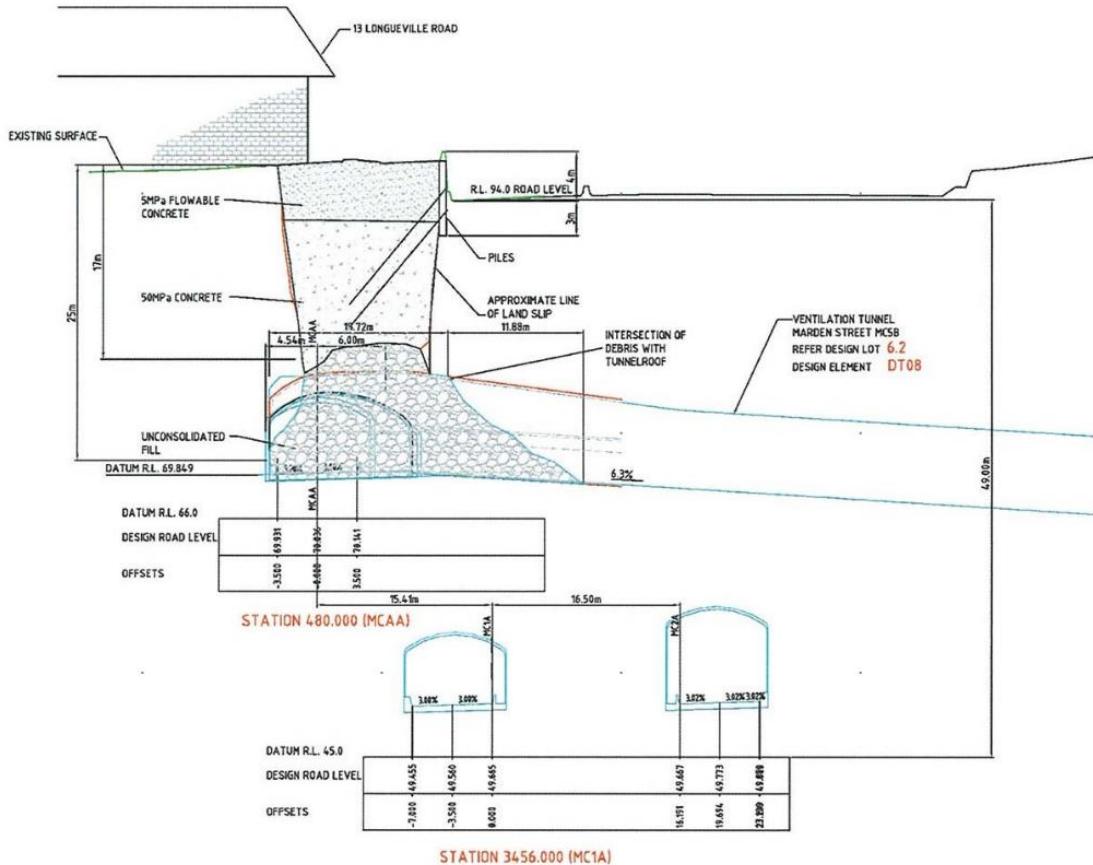


Figure 1. Vertical section through the collapse zone including post failure concrete pours (original from Brown report). Zoom into the PDF file for clearer text.

It is strongly recommended that the three companion papers referenced on the Lane Cove Tunnel Collapse are also read so that the reader can reach their own conclusion about the effectiveness of NotebookLM.

2 BRAINSTORMING USING CHATGPT AND PROMPT ENGINEERING

Table 1 has been largely generated by using the following prompt. In the first instance ChatGPT is told that it is a Project Manager on a large urban tunnelling project to give it the context of the prompt below.

“Please list the likely risk issues and mitigation methods to be managed on this project. There are 5 tunnel faces being excavated simultaneously”

Note that we did not ask ChatGPT to list the risks and mitigation in any order of priority. This was done by the author after reviewing some of the summaries produced by the NotebookLM. The summaries produced by NotebookLM also require the agent to be assigned a role so that it has framework or context around the prompts provided. Note also the process is iterative and some of the input data does not all come from the LCT references; some topics are not addressed at all. For example, the use of fully encapsulated resin rock bolts, only cement grouted rock bolts are mentioned in the LCT references.

A comparison between cement grouted and fully encapsulated rock bolts follows in Table 2.

Table 1. 95% of table content was the generated using prompt engineering in the ChatGPT Model. Priority order (1-21) modified by the author.

#	Likely Issues	Mitigation Methods
1	Tunnel Designer's over Reliance on Contractor Reporting	Ensure the tunnel designer and geotechnical engineer both regularly visit tunnel faces to assess support issues firsthand.
2	Poor Communication Between Teams	Hold daily meetings with clear agendas. Use collaborative platforms for sharing updates and decisions.
3	Inadequate Risk Assessment for the next 24 Hours	Use a risk matrix to evaluate and prioritise risks. Involve all stakeholders in the assessment process.
4	Unforeseen Ground Conditions (e.g., water ingress, weak rock)	Conduct thorough pre-excavation investigations. Have contingency plans and equipment ready for emergencies.
5	Insufficient or incorrect Ground Support Installation	Pre-plan support requirements based on geological data. Conduct regular inspections to ensure compliance with designs. Have contingency support alternatives on site.
6	Lack of Accountability for Decisions Made in Meetings	Document all decisions and assign follow-up tasks to specific individuals. Use meeting minutes for transparency.
7	Insufficient Training for New Team Members	Provide comprehensive onboarding and ongoing training. Pair new members with experienced mentors.
8	Inaccurate Face Mapping	Use advanced laser scanning and photogrammetry for precise mapping. Regularly cross-check with geologists' observations.
9	Misinterpretation of Geological Data	Ensure geologists and designers collaborate closely. Use real-time monitoring and adjust excavation plans as needed.
10	Delayed Shift Boss Reports	Implement a standardised reporting template and set strict deadlines for submission. Use digital tools for efficiency.
11	Excessive Deformation (Surface or Tunnel)	Install real-time deformation monitoring systems. Set thresholds for immediate action if limits are exceeded.
12	Over-Excavation or Under-Excavation	Train operators on precise excavation techniques. Use laser guidance systems for accuracy.
13	Delays in Approval Process	Streamline decision-making by assigning clear roles and responsibilities. Use approved protocols for common issues.
14	Fatigue or Human Error in Reporting or Decision- Making	Rotate shifts to prevent fatigue. Implement double-checking procedures for critical decisions.
15	Inconsistent Construction Summary Reports	Standardise report formats and ensure all teams are trained on how to complete them accurately.
16	Surface Settlement Affecting Nearby Structures	Monitor surface settlement continuously. Use face dowels, canopy tubes, grouting or other stabilisation techniques if necessary.
17	Lack of Alignment Between Tunnel Faces	Use precise surveying and alignment tools. Regularly verify alignment and adjust excavation paths as needed.
18	Inadequate Emergency Response Planning	Develop and regularly update emergency response plans. Conduct drills to ensure readiness.
19	Budget Overruns Due to Unplanned Work	Regularly review progress against budget. Allocate contingency funds for unforeseen issues.
20	Safety Incidents Due to Poor Ground Conditions or Equipment Failure	Enforce strict safety protocols. Conduct regular equipment inspections and maintenance.
21	Environmental Impact (e.g., noise, dust, vibrations)	Implement mitigation measures like noise barriers, dust suppression, and vibration monitoring.

The above table is a generalised list of 'Likely Issues' and 'Mitigation Methods' and has been generated without any pre-knowledge of the project management procedures adopted on the Lane Cove Tunnel project. There is also no specific reference to either cement or resin encapsulated rock bolts (see Table 2 below).

3 COMPARING CEMENT GROUT AND FULLY ENCAPSULATED RESIN ANCHORED ROCK BOLTS

Prompting NotebookLM,

“Is there any reference in the uploaded documentation to resin anchored rock bolts?”

Response: No

Using ChatGPT,

“Compare cement grouted rock bolts with fully encapsulated resin rock bolts in weak rock, no ground water present. Format output in a table.”

Table 2. Comparing cement grouted and fully encapsulated resin rock bolts

#	Aspect	Cement Grouted Rock Bolts	Fully Encapsulated Resin Rock Bolts
1	Grout Material	Cementitious grout	Two-part polyester resin
2	Bond Strength	Moderate (lower than resin)	High bond strength with rock and bolt
3	Installation Time	Slower; grout needs to be pumped and allowed to set	Faster, resin sets within minutes
4	Load Transfer Mechanism	Friction and mechanical interlock along the grouted length	Strong chemical bond along the entire bolt length
5	Early Load Capacity	Delayed (requires curing time)	Immediate load-bearing possible after resin sets
6	Suitability in Weak Rock	Adequate, but may require higher quality control to ensure full encapsulation	Excellent, due to rapid setting and full encapsulation
7	Encapsulation Quality	Variable; risk of voids or incomplete grout filling	High, if installed correctly, provides continuous bond
8	Corrosion Protection	Good (alkaline environment)	Good; resin acts as a sealant
9	Sensitivity to Installation	Sensitive to hole flushing, grout mix, and timing	Sensitive to mixing and insertion speed
10	Cost	Lower material cost, higher labour cost	Higher material cost, lower labour cost
11	Inspection & Testing	Pull testing and coring may be needed to confirm grout fill	Same, but often more reliable outcomes if Quality Control is followed
12	Long-Term Performance	Good in dry conditions, but depends on grout quality	Very good; consistent encapsulation provides durability

Please note the problems associated with the installation of the cement grouted rock bolts are described in Section 4 of this paper.

Please note the first 5 items in Table 2. Given the reported problems the contractor was having installing the cement grout rock bolts the author is surprised *that using their own initiative* they could have switched over to fully encapsulated resin anchored bolts. In any case, resin anchored rock bolts should have been on site as a tunnel support contingency. The installation of the permanent support (i.e. the cement grouted rock bolts) would be carried out later, without the pressure of maintaining excavation productivity targets. There were precedents for this approach that the author is aware of. For the eastern half (the project was divided into two contracts) of the M5 (2001) road tunnel and for the treatment works chamber on the Bondi RIAMP project (2003).

We are not suggesting that the use of resin anchored rock bolts would have prevented the collapse. However, when it became obvious that the geological conditions have changed (or that there were installation issues with the cement grouted rock bolts) and that resin anchored rock bolts would have been more appropriate, it would appear that no resin anchored rock bolts were available on site for this contingency.

4 CEMENT GROUTED ROCK DESIGN INSTALLATION

Prompting NotebookLM:

“Please summarise the issues related to the installation of the cement grouted rock bolts”

NotebookLM response:

“Based on the sources, you can add a note highlighting the lack of communication regarding issues with the cement grouted rock bolts:

It is noted that the tunnel designers, PB, and the geotechnical construction team, PB and PSM, were unaware of difficulties with the installation of CT rock bolts prior to the collapse. TJH tunnelling crews reportedly had significant difficulties with tensioning and grouting the CT rock bolts in the MC5B tunnel and in the MCAA/MC5B intersection. Despite these issues, TJH did not inform PB, and PB did not enquire, whether rock bolts installed in the MC5B/MCAA intersection were properly tensioned and properly grouted. There was no documentation reporting these tensioning or grouting problems, suggesting a breakdown in the Non-Conformance Report (NCR) system. Initial inspections after the collapse revealed issues with the installation and anchoring of rock bolts in the roof of the MC5B tunnel section of the intersection, including little to no evidence of grout on the exterior of plastic sheathed bolts and overwound end anchors preventing grout penetration.

Furthermore, while rock bolt testing was required, there was no specification prescribing the locations for testing, and rock bolts were not tested in MC5B as ground conditions deteriorated. This lack of testing in the area experiencing problems meant that specific performance data in the challenging ground conditions was not available to inform the designers or geotechnical team. The effectiveness of the adopted rock bolting strategy and the stability of the rock bolted roof were therefore compromised by inadequate tunnel roof support installations, including a significant percentage of CT rock bolts that had not achieved end anchorage or a grouted bond in the roof strata”.

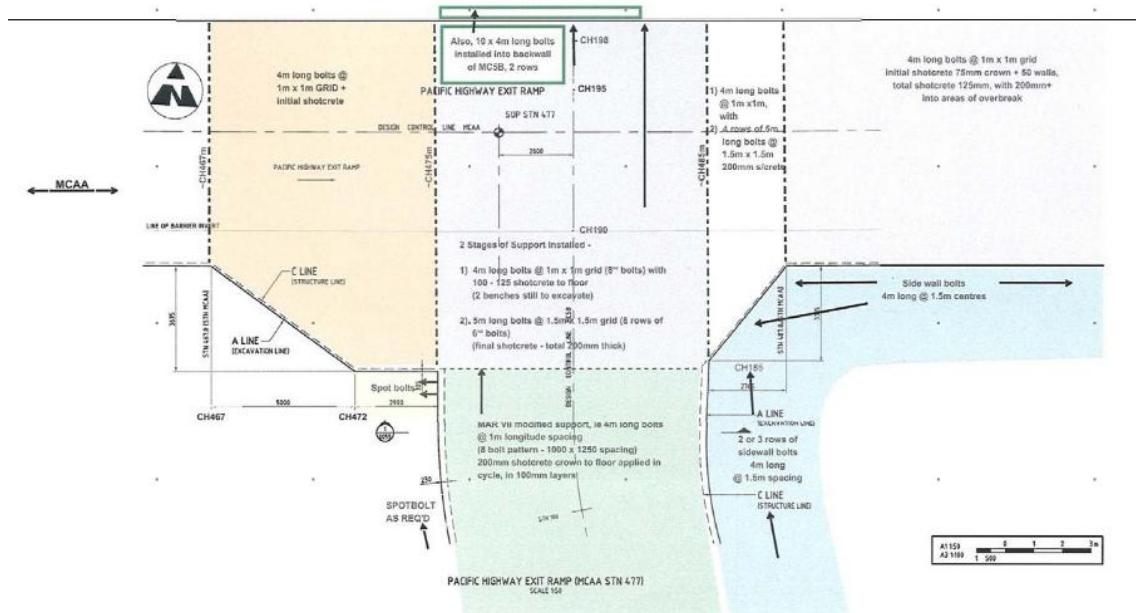
5 WHAT WAS THE DESIGN MISSING?

NotebookLM prompt:

“Was the design approach adequate of such a large tunnel intersection”

NotebookLM response:

“A significant finding from the post-failure investigations and subsequent litigation was the apparent lack of a fully engineered design for the MC5B/MCAA intersection support. Based on the evidence, the design was not based on detailed calculations of the type undertaken post-collapse to assess its suitability. Documents presented as the support design (including reports, memoranda, specifications, Requests for Information (RFIs), emails, mapping sheets, drawings) conspicuously lacked the "Design Documentation" described in the consultancy contract, which should have included engineering calculations carried out specifically for the intersection. The trial judge later confirmed the absence of engineering calculations for the intersection design. There were no engineering calculations for any intersection in the documentary evidence, only for 2-D tunnel sections. There were also no drawings in the support toolbox for the installation of support in intersections”.



6 WERE THE ROCK BOLTS LONG ENOUGH?

NotebookLM prompt:

“Are there any comments in the documentation related to the length of the rock bolts used? Please provide a paragraph summary”.

NotebookLM response:

“Based on the sources, there are indeed comments regarding the length of the rock bolts used in the tunnel design and construction. The amount of rock bolts installed, including their length, varied depending on the Ground Support Determination (GSD) which was based on the ground classification1. Design considerations for the tunnels used precedent practice from earlier Sydney tunnels, which included information on rock bolt lengths related to tunnel spans. For specific areas like the MC5B/MCAA junction, the primary support in the transition zone consisted of 4m long bolts on a 1m by 1m spacing. Due to the increased effective span and relatively low cover at the junction, a secondary support system was augmented, which included 5m long rock bolts on 1.5m by 1.5m spacings. A chart used as a guide during design, compiling rock bolt lengths against spans in the Sydney area, suggested that 6m long bolts should be used in excavations with effective spans of 17m, and if the effective span is taken as 21m, the chart suggests bolt lengths should be at least 7m. In retrospect, it was concluded in one report that the level of support, which would include bolt length, existing in the western side of the transition was inadequate to ensure the excavation's stability given the large effective span, low rock cover, the presence of the dyke, and the poor mechanical properties of the overlying rock mass”.

7 MOTIVATION FOR WRITING THIS PAPER

The motivation for this paper is both professional and personal.

During the LCT project, I was engaged by Connector Motorways to provide high-level review comments, including for the section of tunnel that ultimately collapsed. However, based on the limited documentation I received, I formally advised Connector Motorways that I could not provide a meaningful response due to insufficient information. Despite this, no further action was taken, with the assumption that responsibility lay solely with the contractor. This disconnect underscores a recurring problem in project oversight and accountability. Following the collapse, I was subsequently re-engaged to oversee the remedial design and construction methodology.

I am currently highly motivated to explore the potential of AI in engineering applications. AI has the capability to improve the speed, quality, and objectivity of technical analysis and in doing so, reduce the influence of cognitive bias that often clouds judgement on complex projects.

Finally, I am deeply concerned that despite previous lessons, another major tunnel collapse recently occurred in Sydney — the M6, approximately 18 months ago. This indicates that critical learnings from LCT collapse may not have been adequately transferred to current practice. This paper is an effort to promote ongoing vigilance, learning, and innovation through both traditional engineering scrutiny and AI-based assistance.

8 CONCLUSIONS

This case study has demonstrated the effective use of AI agents such as NotebookLM and ChatGPT in extracting and synthesising key technical and management lessons from complex engineering failures. This proved to be a significant time saver, even with a small dataset (for both researching and writing).

In the author's opinion the key engineering lesson here is the ground support strategy. Given the known limitations and difficulties in installing cement grouted rock bolts, particularly under variable ground conditions and especially production pressures the contractor should have had fully encapsulated resin anchored rock bolts available and incorporated into the tunnel support contingency plan. Resin encapsulated bolts offer clear advantages in weak ground conditions, including faster installation, superior bond strength, and reliable encapsulation, which is especially critical when construction quality control is compromised (refer to Table 2). I would classify the installation of the resin anchored rock bolts as 'temporary works' and hence the responsibility of the contractor.

While it is acknowledged that the use of fully encapsulated resin rock bolts may not have prevented the collapse, their rapid load-bearing capacity and ease of installation should have enabled a more adaptable and responsive approach to deteriorating conditions, especially at tunnel intersections. Importantly, their availability would also have eliminated any reliance on problematic cement grouted bolts until this 'permanent support' was installed in a stable environment (both geologically and production).

The broader failure also highlights the absence of a robust non-conformance reporting system, inadequate face mapping, questionable rock bolt lengths (only 4m) given the effective wide span and a lack of formal engineering calculations for a complex intersection. Together, these deficiencies reflect systemic gaps in design and construction oversight and communication, which must be urgently addressed in future tunnelling projects.

This paper is an effort to promote ongoing vigilance, learning, and innovation through both traditional engineering scrutiny and AI-based assistance. The emphasis here is 'assistance' as AI made no contribution to the scenario put forward here about the use of resin anchored rock bolts as a first pass initial tunnel support option.

As AI technologies continue to evolve and become widely adopted, their use in educating, identifying and even predicting such risks offers a powerful tool for improving both design and construction in all urban tunnelling environments.

Also please note that the three referenced papers on the Lane Cove Tunnel collapse were initially available on the AGS website and published in the Australian Geomechanics Journal were (refer to Vol 54, No. 2 June 2019). However, copies of the three papers can still be downloaded from the internet.

9 REFERENCES

Brown, E. T. (Golder Associates Pty Ltd) (2005) *REPORT ON CAUSES OF SUBSIDENCE, 2 NOVEMBER 2005, LANE COVE TUNNEL PROJECT, SYDNEY, NSW*. Report No. 001-05632178- Rev 1, Golder Associates Pty Ltd.

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