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Case Study on Surface and Subsurface Water Ingress of Barog Tunnel in the State of Himachal Pradesh

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I. INTRODUCTION

A tunnel of 936 m has been constructed by NHAI(NH-05) between Kalka and Shimla Highway for smooth functioning of traffic in the state of Himachal Pradesh. The work of construction was started in the year of 2017 and the work was complected in the year of 2019. From 2019 onwards smooth traffic was plying in this tunnel. Now in the year of 2025, due to intense rainfall this year, some problems have been notified and which will be elaborated with complete treatment details below: -

1) Seepage of water from construction joints in lining part: - Seepage of water from construction joints at gantry number 23, 24, 25, 26, 27, 52, 58, 59 has been observed, thereby causing dampness and leaching at various locations. There might be of every possibility of eruption of waterproof membrane.
2) PQC and pedestal joints: - It is observed that sub surface water is coming out from several locations minimum 5 liter/minute of water especially from grove cutting area and resulting in flowing of water from here and there inside tunnel thereby causing damaging to the PQC part and creating problem for road users.
3) Minor and major cracks: - Some minor, hairlike cracks have been observed at most of the locations. Even some major cracks at very specified locations have been noticed which in turn causing dampness and flowing of water from gantry joints. There might be of every possibility of eruption of waterproof membrane.
4) Chocked drains: - It is observed that at various locations the drains have been chocked and resulting in unavoidable flow of water inside tunnel.
5) Damaged drain cleaning pipe: - Drainage cleaning pipe at gantry number 29 is found damaged thereby causing flowing of water over 4-to-5-liter water/minute.
6) Housekeeping: - The housekeeping inside the tunnel is in very worst condition as the water is flowing from here and there. Dust particles and foreign material are present throughout the tunnel indicating insufficient housekeeping inside tunnel.

II. TREATMENT

1) Seepage of water from construction joints in lining part: -Polyurethane (PU) grouting should be used to treat dampness.
2) PQC and pedestal joints: -Injection cement grouting with admixture should be applied to seal joints. However, if needed PU grouting/Epoxy should be used to treat this problem.
3) Minor and major cracks: - Cement grouting should be used to treat this problem.
4) Chocking of drains: -Cleaning of drains should have to be done for smooth flow of water inside the drain.
5) Damaged drain cleaning pipe: - Repairing of damaged drain cleaning pipes have been required. Moreover, if required PU grouting after cement grouting shall be applied to stabilize water flow.
6) Chocking of drains: -Cleaning of drains is required on regular intervals, which is the most important activity duringto avoid unto wards water channelization.

III. CONCLUSION

Water inside tunnels after lining is treated primarily through a combination of drainage and waterproofing/grouting techniques. Drainage systems collect and remove water, while methods like injecting cement or polymer grouts, applying waterproof membranes, or using water-stop needles address leaks and cracks in the lining. The most common approach involves drainage supplemented by sealing at the source to reduce water pressure and prevent damage to the tunnel structure.

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A. Drainage Methods

1) Blind drainage pipes:

These are laid between the primary lining and the waterproof membrane to collect water before it reaches the final lining.

2) External drainage systems:

In some cases, like in karst areas, external drainage tunnels and systems are used to divert water away from the tunnel.

3) Grouting and water diversion:

Drainage holes can be drilled into the surrounding rock to relieve water pressure.

B. Waterproofing and Grouting Methods:

1) Grouting:

Water-stop needles are used to inject grouting materials into lining cracks or behind the lining to seal them.

- Cement Grout: The most common and cost-effective option, but with lower impermeability.
- Polymer Cement: Offers better waterproofing, bonding, and durability.
- Chemical Grout: More effective but often expensive and potentially toxic.

2) Waterproof Membranes:

Plastic membranes (like HDPE, PP, PVC) are installed on the primary lining to prevent water ingress.

- *Surface Sealants:*

For very small cracks (less than 2mm), surface sealants can assist the lining's natural self-healing properties.

- *Full Plugging:*

A more complex method that aims to seal all weak points in the lining and surrounding rock, but it requires high-quality materials and technology to be successful.

C. Key Considerations:

1) Integrated Approach:

Effective water treatment requires a comprehensive approach that addresses the surrounding rock, the lining structure, and the drainage system.

2) Prevention:

The best strategy is to prevent water ingress during the construction phase through proper planning and geological analysis.

3) Monitoring:

Regular monitoring of the drainage system's condition is crucial, as blockages can lead to increased water pressure and structural damage over time.

Further it may not be placed to mention here that ground water has placed an important role. Water leakage in tunnels and underground structures is a difficult and challenging problem which must be carefully tackled at any stage of the life-circle of an underground structure or tunnel. In this report, a review is made of the recent advances in the prevention and mitigation of water leakage in tunnels and underground structures.

Firstly, the forms of water leakage and the reasons for occurrence of water leakage are analysed in detail.

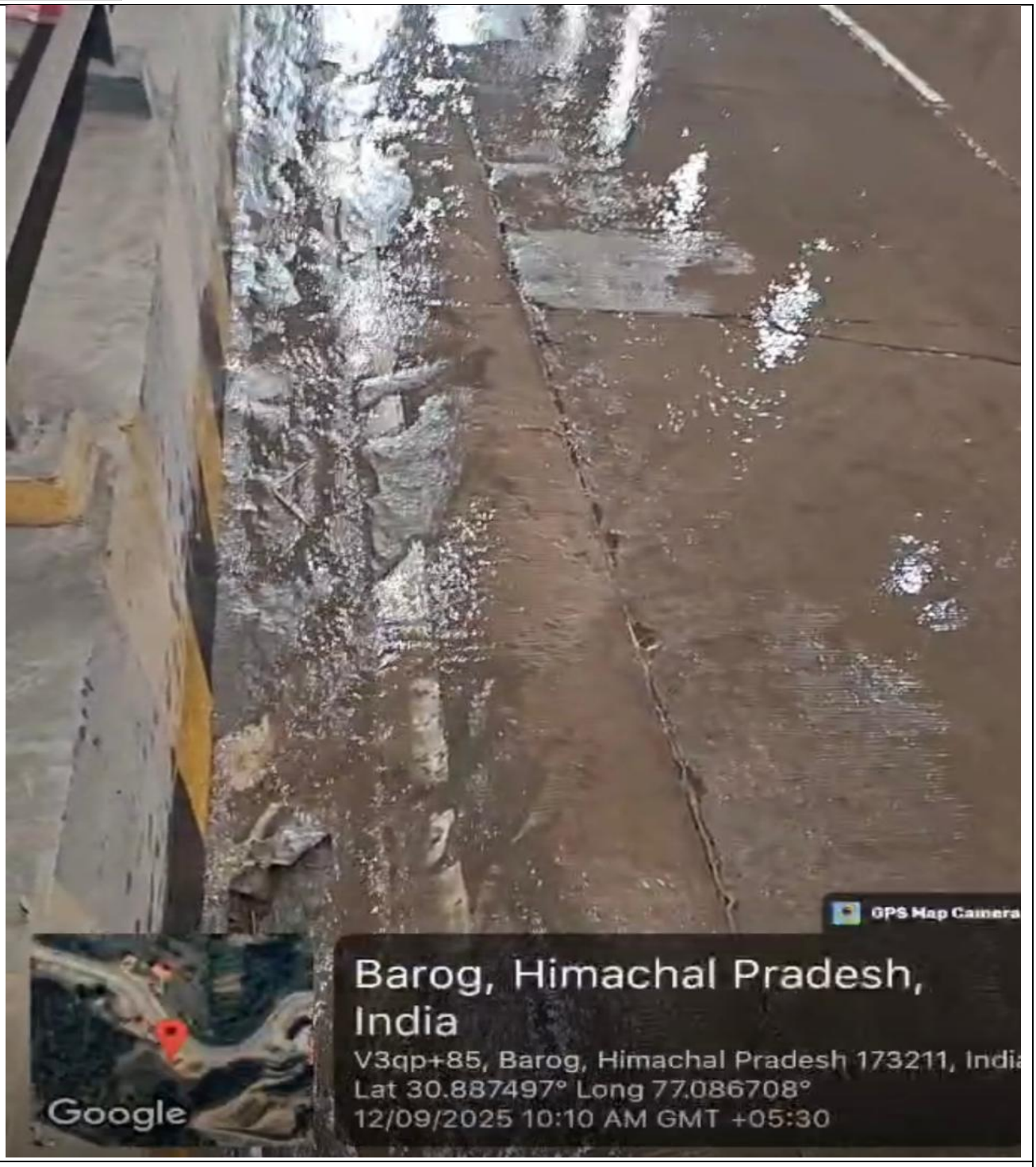
Secondly, the traditional and innovative water leakage detection methods are critically reviewed.

Thirdly, some important waterproofing concepts and leakage mitigation measures are summarized.

Finally, it has been found that water leakage in tunnels and underground structures can be classified into many types according to the occurrence position of water leakage, form, and water content. The causes for water leakage are miscellaneous, involving aspects of hydro geological condition, design, construction, and service environment.

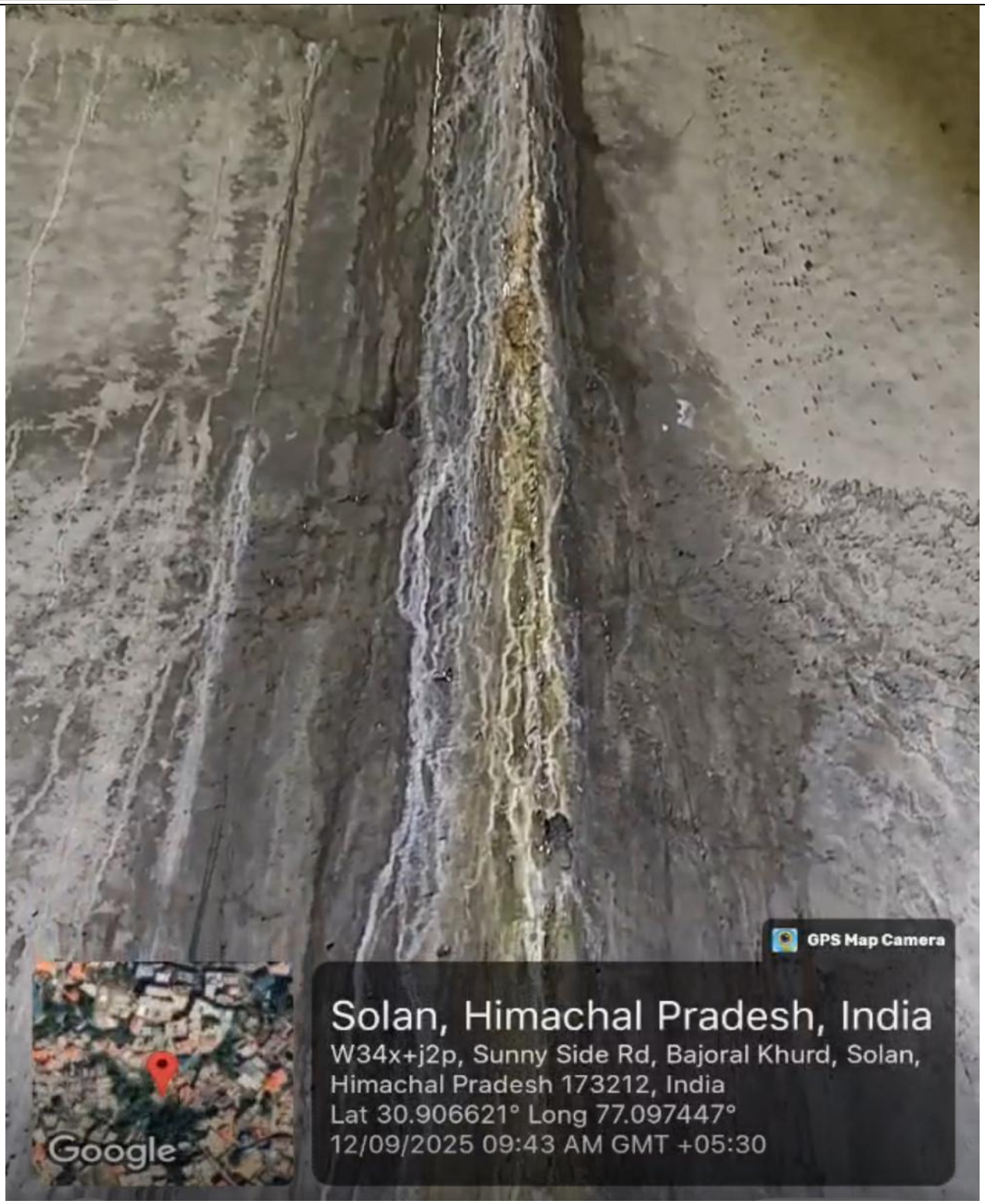
The main method for mitigating water leakage is grouting, and the grout diffusion mechanism, determination of grout amount and thickness, grout-water interaction, and new type of grouting material need to be further investigated.

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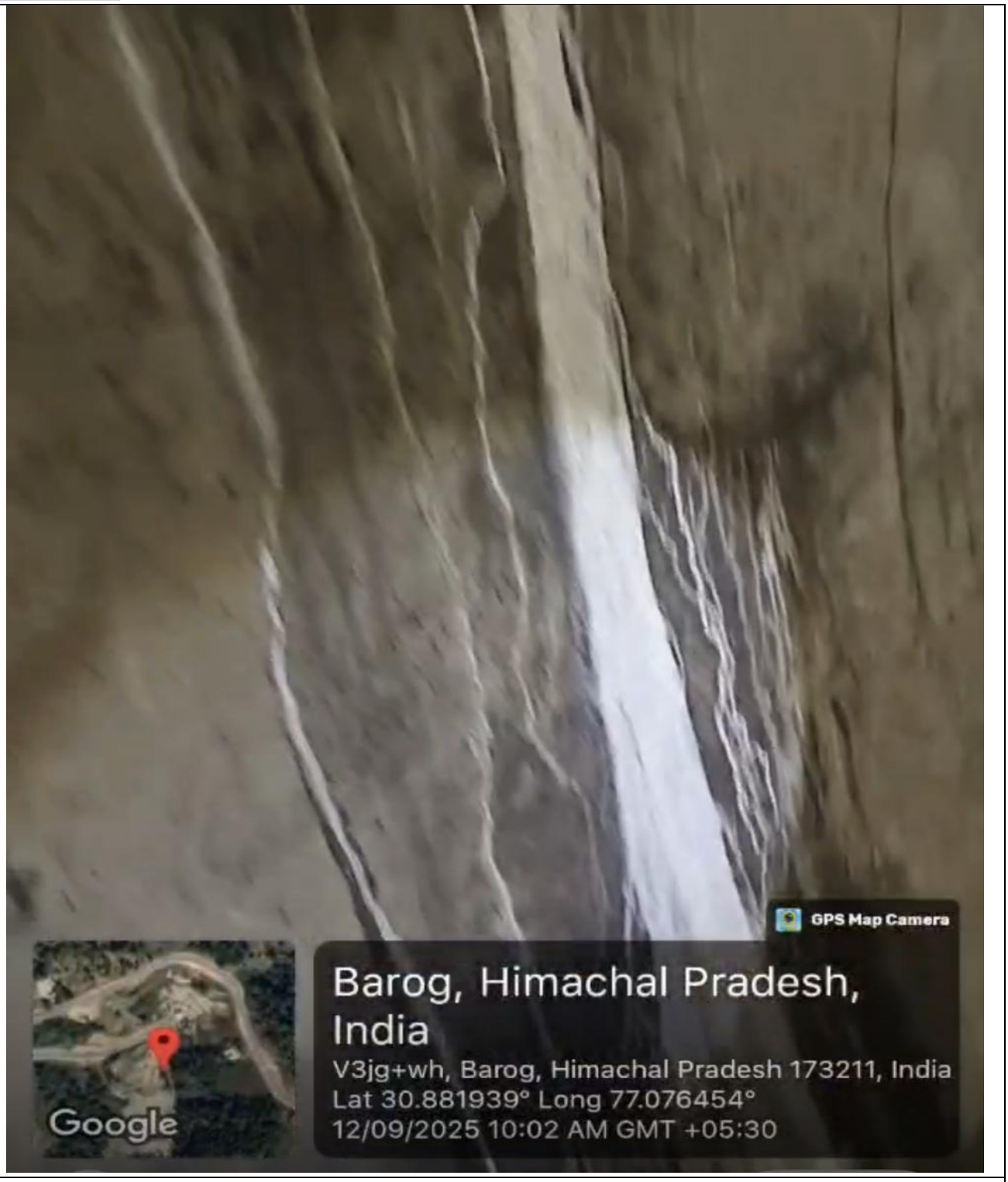
Seepage of water from construction joints of pedestal and PQC.

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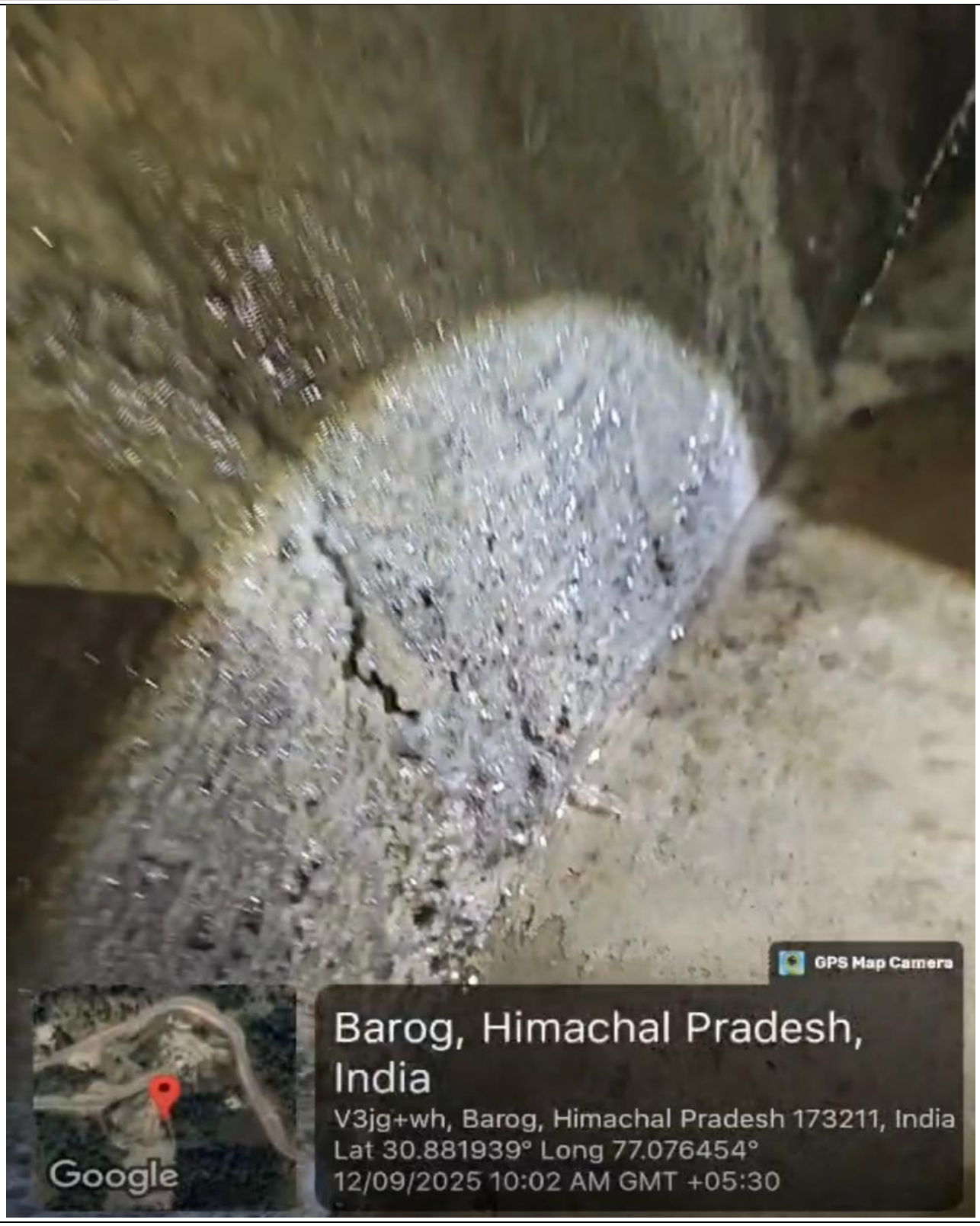


Leaching in lining.

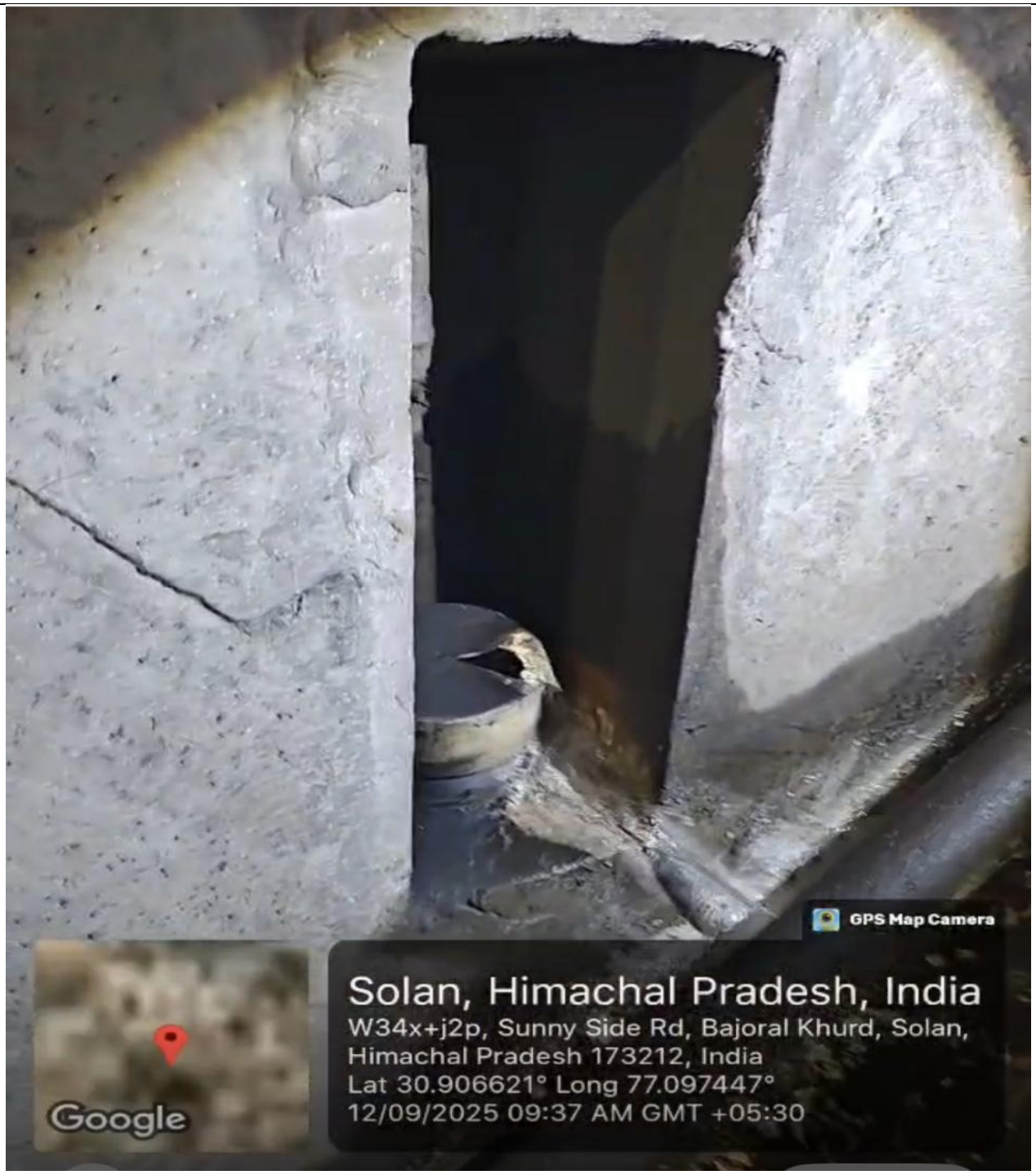
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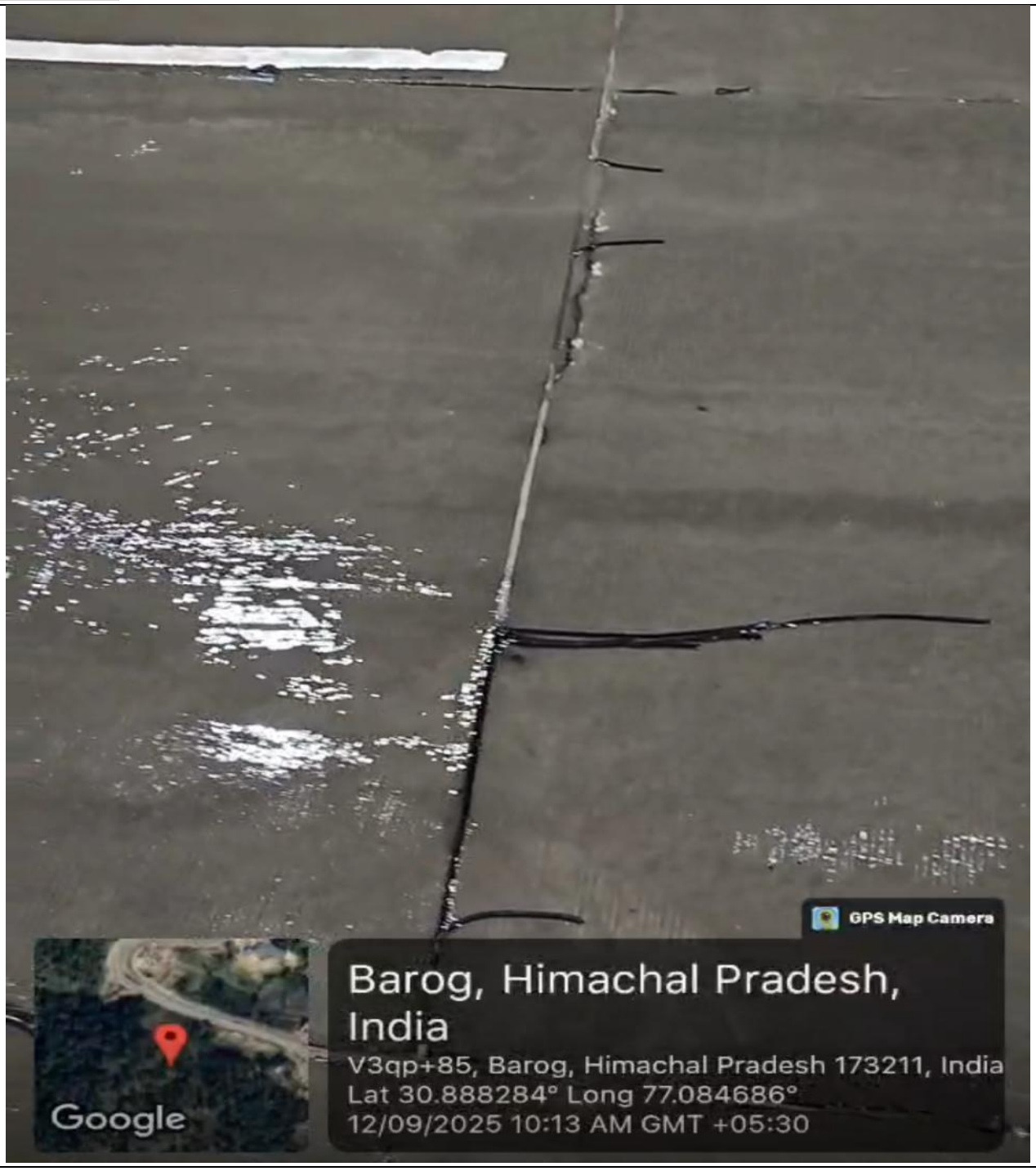
Seepage of water from construction joints.



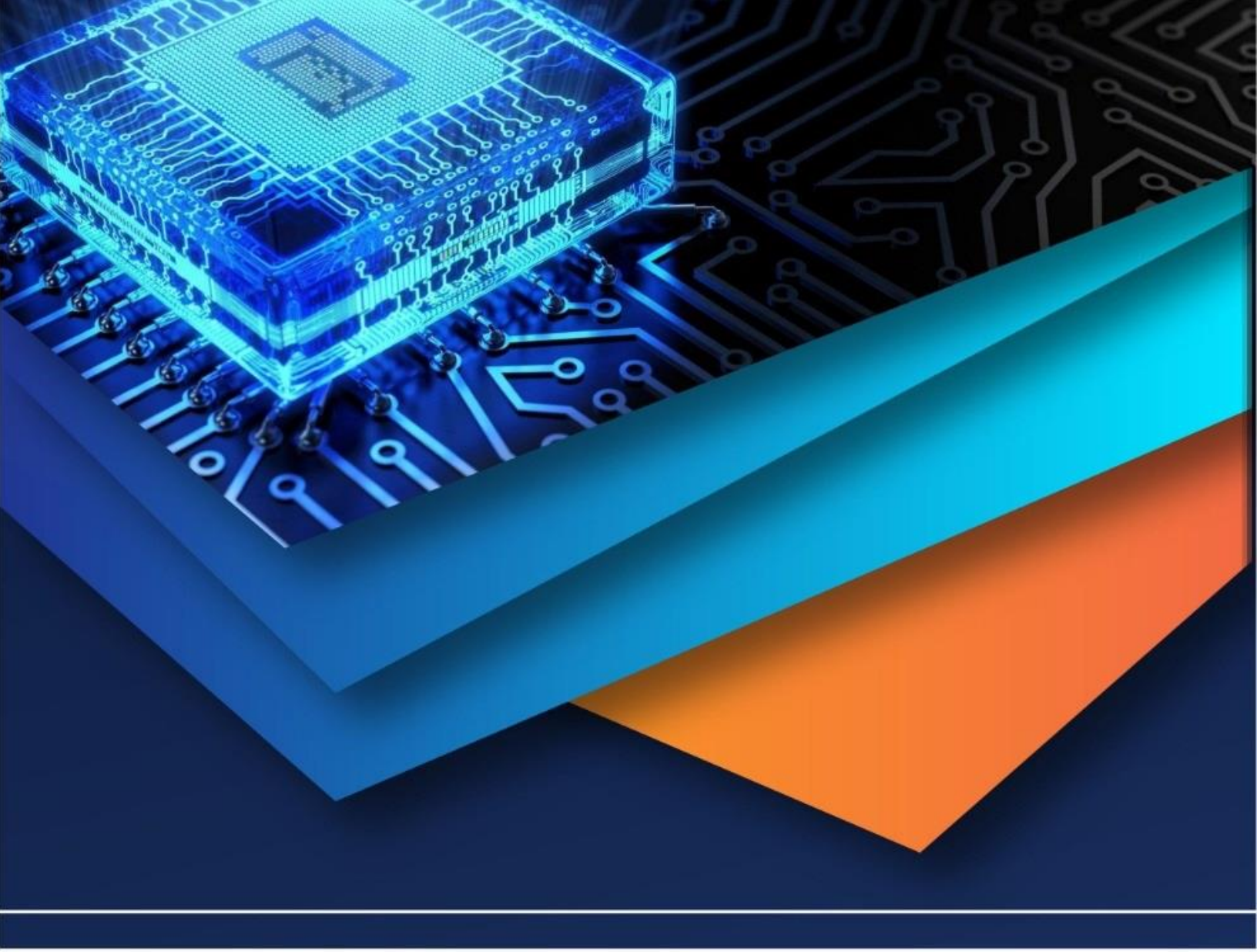
Seepage of water from cracks of lining.



Leakage of water from drain cleaning pipe



Seepage of water from groves of PQC.



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