DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 6.45: Method of tunnel Ventilation for construction and operation, dust control, lighting, and drainage (Part 3)

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Civil Engineering

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Introduction to Tunnel Lighting I

Adequate lighting in tunnels is critical for the safety and efficiency of both construction workers and future users. The primary goal is to ensure visibility and prevent the 'black hole' effect at tunnel entrances, while providing consistent illumination throughout the interior.

Key Points

- Prevents visual adaptation issues for drivers entering and exiting.
- Enhances safety and productivity during the excavation phase.
- Requires specialized fixtures resistant to moisture, dust, and vibration.
- Energy efficiency and maintenance accessibility are key design factors.

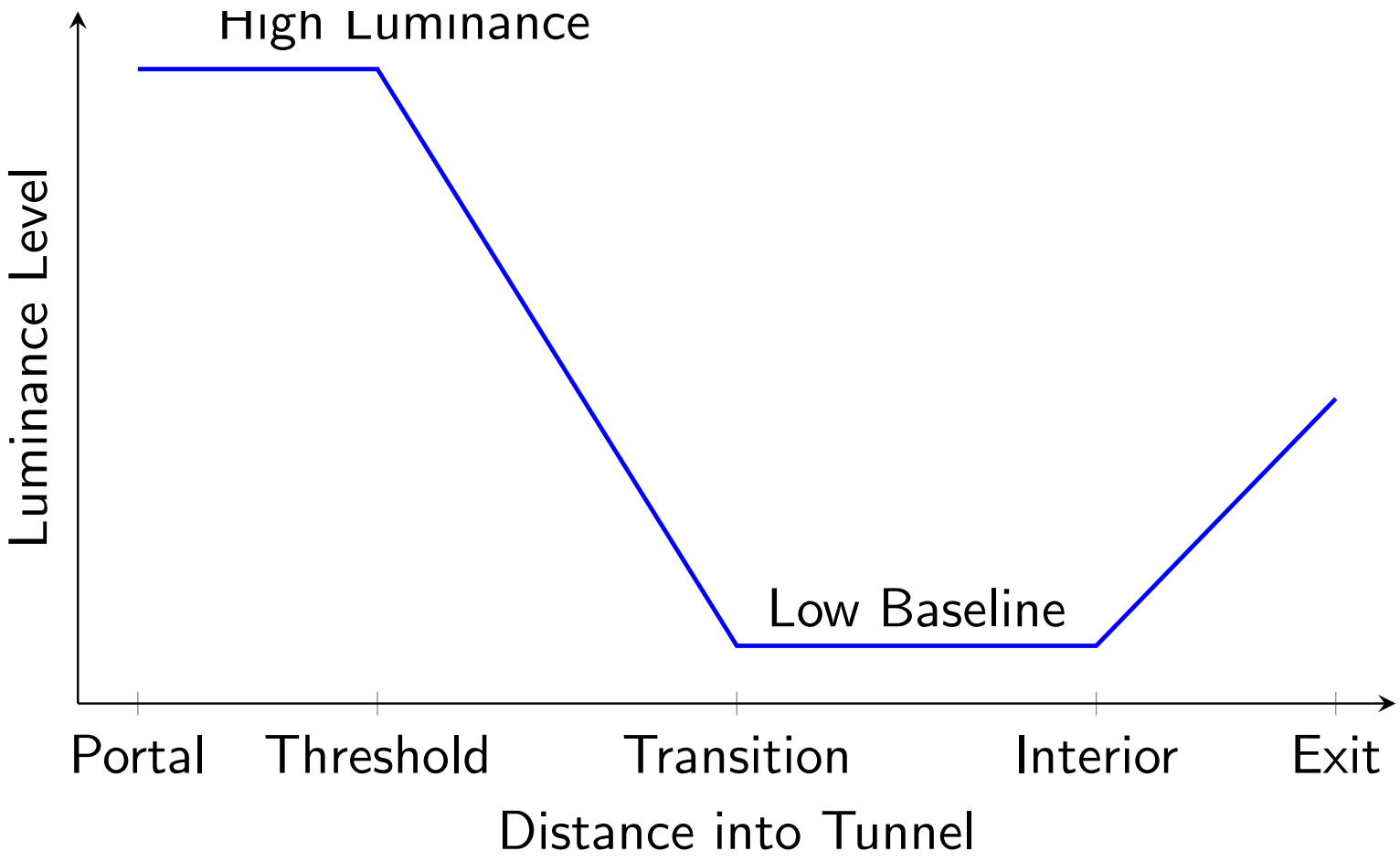
Luminance Zones in Operational Tunnels I

To accommodate the human eye's adaptation from bright daylight to a dark tunnel, operational tunnel lighting is divided into specific zones. Each zone has distinct luminance requirements based on the speed of traffic and ambient outside light.

Key Points

- Threshold Zone: Highest illumination to counter the 'black hole' effect.
- Transition Zone: Gradual reduction in lighting level to allow eye adaptation.
- Interior Zone: Constant, lower baseline illumination for the main tunnel length.
- Exit Zone: Increased lighting to prepare drivers for bright exterior conditions.

Tunnel Lighting Luminance Curve I



Tunnel Lighting Luminance Curve II

Key Points

- Visual representation of the CIE tunnel lighting curve.
- Shows the dramatic drop in required luminance from the threshold to the interior zone.

Tunnel Drainage During Construction I

Managing groundwater and construction water (from drilling and concrete works) is essential to prevent flooding, maintain face stability, and ensure a safe working environment. Temporary drainage systems must be robust and adaptable to advancing excavation.

Key Points

- Sources include groundwater infiltration, drill water, and wash water.
- Utilizes temporary sumps and high-capacity submersible pumps.
- Drainage pipes are advanced along with the tunnel heading.
- Treatment of water (e.g., settling tanks for suspended solids) is required before discharge.

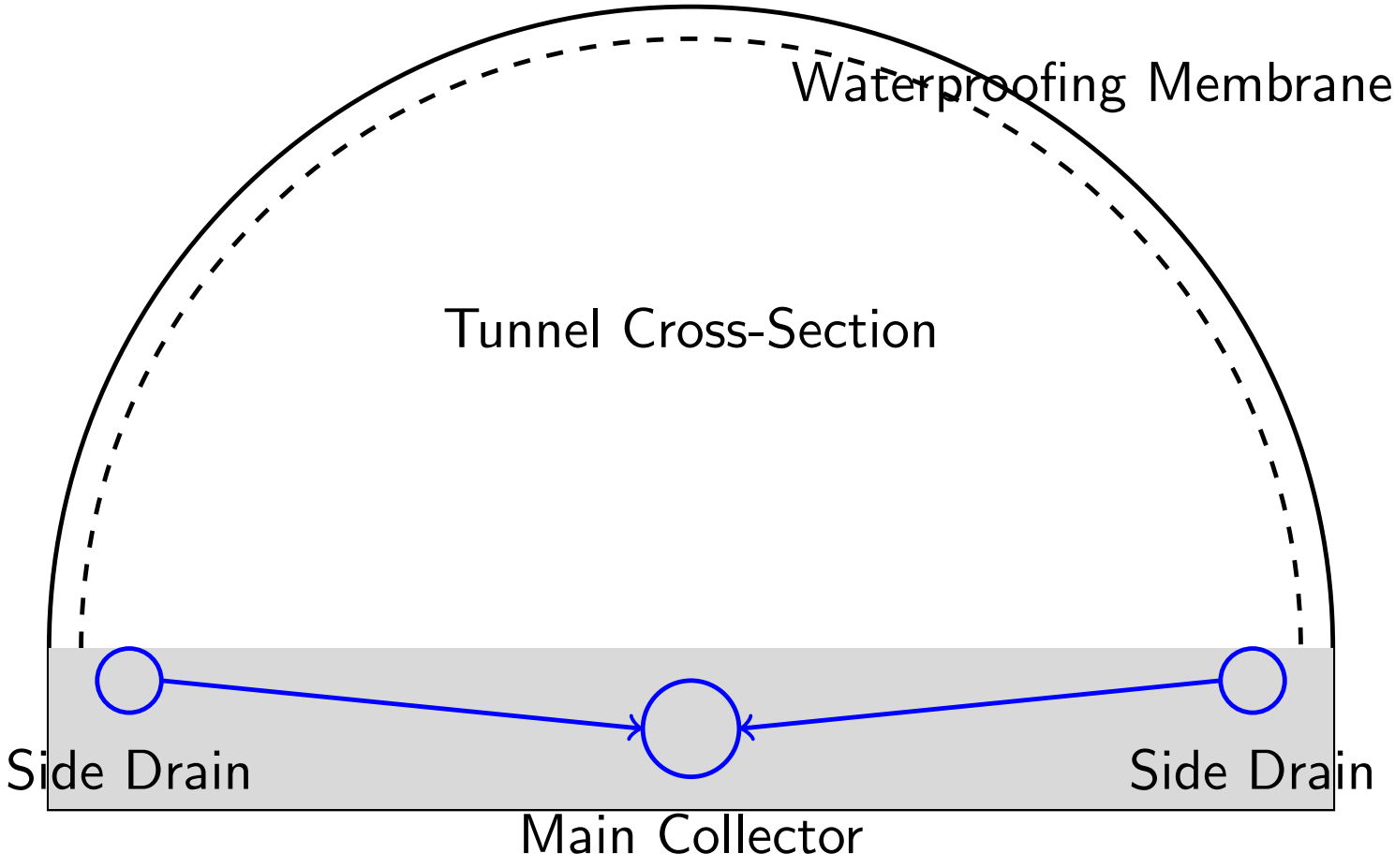
Permanent Tunnel Drainage Systems I

Permanent drainage ensures the long-term structural integrity and usability of the tunnel. It typically consists of a combination of waterproofing membranes and physical drainage channels to collect and divert groundwater away from the tunnel interior.

Key Points

- Invert Drains: Central or side channels located under the road/track bed.
- Fleece and Membrane: Collects water behind the concrete lining and directs it to the invert.
- Transverse Drains: Connect longitudinal side drains to the main collector pipe.
- Maintenance access via manholes or catch basins is necessary to clear blockages.

Cross-Section of Permanent Drainage I



Cross-Section of Permanent Drainage II

Key Points

- Illustrates the typical arrangement of side drains and the main central collector.
- Shows the flow path from the membrane collection system to the longitudinal drains.

Dust Control in Tunneling I

Tunnel construction generates significant airborne dust, primarily from drilling, blasting, and mucking operations. Silica dust is a major occupational health hazard, requiring stringent control measures to protect workers from respiratory diseases like silicosis.

Key Points

- Wet Drilling: Injecting water through the drill steel to suppress dust at the source.
- Water Spraying: Misting muck piles before and during loading operations.
- Ventilation: Providing sufficient fresh air to dilute and remove airborne particles.
- Personal Protective Equipment (PPE): Respirators as a secondary line of defense.

Mechanical Dust Extraction Systems I

In highly mechanized tunneling (like TBM operations) or where natural ventilation is insufficient, dedicated mechanical dust extraction systems are employed. These systems capture dust-laden air near the face and clean it before exhausting it.

Key Points

- Dry Scrubbers: Use fabric filters to trap dust particles; require periodic cleaning.
- Wet Scrubbers: Use water sprays or water baths to capture dust; highly effective but produce sludge.
- Exhaust Ventilation: Draws contaminated air away from the working face through ducting.
- Integrated Systems: Roadheaders and TBMs often have built-in extraction units.

Environmental Control Parameter Comparison I

Comparison of environmental control requirements during construction versus operational phases.

Key Points

- | Parameter | Construction Phase | Operational Phase |
- | :— | :— | :— |
- | **Lighting Level** | Moderate (Constant) | Variable (Zoned for adaptation) |
- | **Dust Source** | High (Drilling, Blasting, Mucking) | Low (Vehicle exhaust, tire wear) |
- | **Drainage Need** | High (Dewatering, unpredictable inflows) | Steady (Controlled via permanent systems) |
- | **Ventilation Goal** | Dilute dust, gases (CO, NOx), provide O2 | Dilute vehicle emissions, manage fire smoke |

Integration of Tunnel Support Systems I

Modern tunnels rely on integrated SCADA (Supervisory Control and Data Acquisition) systems to manage lighting, drainage, ventilation, and dust control simultaneously. This ensures optimal safety, energy efficiency, and rapid response to emergencies.

Key Points

- Sensors monitor air quality, water levels, and ambient light continuously.
- Automated adjustments to fan speeds and lighting intensity based on real-time data.
- Pump stations are activated automatically when sump levels rise.
- Fire detection systems trigger specialized emergency ventilation and lighting protocols.

Summary of Environmental Control Systems I

Effective management of lighting, drainage, and dust is critical for the lifecycle of a tunnel. During construction, these systems protect worker health and enable excavation. In operation, they ensure user safety, structural longevity, and operational efficiency.

Key Points

- Lighting must address human visual adaptation across distinct tunnel zones.
- Drainage systems (both temporary and permanent) are vital for stability and dry conditions.
- Dust control relies on a combination of suppression at source (wet methods) and robust extraction.
- Integrated monitoring and automation are essential for modern tunnel operations.