Title of the Project

State of the art in ecological and economic road construction and maintenance - Partnership for a sustainable and lasting knowledge transfer (PadanaWitra).

Principal Investigators (PIs)

- **Indian PI:** Dr. Ankit Gupta, Professor and Mo&RTH Chair Professor, Civil Engineering Department, Indian Institute of Technology (BHU), Varanasi, India.
- **German PI:** Univ.-Prof. Dr.-Ing. Pahirangan Sivapatham, Chair of Road Construction and Road Maintenance, University of Wuppertal, Germany.

Institutions involved

- Indian Institute of Technology (BHU), Varanasi - Transportation Engineering Section.
- University of Wuppertal - Chair of Road Construction and Road Maintenance,

Short Project Summary (few lines): Brief overview of the project's aims, focus areas, or methodology

The increasing demands on road pavements, driven by higher traffic loads, stricter safety standards, and the urgent need to achieve sustainability objectives, are accelerating the search for innovative approaches in asphalt mixture design and production. Conventional asphalt technologies are proving insufficient under these conditions, as they struggle to balance performance, durability, environmental impact, and regulatory compliance. In addition, rising construction costs and growing environmental concerns have led to stricter restrictions and, in some cases, prohibitions on the quarrying of natural aggregates, further intensifying the need for alternative materials and smarter production methods.

In this context, attention is shifting toward the development of multi-modified asphalt concepts that combine high proportions of reclaimed asphalt pavement (RAP) with advanced modification strategies, ensuring both technical performance and environmental responsibility. The incorporation of RAP not only conserves natural resources but also significantly reduces material costs; however, the use of large RAP contents requires careful engineering to maintain mixture performance and long-term durability. To address these challenges, multifunctional additives play a key role: rejuvenators restore the properties of aged binder and enhance asphalt reusability, while workability additives(chemical or organic) enable mixing and compaction at lower production temperatures. Lowering production temperatures further contributes to sustainability by reducing energy consumption, minimizing greenhouse gas emissions, and improving working conditions during paving.

Another aspect of this project is the assessment of road structures using advanced technologies such as the Traffic-Speed-Deflectometer (TSD) and Ground Penetration Radar (GPR) to efficiently determine sustainable maintenance measures. Unlike conventional methods such as the Falling Weight Deflectometer (FWD), which provides point measurements, the TSD enables continuous, high-speed (up to 80 km/h) assessment of pavement structural condition across entire networks. By measuring pavement deflections under moving loads in real time, the TSD provides critical insights into load-bearing capacity, remaining service life and homogeneous sectioning of roadways.

By replacing the current dual-vehicle approach FWD for structural evaluation and NSV for functional assessment with a single integrated TSD system, the project has the potential to revolutionize pavement management. The expected outcomes include faster, more reliable

network-level monitoring, better prioritization of maintenance interventions and the establishment of scientifically informed pavement management systems to support transportation agencies.

Project Aim:

The aim of this project is to develop and evaluate innovative asphalt mixture design and pavement management strategies that integrate high proportions of reclaimed asphalt pavement (RAP) with advanced multifunctional additives, enabling sustainable, durable, and cost-effective road construction. In parallel, the project seeks to implement advanced assessment technologies, such as the Traffic-Speed-Deflectometer (TSD) and Ground Penetration Radar (GPR), to establish efficient, network-level monitoring and maintenance systems. Together, these approaches will minimize environmental impact, optimize resource use, enhance structural and functional performance of pavements, and support data-driven decision-making for transportation agencies.

Focus Areas:

- **High RAP integration:** Evaluating asphalt mixtures with up to 40% RAP.
- **Multifunctional additives:** Use of rejuvenators and workability additives (chemical and organic) to improve material properties and enable lower production temperatures.
- **Performance and durability:** Assessing fatigue, stiffness, low-temperature resistance, and ageing behavior of modified asphalt.
- **Sustainability and reusability:** Reducing production-related emissions and proving the recyclability of modified asphalt mixtures.
- **Advanced pavement assessment:** Employing Traffic-Speed-Deflectometer (TSD) and Ground Penetration Radar (GPR) for continuous structural and functional evaluation at the network level.
- **Lifecycle analysis:** Conducting comprehensive environmental and economic assessments to compare multi-modified asphalt with conventional practices.

Expected Outcomes: Key goals, impact areas, or potential deliverables

This project involves a research component where both Universities shall engage in research, aiming to deliver sustainable pavement construction practices. The key deliverables include:

1. **Development of Multi-Modified Asphalt Mixtures**
    - Production of asphalt mixtures integrating up to 40% reclaimed asphalt pavement (RAP), polymer modification, rejuvenators, and workability additives.
    - Optimized designs balancing performance, durability, sustainability, and compliance with European and international standards.
2. **Performance Assessment Framework**
    - Comprehensive laboratory testing of mechanical and functional properties (fatigue, stiffness, cyclic compression, and low-temperature performance).
    - Evaluation of workability, compaction, and ageing behavior to simulate long-term pavement performance.
3. **Practical Guidelines and Knowledge Transfer**

- Recommendations for mix design, production, and paving practices with high RAP and additive integration.
- Transfer of knowledge to industry stakeholders, particularly in regions like India, where material shortages and cost pressures necessitate innovative, resource-efficient solutions.

4. **High-Speed, Network-Level Assessment**
   - Deployment of an integrated Pavement Scanner (TSD, GPR, HRM, PPS+) for continuous structural and functional evaluation at speeds up to 80 km/h, generating reliable data on capacity, condition, and service life.
5. **Operational Transformation**
   - Establishment of TSD as a single-system alternative to FWD and NSV, providing direct benefits to agencies (NHAI, MoRTH, NHIDCL, UPEIDA) through efficiency, cost reduction, and integrated pavement management.

High-resolution visuals (optional but welcome): Images or short videos from project activities—such as meetings, lab work, or partner visits—along with captions and photo credits

The project was formally begun on the 1st of April 2025. As of now, 2–3 online meetings have taken place discussing the framework of the project, research plan and coordination strategy. Further preparatory activities are ongoing, including the refinement of experimental methodologies, identification of key performance indicators, and allocation of responsibilities among the participating partners.

Student team from IIT (BHU) Varanasi is expecting to travel on 1st Sep. 2025 to Germany (awaiting Visa) and German team is expected to come subsequently and planned a winter school in December, 2025.

(a) (b)

Fig. 1: RAP from two different sources

(a) (b)

Fig. 2: (a) Laboratory image of the University of Wuppertal, (b) Pavement Scanner