



# Smart Roads with Dynamic Wireless EV Charging

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**ABSTRACT:** The integration of civil engineering pavement design with Dynamic Wireless Power Transfer (DWPT) technology represents a transformative shift in urban infrastructure. This paper explores the development of transmitter coils embedded within pavement layers, connected to a regulated power supply network, designed to charge electric vehicles (EVs) through inductive coupling. The study emphasizes the design of a durable pavement structure capable of housing electrical components without compromising mechanical strength, drainage, or long-term serviceability. Utilizing materials like Glass Fiber Reinforced Polymer (GFRP) and polymer concrete, the system addresses both structural and electromagnetic requirements. Experimental validation through a scaled physical prototype confirms the feasibility of continuous, contactless EV charging suitable for Indian urban environments.

**KEYWORDS:** Dynamic Wireless Power Transfer (DWPT), Inductive Coupling, Smart Road Infrastructure, GFRP Reinforcement, Polymer Concrete, EV Charging.

## I. INTRODUCTION

### 1.1 Background

The adoption of EVs globally is growing rapidly due to environmental awareness and government incentives. However, the key limitation is the availability and convenience of charging infrastructure. Traditional plug-in chargers require vehicles to remain stationary for long durations, occupying valuable urban space. Wireless Power Transfer (WPT) applied dynamically allows for a continuous state of charge, reducing the need for large battery capacities.

### 1.2 Problem Statement

Current EV infrastructure in India relies on static systems that are time-consuming and prone to wear and tear. This project aims to develop a smart pavement that enables efficient energy transfer while maintaining structural strength and serviceability.

### 1.3 Objectives

Design and analyze a smart pavement system embedded with inductive transmitter coils.  
Develop a working prototype demonstrating energy transfer from pavement to vehicle.  
Identify suitable pavement materials and protective coatings for coil integration.  
Ensure the pavement structure maintains durability while accommodating electrical components.

## II. LITERATURE SURVEY

### 2.1 Technical Standards

The Society of Automotive Engineers (SAE) standard J2954 defines frequency ranges (85 kHz), air-gap limits (100–150 mm), and safety standards for electromagnetic exposure. This standard serves as the foundation for the operational parameters used in this study.

### 2.2 Coil and Shielding Research

Resonant inductive coupling is identified as the most efficient and feasible method for EV applications. Studies prove that ferrite tiles beneath the coil can improve coupling efficiency by up to 30% and reduce interference with metallic pavement reinforcement. Furthermore, the use of GFRP reinforcement is recommended near coils to prevent power loss from induced eddy currents.

### 2.3 Global Pilot Studies

Electreon (Sweden/Israel): Successfully deployed modular coils under asphalt, achieving 85–90% efficiency for moving buses and trucks.

KAIST OLEV (South Korea): Demonstrated that DWPT can reduce vehicle battery size by 40%.

Nottingham (UK): Showed real-world acceptance of inductive charging in public areas, increasing operational uptime for taxis by 15–20%.

## III. SYSTEM DESIGN AND METHODOLOGY

### 3.1 Concept of Dynamic Wireless Power Transfer (DWPT)

DWPT utilizes an alternating current in a transmitter coil (Tx) embedded in the road to produce a magnetic field. When a receiver coil (Rx) under the vehicle passes over it, voltage is induced, rectified, and stored in the battery.

### 3.2 Block Diagram and Parameters

The system consists of:

Power Inverter: Converts grid AC to high-frequency (85 kHz) current.

Tx Coil: Flat spiral Litz-wire coil embedded in the pavement.

Rx Coil: Fixed under the EV to capture magnetic flux.

Control Circuit: Activates road segments only when a vehicle is detected, minimizing energy loss.

Parameter	Typical Value	Design Basis
Operating Frequency	85 kHz	SAE J2954
Power Rating (Class 2)	1–3 kW (Scaled)	EV Charger
Air Gap	100–150 mm	Clearance/Efficiency Trade-off
Pavement Cover	25 mm	Limit magnetic loss

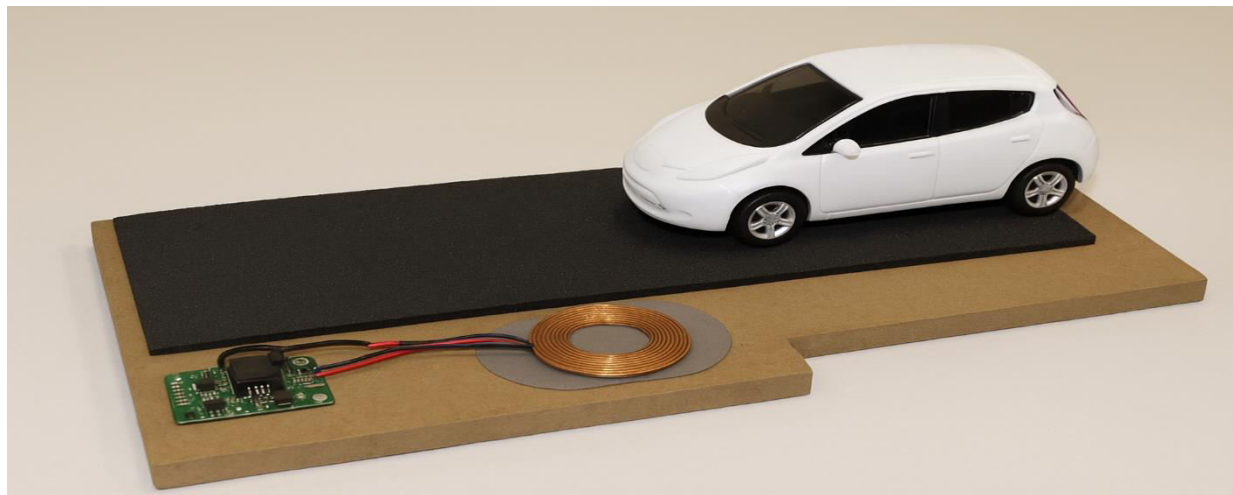


Figure 3.1 – Prototype Model of Smart Pavement with Wireless Charging Setup

Figure 3.1 Model of Smart Pavement with Transmitter

## IV. CIVIL ENGINEERING INTEGRATION

### 4.1 Pavement Structure

The proposed section is a rigid pavement type, selected for its high load-bearing capacity and minimal deformation.

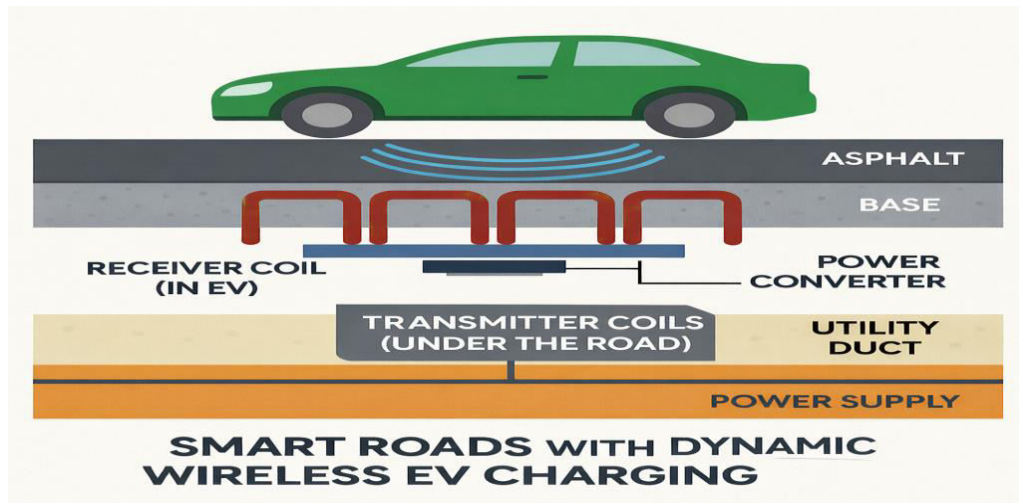
- **Wearing Course (25 mm):** Polymer concrete/epoxy mix for skid resistance and waterproofing.
- **Coil Housing (70 mm):** Polymer mortar with ferrite backing to hold the Tx coil and insulate it electrically.

- **Structural Slab (180 mm):** Fiber Reinforced Concrete (M40) using GFRP rebars to prevent magnetic distortion.
- **Sub-base and Subgrade:** Granular sub-base (150 mm) and compacted soil foundation.

#### 4.2 Structural Analysis

Manual stress analysis was conducted using a 65 kN wheel load.

- **Max Tensile Stress:** 3.8 MPa (within the permissible 4.5 MPa limit)
- **Deflection:** 0.35 mm (negligible). These results confirm the pavement retains its structural integrity despite the internal cavities for electronic module



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### V. EXPERIMENTAL SETUP AND RESULTS

#### 5.1 Laboratory Prototype

A scaled-down model used a 12V DC input, converted to high-frequency AC for transmission. The Tx coil was embedded under a 10 mm polymer slab to replicate pavement cover.

#### 5.2 Observations

The efficiency of power transfer was measured against varying air gaps and misalignments.

Air Gap (mm)	Induced Voltage (V)	Received Power (W)	Efficiency (%)
20	7.8	5.6	84
60	6.3	4.6	74
100	4.2	3.1	58
150	2.8	1.9	46

#### 5.3 Key Findings

- **Optimum Efficiency:** Achieved at a 20–60 mm range.
- **Alignment Impact:** Voltage drops by ~20% for a 25 mm offset.
- **Material Transparency:** The epoxy-coated polymer pavement layer caused negligible loss in magnetic field strength.

### VI. SUSTAINABILITY AND ECONOMIC FEASIBILITY

#### 6.1 Environmental Impact

A 1 km segment of smart charging road supporting 500 EVs daily can reduce approximately 12–15 tons of CO<sub>2</sub> emissions annually. Integrating this with roadside solar panels allows energy to be harvested directly from the infrastructure.

**6.2 Cost-Benefit Analysis**

While the prototype cost was approximately ₹27,000, a full-scale implementation is estimated at ₹25–35 lakh per km. The payback period is estimated at 7–8 years, making it economically viable with mass EV adoption.

**VII. CONCLUSION**

The project successfully validates the concept of a Smart Road Pavement for Dynamic Wireless EV Charging. By combining rigid pavement design with inductive technology, the study proves that roads can be transformed from passive surfaces into active energy corridors. The modular cassette system ensures that maintenance remains practical for Indian conditions.

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